Zbornik četvrte nacionalne konferencije sa međunarodnim učešćem pod nazivom

Primena slobodnog softvera i otvorenog hardvera PSSOH 2021

Univerzitet u Beogradu – Elektrotehnički fakultet

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u Beogradu, februara 2022. godine

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Predgovor četvrtoj PSSOH konferenciji

Uprkos pandemiji i otežanim uslovima rada, i u 2021. godini nastavili smo sa održavanjem dvojezične hibridne PSSOH konferencije (Primena slobodnog softvera i otvorenog hardvera). PSSOH smo započeli u 2018. godini sa željom da se u Republici Srbiji promovišu nacionalni skupovi i neguju lokalne zajednice okupljene oko tih skupova. Iako smo uložili vreme i trud da PSSOH dobije svoju sadašnju formu i da opstane, priznajemo da nas je četvrti put zaredom prijatno iznenadio. Sa željom, da PSSOH opstane i da se razvija još dugi niz godina, nadamo se da ćemo u periodu koji je pred nama motivisati nove članove odbora i mlade koleginice i kolege da se angažuju oko PSSOH i da nas u budućnosti i odmene. Ostali smo verni inicijalnoj ideji da PSSOH treba da bude dvojezična konferencija, te su i ove godine radovi pisani i na srpskom i na engleskom jeziku. Predavači su mogli da biraju na kom jeziku izlažu svoje radove koji je mogao da se razlikuje od jezika na kom je rad napisan. Zbornik i ove godine publikujemo nakon konferencije iz istih razloga kao prošle – da omogućimo naknadnu i javnu recenziju radova koji su prošli anonimne recenzije, ali i da rasteretimo sopstveni raspored i obaveze. Takođe, ostali smo verni dijamantskom pristupu publikacijama koji podrazumeva da nikome ništa ne naplaćujemo i da su radovi dostupni u otvorenom pristupu.

Hibridni tj. kombinovan pristup u organizaciji konferencije je predstavljao veliki teret, pogotovu za Organizacioni odbor, ali je omogućio predavačima po pozivu da odaberu način predstavljanja rada – uživo iz amfiteatra 56 na Elektrotehničkom fakultetu ili virtuelno uključenjem u video poziv. Ograničenje u broju prisutnih u prostorijama Fakulteta je uzrokovalo odsustvo publike, ali kako je veći deo Organizacionog i Uredničkog odbora bio prisutan u prostorijama, nije izostao skoro pa zaboravljeni aplauz i interakcija sa publikom tokom predavanja.

Plenarnu sesiju smo ove godine značajno proširili te smo umesto jednog predavača imali tri plenarna predavača. Italo Vinjoli iz *The Document* fondacije je, na naše veliko zadovoljstvo, ponovo pristao da bude naš predavač i dragi gost. Njegova tema je bila digitalnu suverenost koja je, po našem mišljenju, goruća tema za vreme u kom živimo, bilo da se radi o digitalnoj suverenosti države, univerziteta, institucije ili pak lične suverenosti. Kao i prošle godine, publika je imala prilike da zajedno sa Uredničkim odborom nauči nešto novo od gospodina Vinjolija, ali i da učestvuje u vrlo živoj diskusiji sa iskrenim i direktnim odgovorima koji su bili, kako smo već to i navikli, "bez dlake na jeziku". Kako bi smo upotpunili ponudu plenarnih predavanja aktuelnim temama koje su važne ne samo na inženjere elektrotehnike i računarstva, nego i za društvo u celini pozvali smo profesora Aleksandra Kavčića iz Fondacije Alek Kavčić da održi predavanje o slobodnim udžbenicima i softveru u obrazovanju. Svi smo imali prilike da vidimo barem deo borbe profesora Kavičića za udžbenike za osnovce u Republici Srbiji u proteklom periodu. Ali, na PSSOH predavanju smo mogli da čujemo i motive profesora Kavčića, njegove stavove i da se na žalost upoznamo sa trenutnim stanjem na tržištu udžbenika. Predavanje profesora Kavčića je bilo propraćeno sa najvećom pažnjom i gotovo opipljivom tišinom koja je vladala u zabrinutoj publici u amfiteatru 56 Elektrotehničkog fakulteta u Beogradu. Kako je među svim učesnicima i uživo i virtuelno postojao apsolutan koncenzus da udžbenici treba da budu javno dostupni i slobodni, nadamo se da će se reč profesora Kavčića imati odjeka i u drugim sredinama. Poslednje, ali ne manje važno plenarno predavanje održala je Kalista Redmond, generalni direktor RISC-V *International*. Njeno predavanje je ukazalo na mnoge aspekte RISC-V i uticaje koji ovaj otvoreni skup instrukcija ima na računarstvo danas. Na žalost, gospođa Redmond je bila sprečena da prisustvuje diskusiji uživo, ali je Urednički odbor zahvalan dr Vladimiru Milovanoviću, vanrednom profesoru sa Fakulteta inženjerskih nauka, Univerziteta u Kragujevcu na doprinosu diskusiji. Profesor Milovanović je svojim znanjem i iskustvom, gde bi smo posebno istakli njegov studijski boravak na Univerzitetu Kalifornija (Berkli), bio kompetentan sagovornik na temu RISC-V skupa instrukcija.

Pored uvodne sesije gde su se prisutnima obratili tadašnji dekan Elektrotehničkog fakulteta dr Milo Tomašević, redovni profesor ispred našeg Fakulteta i dr Miloš Cvetanović, vanredni profesor ispred Uredničkog odbora, i plenarne sesije, izlaganje radova je bilo organizovano u još tri sesije: (1) Žene u elektrotehnici i računarstvu, (2) Tehnologije otvorenog koda za primenu u obrazovanju i (3) Primena otvorenog i slobodnog softvera i otvorenog hardvera. Prva sesija posvećena ženama u elektrotehnici i računarstvu je pored biografskog rada posvećenog doprinosu Hedi Lamar u oblasti frekvencijskog skakanja, uključila i predavanje na temu feminističkog mita o kiborgu u kontekstu digitalne revolucije. Sesija posvećenja obrazovanju je bila inspirisana plenarnim predavanjem profesora Kavčića i osim otvorenih udžbenika, uključila je i druge otvorene tehnologije i iskustva saradnika i nastavnika u obrazovanju. Na kraju,

treća sesija je sadržala kolaž predavanja iz oblasti slobodne i dostupne aplikacije za istraživanja u psihologiji, pionirskog rada na temu definisanja FAIR (eng. *Findable*, *Accessible*, *Interoperable*, *Reusable*) principa za otvoreni hardver, pregleda slobodnog softvera za govorne tehnologije, projektovanje analognih i digitalnih kola, kao i otvorenih alata za veštačku inteligenciju, ali i otvoreni generator izveštaja i skripti.

Prvi put smo ove godine imali rad koji je prethodno bio postavljen na preprint server arXiv ("Towards FAIR Principles for Open hardware"), te bi smo ovom prilikom ohrabrili sve buduće autore i predavače da koriste arXiv ili druge preprint servere uz uslov da nas prilikom slanja radova obaveste o postojanju preprinta. Iz razloga, koji nama nije u potpunosti razjašnjen, ovaj rad je preko arXiv servera postigao veliku vidljivost, te bi smo i tu činjenicu istakli kao jednu od prednosti ovakve prakse. Kao i prošle godine, i ove godine, smo postavili sve prezentacije sa održanih predavanja na naš YouTube kanal i podelili ih pod CC licencom, te će naši pratioci, kritičari, prijatelji i svi znatiželjni posetioci moći da isprate događaje sa konferencije bilo kada i bilo gde. Na svim prethodnim, ali i budućim PSSOH konferencijama svi naši gosti i predavači su dobrodošli ako žele da pomognu u skladu sa svojim mogućnostima i sve tretiramo ravnopravno, što je tradicija pokreta slobodnog softvera i otvorenog hardvera, a sada i tradicija PSSOH konferencije. Kako smo najavili u 2018. i realizovali u 2019. godini i ove godine smo ponudili svim autorima koji su na Elektrotehničkom fakultetu Univerziteta u Beogradu objavili otvorene nastavne materijale da ih predstave u Zborniku, te Zbornik sadrži i ovu sekciju.

Postkonferencijski događaji su i ove godine organizovani u sedmici nakon održane konferencije i uključili su tri radionice: (1) pod mentorstvom dr Dejana Tošića, redovnog profesora i dr Milke Potrebić, redovnog profesora studenti Matija Dodović, Jelena Bakić, Katarina Stanković i Nikola Ilić su pripremili SymPyCAP radionicu, (2) studenti Nikola Todorović, ms Nebojša Jovanović, dipl. inž. Sara Živković i saradnik u nastavi Danilo Đokić su pripremili radionicu instaliranja Linuksa – već drugu po redu na PSSOH konferenciji i (3) dr Predrag Pejović, redovni profesor je pripremio i realizovao radionicu na temu kućnih servera pod nazivom "Evolucija telefonske sekretarice --- kućni server".

Organizacija PSSOH konferencije je, kao i ranijih godina, podržana od strane velikog broja koleginica i kolega, ustanova, kompanija i udruženja i ovde ih je nemoguće sve pobrojati. Najzahvalniji smo našim donatorima iz Akademske Misli iz Beograda, ali i LotusFlare kompaniji koja je pokrila troškove štampanja majica za naš Organizacioni odbor i volontera. Zahvalni smo svim predavačima koji su se odazvali našem pozivu i upotpunili sadržaj naše konferencije. Bez Nikole Todorovića i dr Miloša Bjelića, docenta koji predsedavaju Organizacionim odborom ne bi smo mogli da zamislimo PSSOH 2021. Veoma smo zahvalni članovima Organizacionog odbora Dejanu Petkoviću, Dragici Nikolić, dipl. inž. Živani Garašević, Jovanu Sandiću, Mihajlu Pavloviću, dr Nenadu B. Popoviću, saradniku u nastavi Danilu Đokiću, ms Nebojši Jovanoviću, dipl. inž. Pavlu Radojkoviću i dipl. inž. Sari Živković. Zahvalnost dugujemo i svim članovima naučnog i spoljnjeg organizacionog odbora, ali i ms Milanu Antiću. Posebno bi smo istakli angažman Mihajla Pavlovića na pripremi obrazaca u LibreOffice-u. Kako nismo u mogućnosti da sve koji su nam pomogli nabrojimo, unapred se, i ove godine, izvinjavamo svima koje smo propustili da spomenemo.

P.S. U duhu PSSOH tema i sa željom da promovišemo slobodan softver, i ovaj Zbornik smo pripremili u programskom paketu LibreOffice.

u Beogradu, 14. februara 2022. godine

Urednički odbor PSSOH konferencije

Foreword to the Fourth PSSOH Conference

In the face of the pandemic and challenging working environment in 2021, we continued to organize a bilingual hybrid PSSOH conference (PSSOH stands for Application of Free Software and Open Hardware). We started the PSSOH in 2018 to promote national events in the Republic of Serbia and to support local communities gathered around these events. Although we have invested time and effort in PSSOH to get its current form and to survive, we admit that we were pleasantly surprised for its forth edition. With our minds and hearts set on the PSSOH to survive and develop in years to come, we hope to motivate new board members and young colleagues to get involved and/or to substitute us in the future. We remained faithful to the initial idea that the PSSOH should be a bilingual conference. Hence, in 2021 papers were written in both Serbian and English languages. Lecturers could choose language to present their works regardless the language in which they wrote the paper. As in 2020, we are publishing the Proceedings succeeding the conference for the same reasons as last year – to enable subsequent and public review of the papers that have passed anonymous reviews, but also to alleviate our schedule and obligations. Also, we have remained faithful to the diamond open access publication model – we do not charge article processing.

The hybrid i.e., combined approach in organizing the conference was a great burden, especially for the Organizing Committee, but it allowed the speakers to choose the way of presenting their work – live from the School of Electrical Engineering in Belgrade or virtually by participating in a video call. The pandemic caused the absence of the wider audience. But, as the majority of the Organizing and Editorial Boards were present, we experienced an almost forgotten applause and interaction with the audience.

We significantly expanded the plenary session this year, and instead of one plenary speaker, we invited three distinguished speakers. To our great satisfaction, Italo Vignoli from The Document Foundation has again agreed to be our plenary speaker and a dear guest. He talked about digital sovereignty, which, in our opinion, is an important present-day issue, whether we think of the digital sovereignty from the perspective of the state, university, institution, or personal sovereignty. As in 2020, everyone had the opportunity to learn something new from Mr. Vignoli, but also to participate in a lively discussion with honest and straight answers that were forthright. Plenary lecture on free textbooks and software in education was held by Professor Aleksandar Kavčić from The Alek Kavčić Foundation, which in our opinion, is not just important to the electrical and computer engineers, but also to the society as a whole. We have had the opportunity to see Professor Kavičić's struggle for the free textbooks for primary schools in the Republic of Serbia in the past period. But, at the PSSOH, we were able to hear the rationale directly from Professor Kavčić, as well as his views and, regrettably, to get up-to-date with the current textbook market. Professor Kavčić's lecture was followed with the exceptional attention and almost tangible silence from the worried audience in the amphitheater 56 at the School of Electrical Engineering in Belgrade. As there was an absolute consensus among all participants that the textbooks should be publicly available and free, we hope that Professor Kavčić's efforts will resonate in other environments as well. The last, but not the least important plenary lecture was given by Calista Redmond, CEO of the RISC-V International. Her lecture pointed out many aspects of RISC-V, as well as the impact that this open set of instructions has on the computing today. Unfortunately, Ms. Redmond was prevented from attending the live discussion, but the Editorial Board is grateful to Dr. Vladimir Milovanović, Associate Professor from the Faculty of Engineering, University of Kragujevac, for contributing to the discussion. With Prof. Milovanović’s knowledge and experience, where we would especially emphasize his Postdoctoral position at the University of California (Berkeley), he was a competent interlocutor on the topic of the RISC-V set of instructions.

In addition to the PSSOH Introductory session with the welcome notes from preceding Dean of the School of Electrical Engineering Dr. Milo Tomašević, Full Professor on behalf of our Faculty and Dr. Miloš Cvetanović, Associate Professor on behalf of the PSSOH Editorial Board, and the Plenary session, the conference was organized in three sessions: (1) Women in Electrical Engineering and Computer Science, (2)

Open-source Technologies in Education, and (3) Open & Free Software and Open Hardware Applications. The first session consisted of lectures on Hedy Lamarr's contribution to the field of frequency hopping and a lecture on the feminist cyborg myth. The session dedicated to the education was inspired by the plenary lecture held by Professor Kavčić and it included open textbooks, and open technologies and experiences of faculty stuff in education. Finally, the third session included lectures with the topics on free and accessible applications for research in psychology, pioneering work on defining FAIR (Findable, Accessible, Interoperable, Reusable) principles for open hardware, review of free software for speech technology, design of analog and digital circuits, as well as on artificial intelligence and an open generator of reports and scripts.

For the first time this year, we received a paper previously uploaded to the preprint server arXiv ("Towards FAIR Principles for Open hardware"), and we would like to encourage all authors to use arXiv or other preprint servers. The authors using preprint servers should inform us about the existence of a preprint upon paper submission. For a reason that is not entirely clear to us, this work achieved great visibility through the arXiv server, and we would like to point out this fact as one of the advantages of the preprints. Likewise the last year, we have posted all presentations from the lectures on our YouTube channel and shared them under CC license, so our followers, critics, friends, and all curious visitors will be able to replay the conference lectures and discussions anytime and anywhere. At all previous and future PSSOH conferences, all our guests and speakers are welcome if they want to help in accordance with their capabilities and we treat everyone equally, which is the tradition of the free software and open hardware movement, and now as well the tradition of the PSSOH conference. As we announced in 2018 and realized afterwards, we offered all authors who published open teaching materials at the School of Electrical Engineering, University of Belgrade to present them in our Proceedings. Therefore, we are very happy to incorporate this section as well.

Post-conference events were organized in the week succeeding the conference and included the following three workshops: (1) under the supervision of Dr. Dejan Tošić, Full Professor and Dr. Milka Potrebić, Full Professor, students Matija Dodović, Jelena Bakić, Katarina Stanković, and Nikola Ilić prepared the SymPyCAP workshop, (2) students Nikola Todorović, M.Sc. Nebojša Jovanović, B.Sc. Sara Živković, and Teaching Associate Danilo Đokić prepared a workshop on installing Linux – the second in a row at the PSSOH conference, and (3) Dr. Predrag Pejović, Full Professor, prepared and held a workshop on home servers titled "Evolution of answering machine --- home server ".

The organization of the PSSOH conference is traditionally supported by a large number of colleagues, institutions, companies, and associations, and it is impossible to mention them all here. We are most grateful to our donors from Academic Mind from Belgrade, but also to the LotusFlare company that covered the costs for printing T-shirts for our Organizing Committee and volunteer. We are grateful to all speakers who responded to our invitation and generously contributed to the content of our conference. Without Nikola Todorović and Dr. Miloš Bjelić, Assistant Professors the chairs of the PSSOH Organizing Committee, we would not have been able to imagine PSSOH 2021. We are very grateful to the members of the Organizing Committee Dejan Petković, Dragica Nikolić, B.Sc. Živana Garašević, Jovan Sandić, Mihajlo Pavlović, Dr. Nenad B. Popović, Teaching Associate Danilo Đokić, M.Ss. Nebojša Jovanović, B.Sc. Pavle Radojković, and B.Sc. Sara Živković. We also owe gratitude to all members of the Scientific and External Organizational Boards, but also to our volunteer M.Sc. Milan Antić. We would especially like to emphasize the engagement of Mihajlo Pavlović in the preparation of the LibreOffice materials for the PSSOH. As we are not able to list everyone who helped us, we apologize in advance, this year as well, to everyone we failed to mention.

P.S. According to the PSSOH themes and with aim to promote application of free software, this Proceedings is prepared in LibreOffice.

in Belgrade, February 14, 2021.

Editorial Board of the PSSOH Conference

Sadržaj / Table of Contents

Digital Sovereignty

Italo Vignoli
One of the founders and team members of The Document Foundation and main spokesperson
italo@documentfoundation.org

Announcement and Outline for Plenary Lecture

This is the second invited lecture held by Italo Vignoli from The Document foundation at the PSSOH conference. Mr. Vignoli's presentation will cover topics related to the Free and Open-source Software (FOSS) and Open Standards for the digital sovereignty. Participants will have a chance to learn about digital sovereignty and on ways how to achieve structural and technological independence. The talk will also tackle the current initiatives and available solutions, as well as importance of standards and interoperability.

The presentation held by Italo Vignoli at PSSOH 2021 is available on Zenodo repository (doi: https://zenodo.org/record/5713733).

Keywords: subservience; Free and Open Source Software; FOSS; open standards; digital technologies.

RISC-V: The Open Era of Computing

Calista Redmond
CEO, RISC-V International
https://riscv.org/risc-v-staff/

Announcement and Outline for Plenary Lecture

Calista Redmond, the CEO of RISC-V International will give a presentation explaining a tremendous impact that RISC-V as free instruction set architecture (ISA) has in bringing the open-source development model down to the microprocessor level. The benefits of a modular architecture over legacy incremental approaches accompanied with open license model open doors to many opportunities for introduction of innovative technology solutions aiming both the smallest microchip and the largest system on a chip (SoC) based hardware.

Keywords: RISV-V; open ISA; open license; computer architecture.

The Case for Free Textbooks and Educational Software

Aleksandar Kavčić
Founder, Foundation "Alek Kavčić"
https://sr.wikipedia.org/wiki/Aleksandar_Kavčić

Announcement and Outline for Plenary Lecture

Professor Aleksandar Kavčić, an engineer and scientist, the founder of The Alek Kavčić Foundation, is a well-known for his patent off reading records from magnetic memories, however, in this lecture he will set out the facts for a case about free textbooks in Republic of Serbia. Why free textbooks are important for true reform of an educational system? What are the rationales behind free textbooks? How it could be done and what Alek Kavčić Foundation is doing to make it happen? What else needs to be changed in the educational system of Republic of Serbia? Those are just some of the questions that this lecture is going to cover.

The presentation held by Professor Kavčić at PSSOH 2021 is available on Zenodo repository (doi: https://zenodo.org/record/6059400).

Keywords: textbooks; publishers; educational software.

PSSOH 2021, DOI: https://doi.org/10.5281/zenodo.5549780

HEDY LAMARR AND FREQUENCY HOPPING

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ABSTRACT

This paper reconsiders the question of the role of Hedy Lamarr in Frequency Hopping technique, taking as a starting point the historical and descriptive accounts on the items under consideration. By way of illustration, the paper examines the pertinence of Frequency Hopping and Spread Spectrum mainly in the descriptively-oriented manner. This paper is built around six parts. The paper opens with an introduction that sets the scene. It sketches out the scientific contribution of Hedy Lamarr. The second part provides introductory remarks on Hedy Lamarr as an inventress. The third part focusses on Hedy Lamarr's contribution to the invention of Frequency Hopping. The fourth part is a sketchy exercise serendipitously leading to complex ideas of Spread Spectrum and Frequency Hopping. The fifth part is more empirical in nature in that it outlines some linguistic aspects of Frequency Hopping Patent by means of structural linguistic analysis. In this way, the analysed historical-descriptive engineering and linguistic aspects are brought together to elucidate the overall contribution of Hedy Lamarr in the former and current domain of Frequency Hopping.

Keywords: Hedy Kiesler Markey – Hedy Lamarr, Inventress, Frequency Hopping, Spread Spectrum, Electrical Engineering, Discourse Analysis, Structural Analysis, Patent Discourse, Text Linguistics.

1 Introductory Remarks

Hedy Lamarr was best known for her work in Hollywood during the Golden Age of Hollywood. However, less was known about Hedy Kiesler Markey, the inventress of Secret Communication System that embodies Frequency Hopping. This paper looks at the implications of her invention, her patent and her role in Frequency Hopping and Spread Spectrum, from a descriptively-oriented perspective.

This paper is organised around the following parts. The second part sets the scene by introducing a brief overview of Hedy Lamarr as a beautiful woman, a scientist and an inventress. The third part focusses on Hedy Lamarr's contribution to Frequency Hopping from a dynamic perspective starting from the centre and working outwards. The fourth part sketches certain aspects of Frequency Hopping and Spread Spectrum from simple structures to complex ideas whilst delving in the electrical engineering literature on the subject in an attempt to provide a unitary descriptive account of these two phenomena. By way of illustration, the fifth part analyses the text of the patent of Hedy Lamarr inspecting merely the linguistic indicators of patent discourse with the help of the structural

analysis tools, and certain pertinent ingredients of discourse analysis and text linguistics. The sixth part provides certain concluding remarks.

2 Some Remarks on Hedy Lamarr, a Beautiful Woman, a Scientist, and an Inventress

According to *Jewish Women*: *A Comprehensive Historical Encyclopedia*, Hedwig Eva Maria Kiesler, or simply Hedy Lamarr, was the Austrian film star well-known as an exotic beauty, often represented as a foreign temptress in Hollywood-generated films [1]. In addition to her Hollywood career, she also contributed to the development in the field of wireless communications by inventing a frequency hopping technique. More specifically, she was working on generating a frequency-hopping radio signal whilst investing efforts to synchronise its frequency changes between a ship or an airplane and a torpedo.

According to the publicly available records, Hedy Lamarr was born Hedwig Kiesler on 9th November 1914, in Vienna. Hedy Lamarr died on 19th January 2000. Lamarr's mother was Gertrude Lichtwitz, also known as Trude Lichtwitz, who came from a sophisticated family in Budapest, whilst Lamarr's father Emil was from Lemberg, Lwów, in the West Ukraine.

Figure 1: The photograph of the actress and inventress Hedwig Eva Maria Kiesler, also known as Hedy Lamarr. The caption from the original document contains the following text: "Actress and inventor Hedy Lamarr in the MGM film The Heavenly Body, 1944." The photograph was provided by the courtesy of the Jewish Women's Archive - JWA.

Both Hedy's parents were Jewish and, consequently, she was registered at birth as Jewish, yet, according to some sources, she remained strikingly tongue-tied about her Jewish identity (see [1]). It was known that her father was the manager of the Creditanstalt Bankverien, and that the family lived on Osterleitengasse in Döbling in Vienna's posh and fashionable 19th Bezirk, and afterwards they moved to Peter-Jordan-Straße, located also in Döbling District.

According to the pertinent literature, Hedwig Eva Maria Kiesler was the only child of Gertrud Lichtwitz and Emil Kiesler, who provided their daughter with the well off and cultured environment. The same source stated that Lamarr often depicted her childhood period as a kind of lost paradise comprising education at the Döblinger Mädchenmittelschule, memorable walks with her father in the Wienerwald, and piano lessons with her talented mother [1].

According to the publicly available sources, Hedy Lamarr started attending Professor Arndt's acting classes in Vienna (see, for instance, [1]). She was so passionate about acting that she wanted to be actively involved in the machinery of the Austria's largest film studio at that time, more precisely, the Sascha Film Studios. Even though she was in love with acting she explicitly pointed out that she wanted neither to embark on a Hollywood career nor to become a cinema slave.

Figure 2: The photograph of the actress and inventress Hedwig Eva Maria Kiesler, also known as Hedy Lamarr. The caption from the original document contains the following text: "Hedy Lamarr." The photograph was provided by the courtesy of the Jewish Women's Archive – JWA.

Having attended the acting classes, Hedy Lamarr was formally trained under Professor Arndt in Vienna. Officially, her first appearance was in Georg Jacoby's *Gold on the Street*, originally *Geld auf der Straße*, in 1930. She continued her acting career under the auspices of the famed Jewish theater director, Max Reinhardt, in his stage production of *The Weaker Sex*, and then she appeared as the star of Gustav Machatý's 1933 Czech art film, *Extase*, i.e. *Ecstasy*, which, according to the pertinent literature (see [1]) was best remembered in the film history due to the film scenes "in which the teenage Lamarr runs naked through the woods before plunging for a dip into a lake and simulates orgasm with her lover" (see [1]).

Perhaps the most relevant person to be mentioned is Herr Friedrich "Fritz" Mandl, who was an arms merchant as well as a munitions manufacturer from Vienna, Austria. More often than not, Mandl was described as the third richest man in Austria.

According to the publicly available data, Herr Mandl became obsessed with Hedy Lamarr and wanted to meet her in person. Hedy was said to have adored Mandl's charming individuality and his fascinating personality, even though some gossip sources claimed that this attraction was partly due to Mandl's Brobdingnagian wealth. Clearly, Hedy's parents, both of whom were of Jewish descent, did not approve of this relationship, and ultimately, marriage.

On our assumptions, based solely on the descriptively-oriented literature, the disapproval of Hedy's parents might be the case primarily due to Fritz Mandl's tight connection with Benito Mussolini and Führer Adolf Hitler, but they could not prevent her from marrying Mandl. Ultimately, on 10th August 1933, at the age of eighteen, Hedwig Kiesler married Friedrich Fritz Mandl, who was thirty-three years old.

Figure 3: The photograph of the actress and inventress Hedwig Eva Maria Kiesler, also known as Hedy Lamarr. There is no caption in the original document. The photograph was provided by the courtesy of the American Physical Society - APS. APS News, June 2011 (Volume 20, Number 6).

According to the pertinent literature, Hedy Lamarr married six times and witnessed her career fall into decline, whilst remained remarkably silent about her Jewish identity (see [1]).

Before embarking on her Hollywood career, Hedy Lamarr, that is Hedwig Kiesler, to be more exact, spent some time in Switzerland. More precisely, she spent the winter of 1936/1937 before settling in Paris, as a temporary resort. After that period, she headed towards the USA and Hollywood.

Perhaps the most relevant role in Hedy's life in that period pertained to the sophisticated English gentleman, Reginald Gardiner who introduced her to Walter Wanger. However, it ought to be emphasised that Walter Wanger altered the path of Lamarr's artistic life direction. However, since this paper is not oriented towards that part of Hedy Lamarr's life and career, it is necessary to impose an interpretation on her occupation of an inventress.

From [2], it follows that Lamarr was on the road to observe the clash in Europe from the distance of America. In addition to being in the business of selling war bonds and also serving in the Hollywood canteen, she brought the intellectual property acquired in the Mandl's castle (for instance, see [2]). For one thing, it appears that both Hedy Lamarr and other high-profile Germans and Austrians, obtained "a chance to remind their hosts where their allegiances lay", [2]. In Hedy's own words, "[she] constantly worked at the Canteen and [she] worked hard" [2].

In Hollywood, Lamarr became well-known for the diverse roles she played. It may be, then, that Hedy Lamarr enjoyed the financial security that would enable her to dedicate time to her own experimental interests. It appears, clearly, that this was perhaps the most relevant part in her career from the point of view of science and engineering. More specifically, it was exactly during the war that she persuaded George Antheil, the composer and concert pianist, to collaborate with her on her invention of a radio-controlled torpedo-guidance system, which she labelled "Secret Communication System" [2]. According to the quoted reference, a consequence of the approach to this invention just outlined was that the Secret Communication System became widely known afterwards, and, consequently, represented a lesser item of interest.

In Hollywood, Hedy Lamarr was constantly in the glare of the spotlight, but despite all that, she continued to develop her inventions far from any publicity, almost secretively.

3 Hedy Lamarr's Frequency Hopping: Starting from the Centre and Working Outwards

According to the available data, Lamarr became interested in invention as a child primarily inspired by her father, who was an amateur engineer himself (see [3]). Equipped with her ambition to invent new things, she scribbled various diagrams and distinct charts in her notebooks. Even in Hollywood, she set up a mini-laboratory with the chemistry set. But, let us now see Lamarr's frequency hopping.

Frequency hopping, the system which has become associated with the actress and the composer, is a fairly straightforward process, although, in the years preceding and during World War II, its finer points eluded the scientists of the day [2]. Simply put, the frequency hopping procedure is comprised of sending a series of signals from a transmitter to a receiver in a manner that cannot be intercepted thereby allowing for a torpedo to be dropped remotely. Not only does it seem salient that the information pass from a transmitter to a receiver, but it is also essential that the message not be rendered such that it can be jammed easily by a third party (see, for instance, [2]).

In the early years of the war, however, she was having difficulty refining the details of frequency hopping, and precisely due to this fact she needed the help of George Antheil. Even though Antheil was famous for his composition skills, it was through his research on endocrinology that he met Hedy Lamarr, described as the most beautiful woman on earth (see [2]).

Antheil's art background (or music background, to be more precise) suggests that he contributed to the invention of frequency-hopping in terms of inserting the detail from his own music playing practice. Let us continue to suppose that Antheil assumed that swift changes in radio frequencies may be coordinated in the same manner as he coordinated pianos for his work of art. He brought the evidence in favour of his assumption that promptly alternating frequencies ought not to be jammed.

According to [2], Lamarr and Antheil would spend many hours in Hedy Lamarr's villa utilising the old matches and a silver matchbox, which they would place out on her carpet, whilst pondering over the idea how they would develop Hedy Lamarr's initial concept of frequency hopping realisation. For one thing, a whole lot of ideas emerged, one of them being putting a paper roll within the transmitter and the other paper roll within the receiver.

On our assumptions, from the available public records and the pertinent literature, each roll would be perforated in such a manner as to contain a randomly occurring pattern. A consequence of their approach just outlined was that the transmission itself would be expected to switch from one channel to another channel in a secret sequence, which would be far too complex to be intercepted by a third party. Apparently, this approach may remedy, and, at the same time, eliminate any interception, however, both the transmitter and the given receiver ought to be perfectly synchronised by means of a meticulously prepared components, which would be expected to memorise the given sequence of the channels involved. This synchronisation appears to correlate rather closely with the player piano rolls in a work of art put forward by Antheil.

One ingredient of their invention is apparently determined by Antheil's tools, namely, the piano. More specifically, the system was supposed to make use of eighty-eight frequencies, which is an equivalent number to the number of keys on a piano. Summarising, then, we may assume that this part of their invention was tightly connected to piano playing features.

Lamarr came up with the idea of a system that was intended to be utilised in order to activate radio frequencies. Her idea was rather attractive and appealing enough to motivate Antheil to devise a system of hopping between eighty-eight frequencies thereby providing the secrecy of any radio communication, and Lamarr got to the heart of frequency hopping since she was convinced that it could be applied to secure radio communications in such a way as to incapacitate and disable anyone since they would have to be able to follow the movement between frequencies so rapidly and repeatedly (see [3]).

Nevertheless, it should be pointed out the engineering part of the patent text was unselfishly supplied by Dr. MacKeown, a Professor of Electrical Engineering at the California Institute of Technology, who helped the frequency hopping inventors to polish the text of the patent No. 2,292,387. Finally, the patent was given the green light on 11th August 1942, and was given the title "Secret Communication System", and its creators were officially registered as Hedwig Kiesler Markey and George Antheil, respectively. Even though the gist of the patent specified that a high-altitude observation plane could steer the torpedo from above, the response of the navy was that the submitted proposal was not highly functional, and, additionally, the proposed invention was too cumbersome for utilisation within an average torpedo.

As I have already mentioned, in 1942, Lamarr and Antheil received U.S. Patent Number 2,292,387 for their invention, and formally, they may be credited with the invention of frequency hopping (see

Figure 4). Furthermore, it has been argued so far that Lamarr's discovery of frequency hopping seems to have been a crucial founding element in the later development of Bluetooth and Wi-Fi technologies (see, for instance, [3]). However, according to another pertinent record (see [4]), Lamarr and Antheil submitted their joint patent on 10th June 1941, and, subsequently, the patent was granted on 11th August 1942, the text of which contained Lamarr's name represented as Hedy Kiesler Markey, which was actually her married name at the time of the patent submission (see [4]).

Broadly speaking, frequency hopping was not an entirely new concept. Allegedly, and according to some unreliable sources, Nikola Tesla alluded to frequency hopping in certain patents. A similar patent for a "secrecy communications system" was granted in 1920, with additional patents granted in 1939 and 1940 to two German engineers. And in the 1980s, evidence came to light that during World War II, the US Army Signal Corps worked on a communication system that used the spread spectrum concept as well.

Frequency hopping became later better known as spread spectrum technology, and the primary purpose, at least the one proposed by Lamarr and Antheil, was to enable launching of long-range missiles in such a manner as to prevent the third party from electronic jamming. It is though this joint endeavor that Hedy Lamarr realised that she had met the collaborator she desperately needed to develop her patent (see [1]).

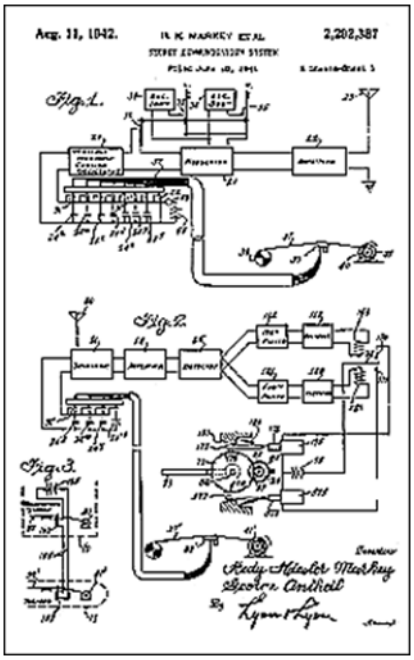


Figure 4: The photograph of the patent excerpt. There is no caption in the original document. The photograph was provided by the courtesy of the American Physical Society - APS. APS News, June 2011 (Volume 20, Number 6).

Perhaps the most striking piece of information refers to the detail that Hedy Lamarr regarded her discovery of frequency hopping as a sort of her key for the gate of science, in the domain of which

she may be finally recognised as a scientist. It was due to this that Hedy Lamarr was not ready to give up on her invention hope (see, for example, [3]). This was apparently determined by her contribution, which ought to be regarded as the basis for the plausible design focussed on a torpedo guidance system.

Strictly speaking, Lamarr's and Antheil's joint endeavour might be broken into two parts. The first one was Lamarr's contribution through the initial idea of frequency hopping, whilst the second one was Antheil's practical experience with his composition, entitled *Ballet Mécanique*. The mentioned composition ought to be regarded as a relevant ingredient encompassing the idea of devising a means of synchronising Lamarr's idea of rapidly changing radio frequencies (see [4]).

For the purpose of clarification, one ought to mention that their joint invention made use of a mechanism not quite equivalent to, but rather similar to piano player rolls aimed at synchronising the changes between the eighty-eight frequencies [4]. Notice, incidentally, that the mentioned number, i.e. eighty-eight, represents the standard number of piano keys. It has been suggested that the preliminary outline of their invention referred also to a high-altitude observation plane that would steer a radio-controlled torpedo from above (see, for instance, [4]).

The question that has been posed in the literature on the subject is the following one: "Did Hedy invent independently or simply borrow the "ideas" she had "retained … in basic form"?" [5]. The quoted source, however, highlights that "The misogynistic debate about whether or not Hedy's ideas were original or borrowed continues to this day" [5].

Let us see the relationship between Antheil and Lamarr. On our assumptions, it may be, then, that their relationship might have been influenced by the fact that both of them were native German speakers, both former members of the European artistic community, and these were sufficient reasons to put them together [5]. In an attempt to answer the question whether it is possible to establish the nature of their liaison and/or friendship, one ought to have recourse to the publicly available data mainly based on idle gossip, which seems to have been the necessary ingredient of the society, at least from the anthropological point of view (see, for instance, [6]). Backed by this idea, one cannot help but pay attention to the detail provided in the literature that Hedy Lamarr wrote her telephone number on George Antheil's windscreen using her lipstick [5].

Additional questions, based on assumptions and gossips, were posed in the literature. The two striking questions, according to the pertinent literature (see [5]), would be: 1. How did an actress and a composer go about inventing a remote controlled torpedo?, 2. What was original about their invention that allowed them to successfully patent it, as they eventually did? [5]. These are just some of the plausible questions. Furthermore, these, and similar questions kept appearing, like the one referring to a problem Hedy Lamarr foresaw in connection with torpedo control by radio, namely, the problem of jamming. According to the literature, she never said how she had known that set frequency radio-control systems had been easily jammed (see, for example, [5]).

A consequence of the approach just outlined might lie in the explanation utilising the concept of serendipity, as well as thinking 'outside the box'. Summarising, then, one may assume the necessity of introducing the concept of 'happy thought', which may be explained in terms of the spontaneous conception – the one which has not been previously presented in the realm of invention.

The concept of serendipity, particularly its diachronic development, and its translatability problems, more specifically, certain difficulties in finding an appropriate translational equivalent, have been discussed in the pertinent literature on the subject so far (see, for example, [7], for a detailed discussion). It was noticed, incidentally, for example, that Claude Shannon and his student Irwin Jacobs had independently formulated Information Theory, at the same time [7].

It has been argued that more often than not the inventive process follows a whole lot of ideas and some thoughts, usually somehow interconnected, which are usually expected to be found separately, stranded, as it were, seemingly unrelated and not obviously connected (see [5]). The quoted reference takes into account the unconventional ways of thinking ‘outside the box,’ which would unavoidably lead to serendipitously establishing the connection between the superficially unrelated concepts thereby setting up the path for creating a brand new idea.

In what follows, I shall attempt to delineate the lines along which Hedy Lamarr’s contribution may be handled, primarily basing my claims on descriptive accounts at hand. The point that needs to be further explained is concerned with outlining Lamarr’s original idea. We have already seen that in case when a radio transmitter and a receiver are synchronised to change their tuning simultaneously, hopping together randomly from frequency to frequency, the radio signal passing between them cannot be jammed (see, for instance, [5]). With this clarification, it is evident why Hedy called this idea “hopping of frequencies”.

Let us continue to suppose that Hedy Lamarr originally employed the German compound word *Frequenzsprungverfahren*, which she consistently utilised in developing her ideas, and her patent, for that matter, and selected the translational equivalent “frequency-hopping process”, or, more precisely, the term “frequency hopping”. Being aware of the fact that mental part cannot be patented, their idea required a physical embodiment, or to borrow the expression, Lamarr and Antheil needed to reduce their idea and invention to practice. Nevertheless, both Antheil and Lamarr deliberately avoided clearly specifying the mechanism for simultaneous change of tuning in their patent text (see [8], for a detailed account). Reducing to practice may remedy and, at the same time, eliminate any doubts about the implementation of a patent.

According to the pertinent literature (see, for instance, [5]), reduction to practice, was to be regarded as fulfilling the U.S. Patent Office formal requirements. Naturally, an inventress, who is legally speaking, a claimant, is obliged to provide a miniature working model of her invention in order to demonstrate the functionality and the plausible operation of her invention. Not surprisingly, since one assumes that even all formal systems cannot be treated on a par (see, for instance, [9]), but rather be utilised as guides, this process of selection may be trivial, but then it should be readily demonstrable.

Even though the joint effort of Lamarr and Antheil was not officially adopted, the patent was utilised before its expiration date, but without specifying the names of the inventress and the inventor (see [2]). Apart from observing that the system was commonly called ‘frequency-hopping’, certain authors highlighted that its official name was ‘Code Division Multiple Access’, or CDMA, to abbreviate it and thus make it shorter (see, for example, [2]). It should be noted that the CDMA was installed on ships in 1962, after the Lamarr-Antheil patent had expired. It seems to me that in this manner, their genuine influence has been neutralised to a certain extent.

In contrast to this attitude towards Lamarr-Antheil patent, subsequent patents, taking their place in frequency-changing, refer to the Lamarr-Antheil patent as the foundation for the given field (see [2]). The last item to be discussed here is that of the legacy of Hedy Lamarr in the domain of Frequency Hopping.

Despite the fact that the Lamarr-Antheil patent was not widely acknowledged at that particular period of the history of science and history of invention, and that sometimes even other patents and intellectual contributions of this sort did not clearly refer to the Lamar-Antheil patent, Hedy Lamarr remained the most glamorous name associated with Code Division Multiple Access and Frequency Hopping, for that matter. As an additional contribution to this claim, one may take into account

Hedy Lamarr's legacy which has been expressed as the explicit and tangible textual evidence of the patent number 2,292,387.

But, before we continue with the linguistic analysis of the patent text, one ought to consider the engineering aspects of 'spread spectrum' and 'frequency hopping' in the section that follows.

4 From Simple Structures to Complex Ideas: Delving into Spread Spectrum and Frequency Hopping

Broadly speaking, the invention of Hedy Lamarr seems to have been represented as the underappreciated intellectual contribution even though Lamarr's frequency-hopping system is integral to modern GPS, secure Wi-Fi, and military satellites (see [10]). Nevertheless, it was Lamarr's collaboration with George Antheil during World War II that solidified her legacy as an inventress.

Their formal patent submission was not well-accepted by the Navy. This piece of information suffices to account for the fact that discouraged by the Navy's attitude, Lamarr and Antheil did not pursue their invention further (see [11]). Although, not accepted by the National Inventors Council, her invention was applied in contemporary Global Positioning System (GPS), secure Wi-Fi, Bluetooth, as well as military satellite technologies [10]. The inventress Lamarr is also credited with developing a scrambler that secures communications, or more precisely, she played a role in the technology, according to the pertinent literature (see [12]).

From the title of this phenomenon, i.e. spread spectrum, it follows that the idea of the intended transmission has to utilise a far wider bandwidth in the electromagnetic spectrum than the bandwidth imposed by the original information signal. The term 'spread spectrum' was coined back in the 1960s by Madison Nicholson and John Raney, two engineers who, according to [12], pioneered in developing this system.

The working definition of the term 'frequency-hopping spread spectrum', or briefly, FHSS, might be the following one: FHSS is said to represent a method of transmitting radio signals in such a manner that it swiftly alternates the carrier frequency among diverse divergent frequencies occupying a large spectral band. Of course, changes are managed and controlled by a code known to both transmitter and receiver.

This tentative and working definition might serve as a starting point in an attempt to re-evaluate some former and current approaches to frequency hopping phenomena in the literature on the subject. However, since this part is mainly descriptive in orientation, we shall neither evaluate nor arbitrate between the assertions cited from the pertinent literature on the subject.

Let us now see some aspects of spread-spectrum which have been utilised in determining the origins of spread-spectrum communications. In the literature describing these origins, the first assertion focusses on the appearance of the concept of spread-spectrum. More specifically, it has been claimed in the literature that the concept of spread-spectrum (SS) has come into view from its confidentiality and clandestineness by means of the path generated through the Global Positioning System (GPS) and the Joint Tactical Information Distribution System (JTIDS), even though, it seems that the history of this robust communication technique remains largely fuzzy to communication engineering experts (see [13]).

The descriptive strength of this historical approach lies in its pointing out the necessity of an interpretation of certain concepts relevant for this topic. The basic signal characteristics, which

pertain to modern spread-spectrum systems, are delineated and further specified in the literature on the subject. According to the quoted reference, [13], these basic signal characteristics establish the nature of the carrier, which ought to be an unpredictable, or pseudorandom, wide-band signal. Furthermore, the next feature refers to the bandwidth of the carrier, and this bandwidth is supposed to be much wider than the data modulation bandwidth. Finally, the third property is concerned with reception. A general convention within this model is that reception is to be accomplished by means of cross-correlation of the received wide-band signal with a synchronously generated replica of the wide-band carrier (see [13]).

Another concept brought to one's attention refers to frequency hopping systems. In the literature, frequency hopping (FH) systems achieve carrier spreading by driving a frequency synthesiser with a pseudorandom sequence of numbers spanning the range of the synthesiser [13]. Moreover, it has been claimed, in the quoted literature, that data may be usually frequency-shift-keyed (FSK) onto the spread carrier but solely in the authentic and flawless form type of this system.

The next approach to be discussed is concerned with further notes on spread-spectrum origins. Certain authors thoroughly describe the period shortly before Pearl Harbor, particularly focussing on the Lamarr-Antheil Frequency-Hopping invention (see [14]). The foreground assumption is that Hedy Lamarr was an inventress of the first frequency-hopping spread-spectrum technique explicitly conceived for anti-jamming communications. Furthermore, the reference [14] stresses that in mid-1941 an application for the Frequency Hopping patent was filed by Hedy K. Markey and George Antheil, without their awareness of the existence of the method of maintaining secrecy in the transmission of wireless telegraphic messages, which was proposed and filed by Broertjes in Germany on 11th October, 1929, and then in the U.S.A. on 2nd August, 1932, respectively.

According to [14] and [15], Hedy Lamarr and George Antheil created large diagrams whilst stretched out on Lamarr's carpeted floor. In particular, it should be emphasised that Lamarr and Antheil concentrated on these precisely created drawings, and afterwards they came up with the idea of a secure, viable and feasible concept of Frequency Hopping Spread-Spectrum. It was also underlined that the design of this specific system utilised the composer's know-how, particularly whilst the two of them were planning to synchronise the radio transmission and reception frequencies by means of identically crypto-code slotted, paper music rolls like those used in player piano audio-frequency mechanisms (see [14] and [15]). According to the layout of their patent, the Frequency Hopping of eighty-eight radio frequencies might be readily accommodated within this pattern. For one thing, Frequency Hopping secretiveness features of the Lamarr-Antheil invention were augmented and enhanced by the introduction of short-pulse transmission aimed at providing low detectability (see [14] and [15]).

In this brief chronological survey, I have noticed that even the state-of-the-art literature proposing new guidelines, concepts and design techniques that can be used for future ultra-low power wireless radio links makes use of the concepts of Frequency Hopping, among other things (see, for example, [16]). According to these authors radio power consumption still seems to represent impediment and obstacle incapacitating the extensive adoption of this technology.

What [16] suggests refers to dissimilar paths which ought to be explored in order to minimise the radio consumption. However, the first and foremost difficulty pertaining to the proposed solutions lies in sort of reduced wireless link robustness. With this clarification, a similar view is then expressed and employed whilst considering some aspects of striking architectures and synthesisers for ultra-low power fast Frequency-Hopping WSN radios [16]. So, one can conclude that even the advanced models and systems employ the legacy of Hedy Lamarr's Frequency Hopping.

Briefly, current approaches to the phenomenon under consideration could be better grasped if we look at the historical perspective of frequency hopping spread spectrum. Let us see the definition, found in the literature, according to which, frequency hopping spread spectrum is a technique that many ultra low power (ULP) radio protocols use to overcome the problems of interference in the crowded 2.4 GHz band [17]. Up to now, we have seen the concise definition of the process, and let us now see how this technique partakes in the process by sub-dividing the 2.4 GHz band, this band being extended from 2.4 to 2.48 GHz into channels of varying frequency [17]. Subsequently, the transmitter broadcasts on a particular channel and if the receiver detects interference, both the transmitter and the receiver jump to a different (and hopefully clearer) frequency. These might be said to be conditions that must obtain for the transmitter and the receiver to be able to carry out the given frequency jumping. Therefore, it is hardly surprising that FHSS is considered to be simple, elegant, and effective, according to the literature (see [17]).

Following the chronological account, proposed by [17], the inventress Lamarr, together with her co-inventor George Antheil came up with a system for radio control of torpedoes. In a nutshell, the quoted reference stated that the idea itself was not new. However, Lamarr's concept of Frequency Hopping aimed at preventing the intended target from jamming the controller's transmissions was quite original (see, for instance, [17]).

In a similar manner of the previous accounts, the observed account also points out that the system uses eighty-eight different carrier frequencies, which is equivalent to the number of keys on a piano. More precisely, this technique was focussed on synchronising the frequency hopping between the transmitter, which was to be located in a plane flying above the torpedo and the weapon itself (see [17]). The quoted source adds that the Lamarr and Antheil's patent obtained the mysterious and puzzling title – "Secret Communication System".

As regards their contribution, diverse contemporary patents in FHSS technology refer to the Lamarr-Antheil patent document as the basis of the field. It has also been claimed that today's Bluetooth low energy and proprietary protocols owe much to the amazing intellect of this beautiful actress and gorgeous inventress (see, for example, [17]). Let us see how some of the relevant terms are defined in some current accounts.

Let us first go to the concept of 'spreading'. More specifically, spreading is determined as a sort of operation of enlarging or spreading the spectrum. In addition to this, it is pointed out that several spreading codes can be used for spectrum spreading (see, for instance, [18]). Historically speaking, spread spectrum systems have been developed since the mid-1950s [18]. Furthermore, spread spectrum systems were initially utilised for anti-jamming tactical communications, guidance systems, as well as experimental anti-multipath systems in the military context and domain (see [18]).

To characterise a spread spectrum system, one has to consult and observe the literature on the subject. Apparently, a spread spectrum system is defined as such a system in which the transmitted signal is spread over a wide frequency band. And this band is much wider than in the case of the minimum bandwidth, which is required to transmit the data being sent. It is highlighted in the literature that band spreading is accomplished by means of a code which is independent of the data [18]. It is necessary to impose an interpretation on a reception, which is, in this case, and according to the described scenario, synchronised to the code, and subsequently, this reception is used to despread and recover the data at the receiver (see [18]). It is widely accepted that spreading the spectrum can be applied in diverse contexts and domains, as is the case with anti-jamming, interference rejection, low probability of intercept, multiple access, multipath reception, diversity reception, high resolution ranging, and accurate universal timing, to name just a few (for a fuller

account, see [18]). A general convention regarding the spread spectrum concepts for multiple access refers to two paramount kinds, the first one being direct sequence code division multiple access, i.e. DS-CDMA, the second one being frequency hopping code division multiple access, i.e. FH-CDMA (see, for instance, [18]).

We have seen so far historical and engineering accounts of the invention under consideration. In a nutshell, in 1941, Hedy Lamarr and George Antheil devised a jam-resistant guidance system for torpedoes, the aim of which was to control the transmission frequencies by means of slotted paper rolls resembling the rolls used in player pianos (see [19]). Additionally, according to the descriptive accounts, certain spread-spectrum ideas were used in World War II, predominantly in the context of radars. It is in this context that synchronisation of the pseudorandom sequences between transmitter and receiver does not represent a problem (see, for example, [19]).

By stressing the common rule of thumb for assessing the efficiency of a modulation scheme, the approach of [20] is not unlike that of the other sources of literature on the subject. More specifically, this modulation scheme efficiency aims at examining how tightly it concentrates the energy of the given signal for a given rate of information. Spread-spectrum modulation techniques are rather different from the compactness of the signal pertaining to the conventional wisdom. This is to say that spread-spectrum modulation signal is to spread the signal over a very wide bandwidth (see [20]).

A similar view of the consulted literature is expressed in [20], according to which communications signals may be increased to a great extent in terms of their bandwidth, or more precisely, by factors of 10 to 10,000. This is obtained by combining the given signals with binary sequences making use of several different techniques. Consequently, the result of this spreading is said to have at least two beneficial effects. The former refers to the signal energy dilution, whilst the latter obtains for the receiver, which may reject strong undesired signals, even the signals of greater strength than the desired spread-spectrum signal power density (see [20], for a detailed account).

The first effect, therefore, may be said to attenuate the amount of power density present at any point within the spread signal, since this signal seems to be very weak. Additionally, the signal dilution amount depends on several factors such as transmitting power, distance from the transmitter and the width of the spread signal. It is a descriptive fact that, on the one hand, the dilution may result in the signal being below the noise floor of a conventional and commonly expected receiver, and consequently be rendered invisible to the receiver, whilst, on the other hand, it can be received with a spread spectrum receiver, according to the literature (see [20]).

What this assertion from the quoted reference suggests is that this occurs mainly due to the fact that the desired receiver owns a spreading sequence copy, which is utilised to despread the signal. An important property that ought to be mentioned refers to non-spread signals that are in this case suppressed in the course of processing. The consulted source agrees with the other consulted data in terms of the validity and effectiveness pertaining to the interference-rejection property of spread spectrum, which has rendered it a popular military anti-jamming technique (see [20], for a detailed account). But, let us now concentrate on Frequency Hopping, since this phenomenon is in the focus of the investigation (and this paper, for that matter).

According to a descriptively adequate account, Frequency Hopping, sometimes abbreviated as FH, represents a form of spreading in which the center frequency of a conventional carrier is altered many times a second in accordance with a pseudorandom list of channels (see [20] for the explanation). Another important concept that has been introduced in the literature on the subject refers to the ‘dwell time’, which is defined as the amount of time the signal spends on any single

channel. An important property of the dwell time is its duration. Namely, the dwell time has to be extremely short, commonly implying less than 10 milliseconds. Only in this case can it avoid interference to a conventional user and from conventional users (see [20] for a brief overview).

Elaborating on spectrum of spread spectrum, the consulted literature (for instance, [20]) demonstrates how each spectrum type of spread spectrum signal depends on several factors, such as the speed at which the spreading code is clocked. And then, each spectrum type of spread spectrum signal is attested by the type of the utilised spreading code, and it depends on whether frequency hopping or direct sequence is being used. In addition to this, the modulation bandwidth and the method of modulation are salient ingredients to which due attention should be given.

Whilst consulting the pertinent literature on the subject, we are frequently made aware of what has been accomplished in the domain of multi-carrier and spread spectrum communications, and one might conclude that this particular field of multi-carrier and spread spectrum communications has became a far-reaching investigation field and an outstanding research topic which calls for and results in an increasing number of diverse research activities (see [21] for a detailed discussion).

It has been also mentioned that new standardisation activities in the framework of beyond 3G concepts have been initiated, in addition to deep system analysis of various multiple access schemes. Finally, multi-carrier transmission might be considered to be a potential candidate to illustrate and underscore the requirements of the next generation system, according to the literature (see [21]). On the grounds of additional spreading, it has been shown (see, for instance, [22]) that multicarrier spread spectrum (i.e. MC-SS) may make available frequency diversity by means of additional spreading in order to overcome severely faded sub-channels.

On the grounds of certain features Frequency Hopping seems to be susceptible to specific application in certain domains. The last approach or more precisely, Frequency Hopping application, to be mentioned in this paper is Frequency Hopping in GSM. Rather than consider which descriptive account correctly captures the gist of Frequency Hopping and the role of Frequency Hopping in some aspects of engineering, as they all seem to highlight one important aspect of the overall Frequency Hopping picture, in the remainder of this part of the paper I shall consider the possibility of yet another case of Frequency Hopping application, confining my descriptive account to the proposal that the radio interface of GSM offers the slow frequency hopping functionality, according to the literature (see [23]).

This brings us to the question of the Frequency Hopping treatment in the literature dealing with its actual application in certain specific domains. Rather than describe the state of affairs within these domains, it is merely asserted that frequency hopping falls into the category of techniques that limits the influence from interference. At this point, frequency hopping is based on a relatively straightforward idea that every mobile station transmits its TDMA frames according to a sequence of frequencies specified by the frequency hopping algorithm [23].

Strictly speaking, a mobile station transmits on a fixed frequency during one timeslot and then, subsequently, jumps to another frequency previous to the next TDMA frame, the uplink and downlink frequencies being always duplex frequencies. Even though there are probably a whole lot of cases that do not easily lend themselves to such a clear-cut division, in the context of GSM at least two different modes of hopping are specified, and are illustrated by cyclic hopping and pseudorandom hopping, according to the literature (see, for instance, [23]).

It seems to me that the actual application of spread spectrum shows to be propitious, as is the case shown in diverse case studies, some of which focus on spread spectrum communication link in spatial scenario with jammer and eavesdropper (see, for example, [24]). Given the pervasiveness of

jamming and eavesdropping the question might be posed concerning the techniques utilised for countermeasures.

The answer provided in the literature (see [24]) seems to be fairly simple. Namely, the synchronisation of transmitters and receivers in space facilitates the space domain techniques utilisation for electronic countermeasures. Jamming and eavesdropping can be avoided by the proper use of space domain operators (see [24]), whilst the positioning of transmitters relies entirely on a considerably richer overall potential of the repertoire of space domain techniques.

To sum up, in a great many instances, Frequency Hopping is defined as the periodic changing of the carrier frequency of a transmitted signal (see, for example, [25]). It is further highlighted that the given time-varying characteristic may potentially supply a communication system with great strength against interference. In addition to this, it is pointed out that, aimed at suppressing interference a direct-sequence system relies on three ingredients: 1. spectral spreading, 2. spectral despreading, and 3. filtering, respectively (see [25] for a detailed discussion). The most prominent term within this framework is the notion of ‘avoidance’, which is mostly grouped under the common label of the fundamental mechanism of interference suppression in a frequency-hopping system. In other words, when the avoidance fails, it is only temporary because of the periodic changing of the carrier frequency [25]. In the part that follows, we shall see some linguistic aspects of the text of the patent of Hedy Lamarr and George Antheil.

5 Some Linguistic Aspects of Frequency Hopping Patent

The patent, entitled “Secret Communication System” belongs to a subset of the set pertaining to formal languages, or, more specifically, formal registers. Even though this part of the paper does not aim at rectifying the persistent theoretical and methodological problems in dealing with the delimitation of terms ‘discourse’, ‘text’ and ‘register’ some observations are, nevertheless, in order. More precisely, my discourse-driven/text-driven investigation has been informed by the following references: [26]—[29]. The pertinent definitions of the terms ‘register’ and ‘style’ have been taken from the following sources: [30]—[36]. The part of my analysis concerned with Formal English, the language of legal documents, textual dimensions and textual variations has been informed by the following references: [37]—[40].

This part of the paper is motivated by the assumption provided by the pertinent linguistic literature, (see [39] for a detailed discussion), that the permanency of writing enables the dissection of texts, so that these texts can be further critically examined. Since this text type is a patent, it belongs to the language of legal documents, and it is argued that legal language covers quite wide scope of activities and sometimes even becomes blurred at the edges (see [38], for a detailed account of this assertion). Also, the language for the formal system consists of a set of terms together with a set of formation rules and meaning postulates appropriate to them [9]. Let us see the actual text of the Lamarr-Antheil Patent.

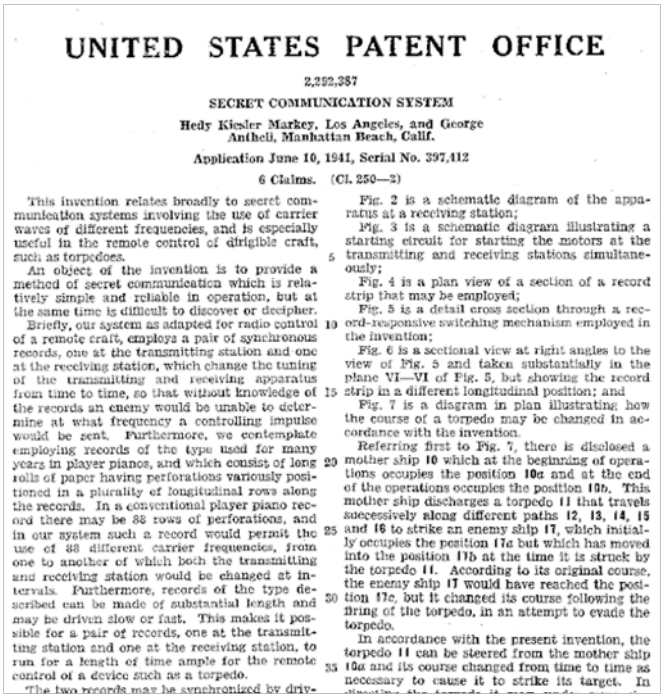
The patent is entitled “Secret Communication System”, and it contains the following initially placed formal elements: the serial number and the application date (see Figure 5). These listed items are said to be the salient formal elements of a patent document type. The text of the patent opens with the following excerpt: “This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies…” [8]. This opening is typical of the text pertaining to legal English documents, since in the patent text, it immediately describes the relation of the invention to be exposed.

The second paragraph starts with the main statement of the patent, claiming that “An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.” [8]. As can be seen from these linguistic items, this part of the patent text provides an object of the invention itself and by introducing the linguistic item ‘a method of secret communication’ it connects this item with the title of the patent. The authors of the patent utilise formal and technical lexical items (e.g. *carrier wave*, *solenoid*, *plunger*, *mother ship*, etc.) which are expected to be utilised in this text type.

Another striking feature of legal texts, the patent not being an exception to the general rule, refers to explicit mentioning of concrete numbers of items employed in the patent. For example, the text claims that “In a conventional player piano record there may be 88 rows of perforations, and in our system such a record would permit the use of 88 different carrier frequencies, from one to another of which both the transmitting and receiving station would be changed at intervals.” [8].

It should be noted that the patent text makes use of the adverbs typically used in Legal English such as ‘theoreof’ in the sentence “Other more specific objects and features of our invention will appear from the following detailed description of a particular embodiment thereof, as illustrated in the drawings, in which Fig. 1 is a schematic diagram of the apparatus at a transmitting station” [8]; and the adverb ‘thereupon’ is employed in the following excerpt: “which thereupon modulates the particular carrier wave” [8]. In addition to formally employed adverbs the authors of the patent also use certain formal conjunctions. More precisely, the conjunction ‘whereupon’ is utilised in the following patent excerpt: “identical with the solenoid 175 are released, whereupon the pawl 177 and plunger 176 are retracted into neutral position by the spring 180” [8]. In addition to this, diverse constructions pertaining to the technical register and formal styles are also used in the patent text, some of which are illustrated by means of the following patent excerpts: “Referring first to Fig. 7”, “In accordance with the present invention, the torpedo II can be steered from the mother ship”, “Under the particular circumstances of”, “In accordance with our invention, we employ variable frequency radio transmitters and receivers for the remote control” (see [8]). Impersonal constructions contributing to impartial and unbiased process description are also employed in the text of the patent, for example, “Actuation of the key L closes main contacts”, “Furthermore the frequency changes can be purely arbitrary, without any periodic recurrence that would render it easy for an enemy to anticipate the frequency at any particular instant.” [8]. The patent text is also freighted with the passive voice, for example “and a signal selector that may be tuned to any one of four different frequencies by connecting thereto different condensers”, “When the condenser 24'd is connected to the selector”, “the transmitter and receiver are both tuned to the same frequency”, “when the transmitting apparatus is tuned to frequencies that are not receivable at the receiving station”, “the signal is amplified in an amplifier and delivered to a detector”, “If a received signal was produced by actuation of the key L”. This utilisation of the passive voice is hardly surprising given the fact that the passive voice allows the patent authors to maintain the discourse topic in the relevant position whilst adding new pieces of information in the employed syntactic constructions.

What all these patent excerpts have in common pertains to their syntactic, semantic and pragmatic aspects. Formal English is expected to be typically found in the written language material, i.e. certain written documents, and is intended for circulation among a somewhat restricted group (see [37]). According to the literature, the vocabulary pertaining to Formal English contains many specialised words (see [37]) and, therefore, the lexis seems to be important in this analysis. Whoever composes a legal document of any sort ought to make an effort to ensure that such a document states exactly what the legal document writer wants to state, and simultaneously, this document should give no opportunity for misinterpretation (for instance, see [38]).



UNITED STATES PATENT OFFICE

2,292,387

SECRET COMMUNICATION SYSTEM

Hedy Kiesler Markey, Los Angeles, and George Antheil, Manhattan Beach, Calif.

Application June 10, 1941, Serial No. 397,412

6 Claims. (Cl. 250—2)

This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies, and is especially useful in the remote control of dirigible craft, such as torpedoes.

An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.

Briefly, our system as adapted for radio control of a remote craft, employs a pair of synchronous records, one at the transmitting station and one at the receiving station, which change the tuning of the transmitting and receiving apparatus from time to time, so that without knowledge of the records an enemy would be unable to determine at what frequency a controlling impulse would be sent. Furthermore, we contemplate employing records of the type used for many years in player pianos, and which consists of long rolls of paper having perforations variously positioned in a plurality of longitudinal rows along the records. In a conventional player piano record there may be 88 rows of perforations, and in our system such a record would permit the use of 88 different carrier frequencies, from one to another of which both the transmitting and receiving station would be changed at intervals. Furthermore, records of the type described can be made of substantial length and may be driven slow or fast. This makes it possible for a pair of records, one at the transmitting station and one at the receiving station, to run for a length of time ample for the remote control of a device such as a torpedo.

The two records may be synchronized by driv-

Fig. 2 is a schematic diagram of the apparatus at a receiving station;

Fig. 3 is a schematic diagram illustrating a starting circuit for starting the motors at the transmitting and receiving stations simultaneously;

Fig. 4 is a plan view of a section of a record strip that may be employed;

Fig. 5 is a detail cross section through a record-responsive switching mechanism employed in the invention;

Fig. 6 is a sectional view at right angles to the view of Fig. 5 and taken substantially in the plane VI—VI of Fig. 5, but showing the record strip in a different longitudinal position; and

Fig. 7 is a diagram in plan illustrating how the course of a torpedo may be changed in accordance with the invention.

Referring first to Fig. 7, there is disclosed a mother ship 10 which at the beginning of operations occupies the position 10a and at the end of the operations occupies the position 10b. This mother ship discharges a torpedo 11 that travels successively along different paths 12, 13, 14, 15 and 16 to strike an enemy ship 17, which initially occupies the position 17a but which has moved into the position 17b at the time it is struck by the torpedo 11. According to its original course, the enemy ship 17 would have reached the position 17c, but it changed its course following the firing of the torpedo, in an attempt to evade the torpedo.

In accordance with the present invention, the torpedo 11 can be steered from the mother ship 10a and its course changed from time to time as necessary to cause it to strike its target. In

Figure 5: The photograph of the patent text. The original caption contains the following text: "Patent filed by Hedy Lamarr and George Antheil for a "Secret Communication System," application June 10, 1941." The photograph was provided by the courtesy of the Jewish Women's Archive – JWA.

As regards the clause structure, and the sentence structure, for that matter, there is a general tendency towards length and complexity in the patent text, which is in line with the observations proposed in the literature (see, for example, [38]). Let us see the excerpts from the text of the patent illustrating this complexity. For instance, the following patent excerpts: "Referring first to Fig. 7, there is disclosed a mother ship 10 which at the beginning of operations occupies the position 10a and at the end of the operations occupies the position 10b. This mother ship discharges a torpedo 11 that travels successively along different paths 12, 13, 14, 15 and 18 to strike an enemy ship 17, which initially- occupies the position 17a but which has moved into the position 17b at the time"; "In accordance with our invention, we employ variable frequency radio transmitters and receivers for the remote control, and change the frequency at intervals by synchronous records at the two stations."; "In accordance with the present invention, the torpedo 11 can be steered from the mother ship 10a and its course changed from time to time as necessary to cause it to strike its target. In directing the torpedo it may, under some circumstances, be observed directly from the mother ship 10, or its course may be followed by an observer in an airplane 18 who communicates his findings to the mother ship 10a." [8].

In patent drafting there are some salient ingredients that ought to be included, some of which have been expected to appear in the patent text. Strictly speaking, Hedy Lamarr's patent contains these formal elements. Let us further examine some formal elements. More specifically, the analysed patent text contains the title of the invention ("Secret Communication System") accompanied by the number 2,292,387 and the names and surnames of the submitting parties (Hedy Kiesler Markey, George Antheil) accompanied by their whereabouts (Los Angeles and Manhattan Beach, California,

respectively). Subsequently, the patent contains the date of submission (10th June 1941), and the serial number 397,412, as well as the precise number of claims ("6 Claims").

The patent contains the statement outlining an object of the invention in the following patent excerpt: "An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher." In addition to this, the patent incorporates a summary of the Secret Communication System and a concise description of the drawings employed in the patent document. In the continuation, the submitting parties, Hedy Kiesler Markey and George Antheil, provide a detailed description of the submitted patent.

Another striking linguistic feature that can be detected is a sort of tentativisation. Namely, it is interesting to note that the patent text contains certain lexical items and discourse devices, which might be interpreted as hedges to a certain extent. The authors of the patent point to the aspects that remain underexplored, when they state that "Apparatus as described in claim 1, including means at the transmitting station for transmitting radio signals of different frequencies to which said radio receiver tuning means are not tunable, and means coordinated with the recordings on said first strip for indicating at the transmitting station when the transmitting apparatus is tuned to frequencies that are not receivable at the receiving station", which might be treated as a patent conclusion.

Relevant to the question of linguistic analysis my direction goes in favour of the structural treatment whilst observing the patent text. Unfortunately, the other perhaps more attractive approaches, as well as the models of analysis no less interesting, could not be taken up in this paper. Therefore, plausible ways of patent text analysis merit further investigation.

Suffice it to say that the employed structural analysis has treated the data in a direct and conventional way, as it has been shown and illustrated by means of some pertinent examples and excerpts. Some other, perhaps more appealing, linguistic approaches, as well as linguistic models and methods might be applied in future research. However, it is felt that this analysis may also serve as a basis for further elaboration.

6 Concluding Remarks

The facts, which have so far been described in this paper, are primarily of descriptive orientation, and are intended to enable the reader to try to form a well-founded judgement of the nature of frequency hopping and, ultimately, Hedy Lamarr's contribution and her invention. After a lengthy process, Code Division Multiple Access (CDMA) was adopted as the standard and Hedy Lamarr and George Antheil's invention became the base of all modern telephone technology (or spread-spectrum technology). Another important aspect of Frequency-Hopping technology is that is seems crucial to Global System for Mobile (GSM) telephones due to the fact that it allows privacy for callers. Strictly speaking, Hedy Lamarr was the most glamorous name associated with this work, and her legacy is contained in the concrete evidence of the patent number 2,292,387.

In this paper, I have re-examined Frequency Hopping primarily from the descriptively-oriented historical perspective taking into consideration the actual application of Frequency Hopping.

To this purpose, I have analysed certain linguistic aspects of the text of the actual patent, submitted by Hedy Lamarr and George Antheil. The neat examples of the illustrative excerpts, cited in that part of the paper, are relatively straightforward cases of typical patent document discourse type.

This paper aims at promoting an interest in the study of Hedy Lamarr as an inventress of Frequency Hopping as there is ample evidence that she contributed to a well-defined field of investigation

within and across electrical engineering, generally, and telecommunications, more specifically. At the same time, this paper may also contribute to a better understanding of heterogeneous aspects of frequency hopping and its role and implications in contemporary theories and applications.

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KIBORG KAO ŠANSA ILI OPOMENA

Da li digitalna evolucija briše ironiju iz feminističkog mita o kiborgu?

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REZIME

Ironična, politička ideja o kiborgu Done Haravej kao hibridu žene i mašine koji razrešava i prevazilazi polarizaciju rodnih identiteta, bila je inspiracija postfeminističke i posthumanističke misli, ujedno se u savremenom tehnološkom okruženju potvrđujući kao mit. Ovaj rad nastoji da sumira poreklo ideje o feminističkom kiborgu i njegovu percepciju u kontekstu digitalnog doba koje je dodatno potcrtalo rodne podele, ali i pružilo novu platformu za preispitivanje ljudskog bića ne samo na planu rodnih identiteta. Pitanje u podnaslovu, iako retorsko, ipak, ostavlja prostor za diskusiju, posebno u kontekstu PSSOH konferencije koja je usmerena na otvoreni pristup i slobodno deljenje dostignuća tehnološkog progresa.

Ključne reči: kiborg, feminizam, Dona Haravej, rod u tehnologiji, posthumanizam.

1 Od „slabijeg pola“ do moćnog hibrida

Današnja pozicija žena u društvu osvajana je praktično sa nultih polazišta, budući da sve do 1948. godine, a u nekim zemljama i kasnije, žene nisu imale ni osnovna ljudska prava. Ideja o ženskom biću oslanjala se na milenijumskim utvrđenjima tradicije i vere, te su i oslobodilački pokreti i feminističke teorije prvog i drugog talasa u 20. veku, bili povezani sa patrijarhalnim modelima i biološkom argumentacijom. Ženski pol je smatran specifičnim, bilo kao podrazumevano „slabiji“, ili kao „različit“ u okviru dve kulture (muške i ženske).
Unutar tradicionalnih postavki tražilo se priznanje vrednosti „Drugog pola“. Jedna od najznačajnijih teoretičarki feminizma, francuska književnica i filozofkinja Simon de Bovoar (Simone de Beauvoir) postavljala je pitanje - zašto je žena na „Drugom mestu“, u odnosu na biološke podele, teze o podeli rada istorijskog materijalizma i „falusne raspodele“ psihoanalize [1]. Dakle, zašto je njena razlika čini manje vrednom - zašto je sposobnost rađanja manje važna od radne sposobnosti, zašto je imati penis prestižnije nego nemati ga, zašto biološke razlike žena i muškaraca moraju da podrazumevaju hijerarhijski odnos u kojem je žena „Drugo“, umesto „bratskog“ udruživanja [1 p61].

Razvoj feminističke misli se potom usmerio na negaciju polnih razlika kao urođenih, koja je utemeljena u performativnom pristupu Džudit Batler (Judith Butler) [2] [3]. U duhu postmodernističkih dekonstrukcija ona uvodi potpunu „reartikulaciju“ polnih identiteta, za koje tvrdi da su društveno a ne prirodno formirani. Oni počinju rođenjem deteta i ponavljaju se i utvrđuju kroz ceo život jedinke kao „oblik kulturnog ponavljanja ili reartikulacije, praksa ponovnog označavanja“ koja je, dakle, veštački utvrđena kao hegemonistička norma [3 p142).

Ovoj tezi pružena je potpora u teoriji rodnih odnosa u knjizi „Vladavina muškaraca“ Pjera Burdijea (Pierre Bourdieu), iznikla iz njegove sociološke teorije o „habitusu“ i antropoloških istraživanja [4].

„Habitus“ je pozicioniran „ispod nivoa svesti“ i obuhvata brojne karakteristike ljudskog bića, „od držanja tela i gestikulacije“ do „mišljenja, načina percepcije i interpretacije društvene stvarnosti“, određen je društvenim položajem, primarno se stiče „procesom socijalizacije u okviru porodice“, a njegovo formiranje se nastavlja „kroz interakcije u okviru određenog društvenog polja“ [5 p181]. Takav, zatvoreni krug u definisanju i praktikovanju roda polazi i završava u telu kao „biološkoj stvarnosti“ u kojoj zapravo „princip društvene vizije konstruiše anatomsku razliku“, koja onda postaje „osnova i garant prirodne očiglednosti“ [4 p18].

Tumačeći mitsko-obredne prakse kabilskog agrarnog društva u Alžiru, Burdije dolazi do zaključaka da su hijerarhijske postavke anatomskih razlika u prirodi neosnovane, te da se iz potrebe za uspostavljanjem dominacije jednog pola proizvoljni društven zakon („nomos“) pretvara u „prirodnu nužnost“ („phusis“) [4 p22]. Na primer, povezivanje „falusne erekcije“ sa „životnom dinamikom punjenja“, iako je ona „svojstvena svakom procesu prirodne reprodukcije“ (kao što su klijanje biljaka ili trudnoća npr.), zapravo je „simboličko registrovanje društvene konstrukcije polnih organa“ kojom se potvrđuju „neosporna prirodna svojstva“ [4 p22]. Odnosno, formiraju se konstrukcije usmeravanjem izbora, „naglašavanjem nekih razlika ili osporavanjem nekih istovetnosti“ [4 p23].

U odnosu na takvu, opšteprihvaćenu „muškocentričnu“ matricu svih stvari i pojava kao univerzalnu i prirodnu, žene trpe „simboličko“ nasilje u činu „doksičkog odobravanja“ (iracionalnog uverenja i podrške) i verovanja: „Potčinjeni primjenjuju kategorije izgrađene sa stanovišta onih koji vladaju vladajućim odnosima, čineći ih tako da izgledaju kao prirodne“ [4 p49-51].

Kao odgovor na utvrđene rodne hijerarhije koje su u trećem talasu feminizma prepoznate kao društveno nametnute, u „Manifestu o kiborgu“ Done Haravej (Donna Haraway) [6] ponuđena je figura kiborga kao otklon od binarnih podela ili njihovo pomirenje, koja je u odnosu na „bratstvo“ Simon de Bovoar i razdvajanje „dve kulture“, bliža performativnom pristupu polu i rodu. Koristeći tehnološku dominaciju savremenog društva, Haravej je izgradila sliku kiborga kao potencijalne sile koja može da poništi biološku i teološku bazu rodnih ideologija, sa ciljem prevazilaženja „querelle des sexes“ i proizvodnje novog, hibridnog, nedeljivog diskursa roda.

U duhu poststrukturalizma i postmodernizma koji osporava binarne podele kao konstruisane ideologije moćnih, gde je ključni pojam – hibrid, srž kulture savremenog sveta u kojoj se mešaju predstave o polovima, visokoj i niskoj kulturi, realnoj i medijskoj stvarnosti, čoveka i prirode, „Manifest o kiborgu“ izvršio je veliki uticaj ne samo u feminističkoj teoriji, već i u teoriji visoke tehnologije i posthumanizma. U studijama koje se bave telom, sajber prostorom, sajber identitetom, česta polazna tačka je upravo kiborg Done Haravej.

2 Simbolika feminističkog kiborga

Zoološkinja, filozofkinja, biološkinja, profesorka feminističkih i tehničkih nauka, Dona Haravej, objavila je svoj ogled „Manifest za kiborge: Nauka, tehnologija i socijalistički feminizam osamdesetih godina XX veka“ 1985. godine. U nastojanju da izgradi „ironični politički mit“ veran feminizmu, socijalizmu i materijalizmu, kreirala je viziju zajedničkih vrednosti i mogućnosti političkih udruživanja, oslanjajući se na razumevanje tela kao kulturne činjenice [6].
Ideju o kiborgu kao hibridu mašine i organizma, Haravej je preuzela iz savremene naučne fantastike, moderne medicine, moderne proizvodnje i replikacije, dakle, iz društvene stvarnosti i „proživljenih društvenih odnosa“, odnosno „političke konstrukcije“, u kojoj je kiborg ontološka pozicija ljudi, „kondenzovana predstava kako imaginacije, tako i materijalne stvarnosti, dvaju združenih središta koja strukturišu svaku mogućnost istorijskog preobražaja“ [6 p605-606].

Iako uviđa da je kiborg produkt „militarizma i patrijarhalnog kapitalizma“, i „državnog socijalizma“, odnosno njihovo „nezakonito potomstvo“, ona veruje da kiborg izmiče iz utvrđenih definicija dualiteta i „priča o poreklu u zapadnom smislu“, kao suštinski „opozicion, utopijski i potpuno lišen nevinosti“. Kiborg nije izašao iz raja niti se može svrstati u javno ili privatno, prirodu ili kulturu, heteroseksualno ili homoseksualno, muškarca ili ženu, čoveka ili životinju, na njemu nije primenjiv „mit o prvobitnom jedinstvu, blaženstvu i užasu“, niti o Frankenštajnu, Edipu i organskoj porodici: „Kiborg je odlučno opredeljen za pristrasnost, ironiju, intimnost i perverznost“ [6 p607].

Haravej prepoznaje tri oblika „ukidanja graničnih linija“ na kraju 20. veka: između ljudskog i životinjskog, organizma i mašine i fizičkog i nefizičkog [6 p607-610). Ljudska animalnost i povezanost čoveka sa drugim bićima vodila je ka ideji o „prekoračenju pukotine između prirode i kulture“: “živahnost mašina“ u odnosu na sve manju pokretnost ljudi stvorili su dijalog između materijalizma i idealizma, dok se „fluidnost mašina“, koje su svugde, nevidljive, tiče „svesti i njene simulacije“ [6 p607-610). Autorka kiborga vidi kao rezultat „prekoračenih granica i moćnih spojeva“, koji može biti političko sredstvo za konačno preuzimanje moći, stvaranje „kontrolne mreže“ („grid of control“) koja bi prekrila čitavu planetu, kao i prevazilaženja „parcijalnih identiteta i protivrečnosti“ [6 p610].

Da bi objasnila kontekst u kojem ideja o kiborgu može da funkcioniše politički, Haravej podseća na cepanja feminističkih teorija koja su usledila nakon konačnog priznanja društvenog konstituisanja roda, rase i klase, ukazujući da te kategorije više ne mogu pružiti osnovu za „verovanje u „esencijalno jedinstvo“. U tom ključu Haravej predlaže i sopstvenu političku misao: „Kiborg-feministkinje moraju da tvrde da „mi“ ne želimo više nikakvu prirodnu matricu jedinstva i da nijedna konstrukcija nije celina“ [6 p615].

Njeno je mišljenje da su i marksističko-socijalistički i radikalni feminizam konstituisani kao „totaliteti“, bez obzira na ženske „partikularnosti i protivrečne interese“, odnosno da su pratile logiku „belog humanizma“ da bi utvrdile svoj „revolucionarni glas“ uspostavljanjem temelja jedinstvene dominacije [6 p618-619]. Ona smatra da treba težiti ka stvaranju delimične, stvarne povezanosti, a ne pronalaziti svoje mesto u svetskoistorijskim sistemima dominacije [6 p621].

Autorka upozorava da je stvarna situacija žena „njihova integracija/eksploatacija u jednom svetskom sistemu produkcije/reprodukcije i komunikacije”, koji naziva „informatika dominacije“ [6 p622]. U takvom sistemu strategije kontrole biće formulisane kategorijama „stopa“, „troškova ograničenja“, „stupnjeva slobode“; na primer, „strategije kontrole nad ženskom sposobnošću da rađaju nova ljudska bića“ biće iskazane „na jezicima populacione kontrole i maksimiranja postizanja cilja za pojedinačne donosioce odluka“ [6 p621].

Nasuprot tom okviru Haravej predlaže drugačiji sistem u kojem su komunikaciona tehnologija i moderna biologija „oruđa za preoblikovanje tela“ u kiborga kao „postmodernog kolektivnog i ličnog sopstva kojeg feministkinje treba da kodiraju“ [6 p621]. Ali ne totalitetom i dihotomijama već ideološkim „umrežavanjem“ koje obuhvata „obilje prostora i identiteta, te propusnost granica ličnog i političkog tela“ [6 p630].

„Kiborg-politika jeste borba za jezik i borba protiv savršene komunikacije, protiv onog jednog jedinog koda koji sva značenja savršeno prevodi, te središnje dogme falogocentrizma. Zato će kiborg-politika insistirati na šumu i zagovarati zagađivanje veseleći se nezakonitim stapanjima životinje i mašine. To su sparivanja koja Muškarca i Ženu čine tako problematičnim, podrivajući strukturu želje – silu za koju se zamišlja da generiše jezik i rod – pa tako i strukturu i moduse reprodukcije „zapadnog identiteta“, prirode i kulture, ogledala i oka, roba i gospodara, tela i duha“ [6 p635].

Dualizmi zapadnih tradicija, kao što su sopstvo-drugi, kultura-priroda, muško-žensko, aktivno-pasivno itd., koji su vodili ka postojanju „Jednog“ – moćnog koji uključuje i „drugog“ – nebitnog, ali višestrukog, „bez jasne granice“, sada su osporeni zahvaljujući „kulturi visoke tehnologije“. Mašina i organizam, tehničko i organsko ne mogu se „fundamentalno ontološki razdvojiti“, a jedna od posledica ili dokaza jeste da postoji povezanost sa našim oruđima, čak „stanje zanosa“, recimo, kod korisnika računara [6 p636-637].

Kiborzi podrazumevaju ironiju, ponovo razmatraju utvrđene identitete, polnost, materinstvo, sa intimnim osećanjem granice i njene konstrukcije i rekonstrukcije, ali bez poriva za razvijanjem totalne teorije. Haravej zaključuje: „I mada su i kiborg i boginja zajedno uhvaćeni u spiralni ples, više volim da budem ono prvo nego ovo drugo“ [6 p640].

3 Tehnički nesposobna, „blažena tehno-zečica“

Dok je u političkoj sferi proglas Done Haravej uticao na brojne antiglobalističke, antiratne pokrete, pokrete za zaštitu prava životinja i druge organizacije i inicijative protivne politici totaliteta, u teoriji kulture njena figura kiborga posmatrana je dvojako, kako sumira Krista Lajnz (Lynes): „kao prevazilaženje ograničenja tela, transcendencija svesti u mašini i obnavljanje subjekta“ i kao „apokaliptična posthumanistička budućnost u kojoj će mašine na kraju nadjačati čovečanstvo i u kojoj će subjekt humanizma izgubiti izbor, koherentnost, autonomiju i racionalnost“ [7 p1]. Feministički tekstovi zasnovani na ideji kiborga naglašavali su “konstruisanu prirodu roda u odnosima moći, i materijalnost tela koja su postojala kao ograničenje, živo iskustvo ili kao otpor“ [7 p1].

U kontekstu ekspanzije sajber prostora i digitalne evolucije, kritički osvrti na tehnološke potencijale u polju individualnog i društvenog napretka, usmereni su i na biotehnološke i na diskursne manifestacije simboličkog povezivanja ljudi i mašina, ali i na ekonomske posledice. En Balsamo (Ann Balsamo) upozorava da se „savremeni tehnološki diskursi oslanjaju na logiku binarnog rodnog identiteta kao temeljnog organizacionog okvira“, u kojem rod deluje „i kao presudno kulturno stanje i kao društvena posledica tehnološke primene“ [8 p9-10].

Sa jedne strane, odnos rodnog otelotvorenja prema novim tehnologijama strukturiran je „ideološkim i kulturnim procesima koji ostaju duboko patrijarhalni“, i koji se odnose na imobilizaciju žena u novim tehnologijama i na neravnomeran rodni pristup tehnološkom razvoju [7 p6]. Džudi Vajsmen (Judy Wajcman) tvrdi da je „identifikacija između muškaraca i mašina postala seksualni stereotip, onaj koji je imao konstitutivne i asimetrične efekte na muškarce i žene, uključujući različite stepene izloženosti tehnologije u detinjstvu, različite uzore, različite oblike školovanja, kao i odvojena tržišta rada - što je sve dovelo do predstava muškaraca kao „tehnološki obdarenih“, a žena kao „tehnički nesposobnih“ [9].

Otud su i rodne politike tako zdušno usmerene na uključivanje žena u tehnologiju. U evropskim granicama, konkretno u politici Evropske Unije, na desetine, možda i stotine, dokumenata, studija, analiza, preporuka, rezolucija, nastoji da promeni rodne dimenzije u procesu digitalne transformacije društva i ekonomije. U tom smislu politika prati metaforu kiborga koja se odnosi, između ostalog, i na upotrebu mašina kao oruđa u političkoj akciji promene sveta i na preuzimanje odgovornosti za odnose nauke i tehnologije u društvu do ravni svakodnevnog života.

Jedan od poslednjih usvojenih dokumenata koji se bave ovom temom, Rezolucija Evropskog parlamenta od 21. januara 2021, o premošćivanju digitalnog jaza između polova, posebno naglašava da će kriza uzrokovana pandemijom koronavirusa „verovatno dovesti do trajnih promena života u Evropi, u kojem će digitalizacija imati vrlo važnu ulogu“, kao i da se „tržište rada zbog pandemije suočava sa izazovom velike digitalne transformacije“ koji preti dodatnim produbljivanjem rodnog jaza [10].

Rezolucija prepoznaje da rodni stereotipi produbljuju rodne razlike u digitalnom sektoru sprečavajući potpuno učešće žena kao korisnika, inovatora i stvaralaca. U dokumentu se navodi: da žene predstavljaju samo 17 % svih studenata i 17% svih stručnjaka u oblasti IKT u EU, 22 % stručnjaka za veštačku inteligenciju, 20% u oblasti sajber bezbednosti; da zarađuju 19% manje od muškaraca u ovom sektoru; da je „rodni jaz među softverskim programerima i inženjerima u pogledu uključenosti žena u tom sektoru zabrinjavajući, kao i potencijalne svesne i nesvesne rodno diskriminatorske pristrasnosti u primenama veštačke inteligencije, video igrama i igračkama i drugim aplikacijama“; da je „prijavljen veliki broj slučajeva seksualnog uznemiravanja na mestima gde se obavlja obrazovanje u oblasti nauke, tehnologije, inženjerstva i matematike“; da „veliki broj žena napusti visoko obrazovanje, akademske mogućnosti i karijeru u sektoru IKT („leaky pipeline”), uglavnom zbog loše ravnoteže između poslovnog i privatnog života, organizacijskih ograničenja i okruženja u kojem preovlađuju muškarci“; da je potrebno kroz rodnu prizmu produbiti razumevanje novih oblasti, kao što su algoritamsko donošenje odluka, tehnologija lanca blokova i kriptovaluta i nadzor podataka i izraditi strategije za njihovo rešavanje… [10].

Dok su, dakle, pretnje eksploatacijom žena u informatičkoj realnosti 21. veka produbljene u odnosu na upozorenja Haravej iz 1985, nasuprot predlozima za njihovo prevazilaženje u „stapanju“ sa mašinama, sa druge strane, u ideološkom smislu, kiborg je smešten „u prostoru igre“ ili simbolizuje „nove oblike kartezijanske transcendencije signalizirane ostavljanjem tela“. I sama Dona Haravej prepoznaje, decenijama nakon svog inicijalnog proglasa, da se kiborg pretvara u (post)feminističku „blaženu tehno-zečicu“ [11]. Po mišljenju Ketrin Hejls (Katherine Hailes), sa širenjem umreženih i programabilnih medija, „kiborg jednostavno, nije dovoljno umrežen“, jer kao jedinstvena, hibridna celina, „ne nudi nužno objašnjenje načina na koje ljudi i mašine postoje zajedno u koevoluirajućim i međusobno povezanim sistemima“ [12 p159, 165].

Utoliko se inicijalni post-rodni kiborg, kako zaključuje Amanda du Priz (du Preez), iako pokušava da amortizuje sve mitove i utopije o poreklu, potvrđuje kao „originalni mit o potpunosti“ koji priziva utopiju bez roda „kao himera koja treperi šifriranim horizontom „ne-mesta““ [13 p150].

4 Ironija opstaje

Mit o kiborgu razvio se iz negacije pola kao datosti i napuštanja binarnih „prirodno podrazumevanih“ podela. Međutim, kako će pokazati decenije koje su usledile nakon njegove formulacije, dekonstrukcija binarnih podela može se nadmašiti implicitnim učvršćivanjem razlika, formalnim priznavanjem prava i značaja Drugog, čime se čuva osnovna matrica dva pola. Novi biologizam sa potrošačkom ideologijom i vrednosnim imperativom materijalnog, određuje nove rodne uloge koje su i dalje na suprotstavljenim stranama. Kiborg je svoje suštinsko mesto zadržao u fikciji.

U tom svetlu mogla bi se opravdati Burdijeova teza prema kojoj se „simbolička revolucija“ koju je zahtevao feministički pokret ne može svesti na „prost razgovor svijesti i volja“: „prekid odnosa saučesništva koji žrtve simboličkog nasilja imaju sa vladajućim, može se očekivati samo radikalnom promjenom društvenih uslova proizvodnje dispozicija koje navode potčinjene da zauzmu isto stanovište vladajućih, i o samima sebi, i o vladajućima“ [4 p60].

Haravej se u svom kasnijem radu, u knjizi „Kada se susretnu vrste“ opire prisvajanju tehnofilne utopije, i ističe „privrženost, odgovornost i brigu“ kao afektivne pojmove kroz koje zamišlja feminističku politiku za 21. vek i ostvarivanje međusobne povezanosti i društvene pravde [14]. U jednom skorijem predavanju predlaže novu sliku za promišljanje/sprovođenje politike: „kompost“, kao najprikladniju figuru za „hvatanje u koštac sa običnim“ [7 p9-10]. Međutim, njen kiborg-feminizam ostaje simbol kontra-politike koja pomera granice i preispituje rodne identitete: „Iako

kiborg možda više nema blasfemičnu moć koju je imao u svojim najranijim artikulacijama, blasfemija se i dalje dokazuje kao korisna strategija za feminističku figuraciju [7 p12].“

U širem okviru posthumanizma mit o kiborgu između perspektiva utopije i apokalipse, kao i u postfeminizmu, opominje na spuštanje u „blato običnosti“ u procesu stvaranju sveta bez granica i slobodnih ljudi u njemu. Uključujući žene.

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AN ENGINEERING TEXTBOOK TYPESETTING USING SPHINX DOCUMENTATION GENERATOR

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Abstract / Резиме

One of the things that the ongoing Information age has recently brought is reading books on various handheld and portable electronic devices. Novel e-book formats enable inclusion of more interactive contents that is not only generally convenient but is also suitable for engineering and scientific textbooks. Besides the established portable document format (PDF) that presents de facto standard for physical book printing and publishing, e-reader and the Web book editions are becoming more popular. This paper describes a typesetting workflow which is based on Sphinx documentation generator that can produce different output formats out of a single plain text input source code. It is elaborated how the text can be formatted and how different book elements such as figures, diagrams and video clips can be built-in with a special Sphinx directives. However, the accent was placed on embedding source code into the textbook itself and giving readers the ability of copying and executing it with ease. The presented concept is practically demonstrated for an example case of a programming textbook which is made available in three different formats and open under a permissive license. An automated continuous integration and new release delivery is supported and implemented to allow and facilitate quick and widespread book adaption with a hope that electrical engineering and computer science students would be intrigued and that their learning process would be more efficient as well as more productive.

Једна од ствари коју је текуће информатичко доба донело јесте читање књига на разним џепним и преносивим електронским уређајима. Нови формати електронских или е-књига омогућавају укључивање интерактивних садржаја који нису погодни само у општем смислу, већ су надасве прикладни и за уџбенике из инжењерских, научних и техничких дисциплина. Поред такозваног PDF формата који представља дефакто стандард за објављивање штампаних књига, интернет издања, баш као и издања за читаче е-књига постају све популарнија. Овај рад описује поступак слагања текста заснованог на Sphinx генератору документације који из јединственог чисто текстуалног улазног изворног кода може да произведе и врати различите излазне формате. Изложено је како се текст може форматирати и како се различити књишки елементи, као што су слике и дијаграми могу уградити користећи се посебним Sphinx директивама. Међутим, акценат је ипак стављен на уграђивање изворног кода унутар самог уџбеника и на давање читаоцима могућности лаког копирања и извршавања истог. Представљени концепти су демонстрирани на практичном примеру уџбеника програмирања који је направљен тако да буде доступан у три различита формата под допусном лиценцом. Аутоматизован начин за непрекидну интеграцију и испоруку нових издања је подржан и имплементиран како би се омогућила и олакшала широка употреба књиге уз наду да ће студенти електротехнике и рачунарства бити заинтересовани за изложене концепте и да ће самим тим и њихов процес учења бити ефикаснији и продуктивнији.

Keywords: documentation generator, e-book formats, source code, textbook, typesetting.

Кључне речи: генератор документације, е-књига, изворни код, слагање текста, уџбеник.

1 Introduction

The world has changed drastically over the past few decades. Living an everyday life people often take technological gadgets for granted, seldom digressing to observe the long-term impact that the so-called Digital Revolution has brought. The digital, or also by many considered the Third Industrial Revolution which started in the second half of the 20th century simultaneously marked the beginning and has brought the society to the Information Age. Central to the aforementioned revolution is the mass production of integrated and solid-state circuits, themselves based on transistors, and the derived products and technologies such as computers, cellular/mobile and smartphones, as well as the Internet.

Although the Information age, also known as the New Media Age [1], is enabled by the development of semiconductor devices, it is foremost characterized by the onset of use of information technology. This period has also been marked by the expansion of communications with a widespread use of mobile phones and the Internet, which have caused fundamental changes in individuals' personal lives and the whole human society. Generation Z are the first social group that has grown up with access to portable digital technology and the Internet from an infancy and childhood thus commonly being dubbed as "digital natives". Most members of Generation Z are not only children of, but are also being taught in schools and universities, trained in sports activities, and supervised in general by Generation X.

In spite of profound transformations in the overall surroundings between generations X and Z, a rare medium that has not become obsolete and that is still resisting an essential modification is certainly a book. As one of the cornerstones of civilization, books have been around for millennia adapting slowly from clay and wax tables, over papyrus scrolls, up to present day e-books (short for electronic book) which are keeping pace with the current media age. Book selling and collection storing points such as bookstores and libraries also exist, even though website-based versions of both are omnipresent.

Contentwise, common book separation is in fiction and non-fiction ones. While many literary book forms such as novels, poetry and even comic books published today fall in the former broad category, all other material can be included under the umbrella of the latter one. Fiction books today dominantly consist of plain text and optional figures and images whose use ranges from occasional to prevalent such as in comics and graphical novels. Constituting elements of the non-fictional books can generally be more diverse. As opposed to fictional books, it is not seldom that non-fiction books are not intended to be read or studied from cover to cover but can rather serve as a reference, e.g., like a dictionary.

Nearly all academic literature is non-fiction. Besides plain text and images, schoolbooks and textbooks can contain many variations of each, such as mathematical equations and formulas and programming code snippets, or diagrams, figures, (photo)graphs, maps and plots, just to name a few. Since more and more books are published (also) in electronic format, hyperlink referencing that enables convenient and quick referencing and navigation started to accompany and to replace traditional indexes which are becoming less preferred to standard text search. With the prevalence of computers (in their desktop and portable form) and the Internet, some traditional book forms, e.g., like telephone directory, ceased to exist in hard paper version, while other tend to coexist in electronic and traditional formats.

The peculiarities of engineering and scientific textbooks are two-fold. Firstly, besides paragraphs of standard text they usually contain equations, physical formulas as well as an exemplary code snippets that describe actual calculation, method execution or implementation in a command-line interface (CLI) or a (domain-specific) programming language of the tool of choice that is presented. Secondly, these kind of textbooks are often published in smaller volumes (relative to the general public fictional books such as *belles-lettres*) and are hence frequently written and typeset by their authors themselves who are by the rule skillful professionals knowledgable in the typesetting tools of choice, or at least are in possession of above average word processing proficiency levels as compared to general population.

This paper describes a relatively recent documentation generator tool named *Sphinx* and how it can be utilized by the authors to typeset and produce a modern engineering and scientific textbooks.

1.1 Engineering and Scientific Textbook Specifics

Dominance of handheld and pocket-size portable communication and computing devices (with permanent Internet connection) inevitably led to preference of electronic book versions versus old-fashioned physical book entities. There are a number of arguments that speak in favour of e-books. Namely, they are present always, since a personal portable computer or a smartphone is always with the person owning it. Just like other software they do not wear out nor there is any naturally associated copying and multiplication difficulty. If legally allowed, they can be shared among individuals by a single click or a tap. Furthermore, electronic content can be listed and searched much faster. Finally, additional material, appendices, revisions, errata and updates can be much more easily distributed and published in an electronic format. Nevertheless, for many the joy of physical book reading will perhaps never disappear even if conveniences such as battery and power outlet free "operation modes" are put aside.

A prerequisite for any engineering and scientific discipline to attain a high community acceptance is that it must lay on solid theoretical foundations and to be well-understood. These ideas are naturally conveyed using formulas which represent equations, theorems, etc., and common for it is that the underlining fundaments do not change (at least not on a short-term basis). This is one of the reasons why some classical master pieces in engineering and science, e.g., physics [2] or programming, do not lose audience nor popularity with time. Another requirement, especially for applied methods and practical disciplines to reach the full impact is to be supported by well-maintained and mature software libraries and tools which are meant to accelerate, automate and simplify common tasks. Therefore, all textbooks apart from purely theoretical ones by the rule also include exemplar code that should be easy for practitioners to apply, extend, modify and tailor to suit their own needs. In addition to previous specific elements, there will always be unavoidable general illustrations and plain text descriptions.

An all-inclusive engineering and scientific textbook tends to be comprehensive and to incorporate both the theoretical and the practical materials that are often intertwined. While the former part by the rule does not change over the average lifetime of a university textbook, keeping the latter one up-to-date with the latest developments in the field requires major reworks that appear in new book editions and revisions. Actually, documenting the practical tool details, especially when it comes to programming code leans more towards writing a software documentation for which there already exist well-established tools and workflows. Finally, as permissive licenses are gaining in popularity [3] it is not uncommon any longer that someone else but the author himself updates the material. Naturally, the more convenient way for something like that to be accomplished, the more likely it will happen.

The intention to teach the computational and critical thinking skills necessary to formulate problems, the mathematics to solve them, and the tools to practically implement those solutions all in one place presents a formidable challenge. The aim of an engineering and scientific textbook should be to present a unified resource to bring students up to speed and prepare them for smooth industry acceptance or a career in research. Nowadays, there are many excellent textbooks but only a very few of them [4] that are up to date and engaging with the very latest hands-on tutorials. Commonly, such tutorials and code examples can be found elsewhere on the Internet, but are scattered across various blog posts or repositories thus tedious to look for and non-trivial to find. Moreover, such examples typically focus on *how* to implement a given approach, but leave out the discussion of *why* certain algorithmic decisions are made. Also, many resources are hidden behind the paywalls of commercial providers.

To summarize, the goal of a far-reaching engineering or scientific textbook resource should be to (i) be freely available for everyone; (ii) offer engineering and/or sufficient technical depth to provide a good and solid starting point; (iii) include runnable code examples thus showing readers how to solve problems in practice using appropriate tools for the field; (iv) allow and be ready for rapid updates, both by the authors themselves and also by the community at large; and (v) be optionally complemented by some sort of a forum for interactive discussion of technical details and to answer questions. This paper tries to describe technical means centered around Sphinx tool [5] to achieve the above set goals.

The paper is organized as follows: Section 2 presents motivation for use of different book formats and presents limits of the currently available conversion tools, while sections 3 and 4 respectively give a brief workflow description of the Sphinx documentation generator and example case of one textbook.

2 Multiple Textbook Formats and Conversion Tool Limitations

The goals set at the end of the previous section are often conflicting. Namely, from the distribution perspective, textbooks are normally available in the so-called Portable Document Format (PDF), an open file format originally developed by Adobe but now accepted as an international standard (ISO 32000). Vast majority of physical books are sent for printing in PDF and are also stored on computers and computing devices independent of their hardware, operating system or application software that is used to view or edit such documents. Almost all text and word processing software has the ability either to export or directly save its outputs as a PDF file. However, equations, theorems, and citations are best managed and laid out in LaTeX [6] which is a typesetting software system for document preparation widely used in academia [7] for the communication and publication of scientific documents (research preprints, textbook drafts, conference proceedings, journal articles, etc.) in many fields [8], including but not limited to mathematics and statistics, computer science, engineering, physics, and more recently also economics, linguistics, quantitative psychology, philosophy, and political science.

On the other hand the Internet web pages are native in the HyperText Markup Language (HTML) and JavaScript code used for dynamic behavior. Besides the printed book material also downloadable as a PDF, to reach a wider audience as well as to make the material more comfortable to digest from computers and handheld devices, a website textbook version is highly beneficial. Namely, if a book contains any kind of an executable source code it is much easier to copy it than to retype it. Additionally, if possible a direct on-click code execution might be supported especially if an in-browser JavaScript compiler or interpreter exists and if the free and open-source software (FOSS) tools are being exploited. Even though it is certainly not impossible to achieve on-site execution of the code written for some proprietary software, it is much seldomly straightforward to do so due to technical and legal difficulties since non-free closed-source tools are often subject to restrictive licensing terms.

Besides the HTML and the PDF versions, it would be desirable to also support some of e-book file formats that are desirable for e-reader devices and gadgets. E-readers are preferable [9] since they can hold many books limited only by their memory while most of them use e-ink display technology that is not back-illuminated and therefore seem to cause no more eye strain [10] than a traditional book and certainly less eye strain than LCD screens, simultaneously with a substantially longer battery life.

The first idea that naturally comes would be to target either a PDF, i.e., a LaTeX more precisely, or an HTML textbook version and then to perform an automatic conversion to the other formats. No matter how attractive this approach sounds, in reality it is difficult to obtain a high-quality result across all targeted outputs. Specifically, whoever has at least once tried to print a web page can predict the PDF quality and usefulness that is the outcome of the HTML-to-PDF conversion process. The other way around, conversely PDF-to-HTML works even worse, especially for diagrams and math which generally speaking render to be useless. To be honest, using PDF as an intermediate format when converting from LaTeX to HTML is not helpful since in one such conversion much of the structural information is irreversibly lost and cannot be successfully recovered. It is worthwhile considering a direct LaTeX-to-HTML conversion as both are structural markup languages used to describe the document structure, e.g., sections, emphasize, formulas, etc. Perhaps the most comprehensive and universal tools for such tasks are LaTeX2HTML [11], LaTeXML [12], TeX4ht [13] which are all amazing conversion tools but each with its own set of limitations that are associated either with inherent use of device independent (DVI) file format as another type of intermediary, or use of rasterized bitmaps to convert mathematical symbols, diagrams and other “difficult” elements. Generation of easily executable and runnable source code samples are not among the features that can be expected out of any conversion tool.

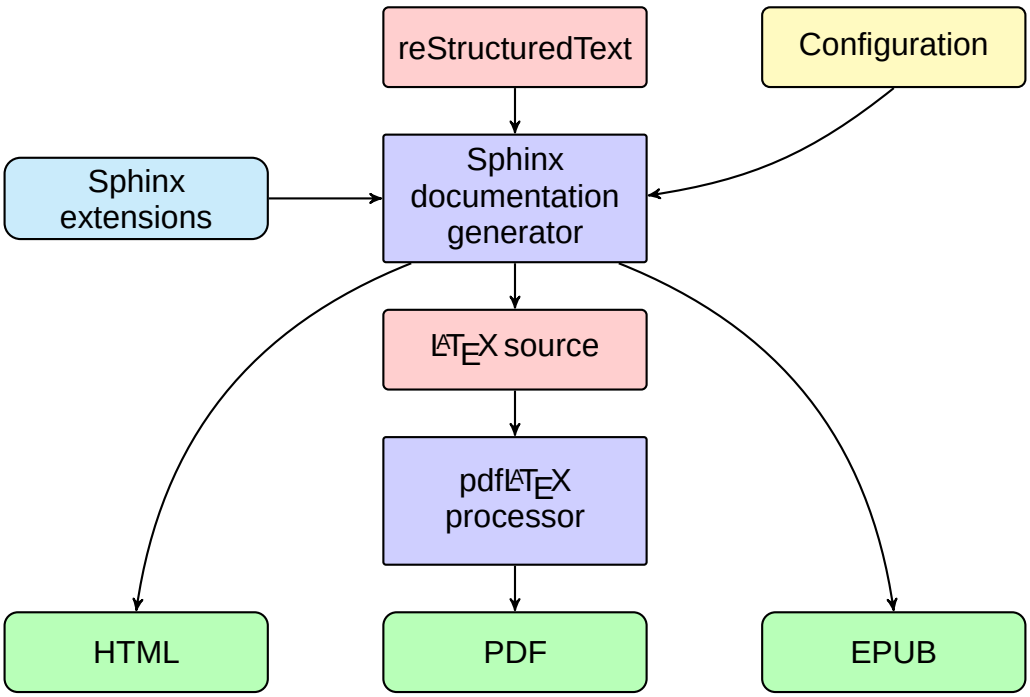

Figure 1: A typical Sphinx workflow as used in the example case for producing three output formats.

3 Sphinx — Python Documentation Generator (to rule them all)

Instead of relying on conversion tools, it would be much simpler, and for that sake much better, to use a single documentation generator to produce every type of aimed output formats. There exist a vast number of documentation generators but only a few that besides HTML can concurrently yield additional outputs such as LaTeX and indirectly PDF, and hardly any with the native e-book support.

One of the most popular documentation generators is Sphinx [5], a tool that makes it easy to create documentation principally for Python and C/C++ projects, but also any other documents consisting of multiple reStructuredText sources. Being part of the Docutils project [14] that was initially made to extract comments and information from Python programs, as well as to format them into various forms of program documentation, reStructuredText [15] is a lightweight markup language (very similar to somewhat younger and more popular cousin Markdown [16]) designed to be easily readable by human programmers and at the same time processable by adequate automatic parsers and translators.

The philosophy of reStructuredText (reST) and its key design goal was the readability, that is, it should be publishable as-is, as plain text, without looking like it has been marked up with tags or formatting instructions, unlike HTML, LaTeX or Rich Text Format (RTF), which for that matter all have obvious tags. Its main inspiration comes from unofficial conventions for marking up plain text e-mails.

Some well-known and already established software projects, like the Linux kernel, transitioned to reST, that has been a core component of Sphinx toolchain, for documentation generation and publishing.

Although Sphinx has been originally developed in 2008 for the Python project documentation, since then it has seen a wide adoption not confined to Python. In its essence, Sphinx converts input reST files into HTML websites and other formats like PDF (via LaTeX) and ePub, a popular vendor-independent XML-based open electronic publication standard. The EPUB format is widely used on electrophoretic display (electronic paper) readers. In addition to reST sources that encompass the actual documentation content, a typical Sphinx workflow accepts a configuration file as well, and just as shown in Figure 1 diagram produces the outputs. Along with the three mentioned outputs of interest, i.e., HTML, LaTeX (for printable PDF versions) and ePub, it can also yield Texinfo, manual pages and plain text.

The inclusion of programming code snippets, notes, figures, images, and other graphical or visual effects and elements is achieved through the use of special directives embedded directly into the reST.

A feature that separates Sphinx is that it comes with a natural code support in a sense that any kind of a programming source code can be included, highlighted and manipulated naturally. For the case of interpreted languages like Python, a built-in prompt and output hiding and showing (in HTML) and automatic output tests and validation through external modules such as `doctest` [17] is also supported.

With a help of external components, also known as (third-party) Sphinx extensions, such as **activecode** from the `runestone.academy` [18], an interactively enhanced electronic textbooks can be created.

There exist more than a dozen built-in and more than a hundred unofficial third-party extensions to Sphinx with which various kinds of special features can be accomplished. Without an ambition to cover extensions in depth and thoroughly, but rather just to give a feeling what can be realized, for example, with a built-in Graphviz [19] extension diagrams of graphs and networks can be directly coded into reST source. Similarly, general figure drawing can be done with a third-party extension that incorporates PGF/Ti*k*Z [20], a widely used pair of languages for producing vector graphic drawings.

Perhaps the nicest feature of all, at least from a perspective of an engineer or a scientist, is that all Sphinx inputs are purely textual and all execution goes directly from a command line. This allows to track changes and to collaborate with others with ease using a (remote) Git repository, as well as to build upon it by assembling a full automation server for workflow execution in a continuous integration (CI) and continuous deployment (CD) manner. The key takeaway is that even if at present day there exists no workflow perfectly suited to address all of the demands placed upon modern engineering and scientific textbooks, the software tools centered around Sphinx as a rendering engine are available, moreover they are FOSS and effortlessly extensible with the built-in, third-party, or self-made add-ons.

4 An Example Case of a Modernized and Pythonic Version of the Classical “Wizard Book” a.k.a. SICP in Serbian Language

One of the best and most influential computer science textbooks of all time is certainly the MIT Press’ classic Structure and Interpretation of Computer Programs (SICP) [21] written by Harold Abelson and Gerald Jay Sussman with Julie Sussman, professors of the Massachusetts Institute of Technology. The book teaches fundamental principles of computer programming which are exposed using Scheme [22], a dialect of Lisp. However, due to various reasons there was a shift in the original MIT course 6.001 and it is replaced by a new class which uses Python instead. Despite being the book of programming (as a paradigm) and not of a particular programming language, SICP is not as attractive to Generation Z as it was for previous generations. Since to the best of the author’s knowledge, neither a direct SICP translation, nor books that derive from it were available in Serbian language, the author has decided to write a “pythonic” one (and also to fulfill one of the mandatory conditions for academic advancement).

A mitigating circumstance was that the original SICP was legally accessible under the Creative Commons license and that a lot of quality reworked materials were attainable, some [23] even for Python.

Prior to that, the author was teaching fundamentals of programming to electrical engineering and computer science freshmen and was aware of an average university student habits that are also associated with handheld devices, such as constant lack of time, patience, and long-term focus. Therefore, to create a book that would be interesting for a student to scroll through it quickly, grasp as much as possible in the limited interval by either copying example code or executing it inside the browser, thus instantly obtaining the result was a logical decision. Besides HTML that would be residing on the Web [24], both an e-book version and a printed physical book was published [25] for everyone who wanted to have it in a regular textbook format. Naturally, Sphinx was used to produce all the outputs out of a single reST source [26], and the appropriate CI/CD pipeline is made to facilitate future updates.

More specifically, the continuous integration proved to be fairly useful particularly for the Python doctest [17] examples that are automatically executed to verify that they work exactly as shown. Such a system managed to catch some subtle modifications and lack of backward compatibility between different Python versions. On the other hand, the continuous delivery and deployment on every commit trigger a series of actions to execute Sphinx workflow of Figure 1 and produce the three outputs available for download. Major releases, for example, the first edition, are handled with git [27] tags.

Not only the complete textbook source code is available on GitHub [26], but also the workflow for the so-called GitHub Actions which allows building continuous integration and continuous deployment pipelines for testing, releasing and deploying software without the use of third-party platforms and that is, at the moment of writing this paper, free of charge for all public open source projects.

Thus, everyone can fork the repository, change something, for example fix a typo, or add another example or even a complete chapter, and send the appropriate pull request for committing of the made changes into the main branch. Not that the expectation exists or that it is likely, but the ability is there.

Finally, the main beneficiaries of such a textbook should be students themselves. Not only that they should be learning the fundamental principles of computer programming, like recursion, abstraction, modularity, and programming language design and implementation, and not only that they would have the ability to quickly see and exercise practical code samples and snippets, but they could be intrigued by the flow itself. They might get curious how everything is set, and then start learning about version control systems like git, or how reST source code which is available to them gets translated to PDF, HTML, and EPUB, maybe they delve more into LaTeX and thereby raise their overall computer skills.

With the hope that something along the previous lines of thought will actually happen, this textbook is devoted to all of the author's students, past, current and future ones, and also dedicated to his teachers and professors who have enabled him to reach and see this far by "standing on *their* shoulders" [28].

5 Conclusions

One of the characteristics of the ongoing Information age is the exponential publishing growth and new media that has transformed the traditional book industry. New electronic formats have been introduced and book content can be consumed on-line. Most books are published by a small number of very large book publishers, but thousands of authors self-publish their own works. Academic textbooks are no exception. To keep pace with the current developments and stay up-to-date a publication should be available across different platforms (both, electronic and physical) to satisfy the demanding needs.

There are a number of advantages of different electronic book formats which can interleave plain text with formulas, figures and (executable) code, especially in engineering and scientific disciplines. If a single author aim is to support all of them using traditional workflows it would either take prohibitively long time or would not yield acceptable results. Therefore, a sort of an agile software development [29] flow that is centered around Sphinx documentation generator is introduced. With an adequate content description in reStructuredText, one can simultaneously produce: HTML suitable for on-line version, as well as PDF and EPUB which are *de facto* standards for physical book printing and open e-reader format, respectively. Writing books in a software coding style yields a plethora of additional benefits.

The previously mentioned Sphinx-based workflow is exercised on an example case of writing an electrical engineering and computer science textbook. Besides manual workflow execution the process is automated in a CI/CD fashion hence enabling quick releases and snapshots prepared after every change/fix. Additionally, other teachers and professors can more easily adapt (by forking followed by adding new, or discarding and cutting existing material) the manuscript and tailor it to suit their own needs which is enabled by the permissive license. To the best of the author's knowledge, this is the first textbook published in Serbian language that uses such a flow and is provided in the three formats.

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OTVORENI (INTERAKTIVNI) UDŽBENICI – PREGLED I PRIMER

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REZIME

Otvoreni obrazovni resursi su besplatni edukativni sadržaji, najčešće u digitalnoj formi, koji mogu slobodno da se preuzimaju, koriste, prilagođavaju i distribuiraju. Ovi sadržaji imaju potencijal da unaprede (formalno) obrazovanje ne samo u tehničkom, već i u konceptualnom smislu, podstičući uključenost učenika u nastavni proces i angažovanost nastavnika u kreiranju obrazovnih materijala. Udžbenici imaju poseban značaj za realizaciju nastavnih programa, pa su tako i otvoreni udžbenici prepoznati kao alatke koje bi mogle da doprinesu kvalitetu, efikasnosti, pristupačnosti i pravičnosti obrazovanja. U ovom radu je dat kratak pregled popularnih biblioteka otvorenih udžbenika, a potom je opisano nekoliko besplatnih alatki za kreiranje i publikovanje otvorenih interaktivnih obrazovnih materijala. Prikazane su osnovne funkcionalnosti otvorenog interaktivnog udžbenika napisanog za potrebe kursa Uvod u statistiku na Filozofskom fakultetu u Novom Sadu. Na kraju rada dat je osvrt na potencijalne probleme vezane za izradu i upotrebu otvorenih udžbenika, a koji se tiču održivosti, podrške državnih i visokoškolskih institucija i informisanosti nastavnika i studenata.

Ključne reči: otvoreni obrazovni resursi, otvoreni udžbenici, interaktivna nastava, otvorene (CC) licence, repozitorijumi, informaciona i digitalna pismenost.

1 Otvoreni obrazovni resursi

Informacione tehnologije su unapredile naše sposobnosti da pronalazimo, obrađujemo, skladištimo, razmenjujemo i prikazujemo informacije. Nikada do sada u ljudskoj istoriji nije bilo moguće tako lako i brzo pristupiti tako velikoj količini (multimedijalnih) sadržaja. Opravdano je očekivati da sveprisutno računarstvo, unapređenje klasičnih i stvaranje novih vidova i kanala komunikacije, kao i eksponencijalni rast količine raspoloživog znanja, bitno poboljšaju kvalitet, efikasnost i dostupnost obrazovanja na globalnom nivou. Entuzijazam vezan za ovakva očekivanja izrazio je i jedan od pionira računarstva Bil Gejts iznoseći predviđanje da će u bliskoj budućnosti na vebu biti dostupni besplatni kursevi i nastavni materijali kvalitetniji od onih koje nude najbolji svetski univerziteti [1]. Pored toga, njegov stav je i da se osobama koje žele da uče moraju priznati znanja i veštine koje imaju, bez obzira na to kako su ih stekli. Pomalo anegdotski ali ilustrativan primer ovakvog viđenja uloge slobodnog onlajn obrazovanja je podatak da neki od najpoželjnijih poslodavaca današnjice, kao što su Gugl, Epl, Tesla i IBM, prilikom zapošljavanja ne insistiraju na tome da kandidati imaju univerzitetske diplome [2]. Čini se da Gejtsovo predviđanje nije daleko od ostvarenja jer internet nudi jedinstvenu mogućnost da se obrazovanje demokratizuje i otvori za sve. Nove informacione tehnologije imaju kapacitet da promene klasičnu (kartezijansku) paradigmu nastave prema kojoj se znanje posmatra kao materija koja se prenosi sa učitelja na učenika i da pretvore obrazovanje u

stalnu, inkluzivnu i interaktivnu društvenu aktivnost u kojoj su đaci i studenti ravnopravni učesnici i moderatori procesa učenja u širem društvenom kontekstu [3].

Nadu da će informacione tehnologije zaista unaprediti kvalitet, efikasnost i dostupnost obrazovanja potkrepljuju različite inicijative, strategije i projekti realizovani u toku prve dve decenije 21. veka. Evropska komisija je u više dokumenata i programa iskazala jasnu podršku otvorenom obrazovanju kao načinu da se inovira proces nastave, ali i da se unapredi mogućnost zapošljavanja i modernizuje tržište rada [4]. Unesko je u nekoliko preporuka i akcionih okvira definisao osnovne ciljeve kojima bi trebalo da teže sve članice UN, a koji naglašavaju potrebu za razvojem infrastrukture i pratećih politika za podršku kreiranju obrazovnih materijala čije će korišćenje, prilagođavanje i deljenje biti besplatno [5]. Privatne dobrotvorne fondacije, kao što su Vilijam i Flora Hjulit, Endrju V. Melon i Bil i Melinda Gejts, značajno pomažu projekte u oblasti otvorenog obrazovanja. Na kraju, sve veći broj (elitnih) svetskih univerziteta prepoznaje važnost i prednost diseminacije otvorenih obrazovnih sadržaja, što predstavlja možda i najvažniji podsticaj ideji otvorenog obrazovanja. Ovde na prvom mestu treba pomenuti univerzitet MIT na kojem je 2002. godine pokrenut repozitorijum besplatnih onlajn predavanja *OpenCourseWare*[1] kao jedna od najznačajnijih inicijativa otvorenog obrazovanja. Deset godina kasnije, MIT u saradnji sa univerzitetom Harvard pokreće i servis *edX* koji trenutno nudi preko 3.000 besplatnih kurseva sa više od 160 prestižnih univerziteta i institucija.

Okosnicu otvorenog obrazovanja predstavljaju otvoreni obrazovni resursi (OOR) (engl. *OER – Open Educational Resources*). U ovom tekstu upotrebljen je doslovan prevod termina kako bi se ukazalo na nekoliko važnih činjenica vezanih za kreiranje i diseminaciju besplatnih edukativnih sadržaja. Prvo, termin „otvoreno“, kao i u slučaju otvorene nauke, otvorenog pristupa ili otvorenog koda, ne treba izjednačavati sa terminom „besplatno“ [6]. Iako su u pitanju sadržaji koji su zaista besplatni za krajnje korisnike, njihova izrada nije besplatna. Osim toga, „otvoreno“ je širi termin koji podrazumeva specifične, veće slobode koje se daju krajnjim korisnicima, bez obzira na to da li je njihova potreba i namera da uče ili da podučavaju. Slobode koje čine određeni obrazovni sadržaj zaista otvorenim obično se označavaju skraćenicom 5P (engl. *5R*) i podrazumevaju prava korisnika da taj sadržaj preuzimu i pohrane (engl. *retain*), (ponovo) primene (engl. *reuse*), prerade (engl. *revise*), pomešaju i povežu sa drugim sadržajima (engl. *remix*) i proslede (engl. *redistribute*) [7]. Drugim rečima, digitalna verzija udžbenika dostupna na vebu isključivo za besplatno preuzimanje i čitanje jeste primer besplatnog (*gratis*), ali ne i slobodnog (*libre*) otvorenog pristupa, tj. otvorenog obrazovnog resursa.

Termin „obrazovni“ u gornjem prevodu upotrebljen je umesto često korišćenog termina „nastavni“ da bi se naglasila činjenica da OOR ne moraju nužno da budu povezani sa procesom nastave, barem ne u klasičnom smislu. OOR učenicima obezbeđuju individualizovano, neprekidno, samostalno i celoživotno slobodno obrazovanje, sa ili bez pomoći osobe koja podučava. Može se reći da OOR omogućavaju učenicima da postanu (sopstveni) nastavici. Na kraju, termin „resursi“ upotrebljen je umesto termina „sadržaji“ ili „materijali“ da bi se ukazalo na to da uspeh OOR ne može da se bazira samo na spremnosti autora da svoje obrazovne sadržaje postave na veb i dozvole njihovo besplatno preuzimanje. OOR ne treba svoditi na naučne članke, monografije, udžbenike, prezentacije, testove, silabuse, audio snimke, video materijale i druge izvore koji se koriste u obrazovne svrhe, jer njihova izrada i upotreba iziskuje i angažovanje drugih resursa - od tehničke podrške i održavanja potrebnog softvera i hardvera, preko dodatnih kompetencija autora za izradu OOR i dodeljivanje prikladnih licenci za njihovo korišćenje, pa sve do institucionalne podrške. Ovo poslednje se ne odnosi samo na materijalna sredstva, već i na obezbeđivanje pratećih pravnih dokumenata (pravilnika, politika, ugovora) kojima se reguliše proces izrade i korišćenja OOR, kao i na stvaranje podsticajne klime i

1 Čitaocima se preporučuje da veb stranicama opisanim u tekstu pristupaju koristeći hiperlinkove koji su dostupni u elektronskoj verziji ovog rada.

okruženja za njihov razvoj i promociju. OOR stoga treba shvatiti kao deo šire *otvorene obrazovne infrastrukture* koja obuhvata još (barem) i *otvorene kompetencije* za upotrebu novih tehnologija i novih formata nastave, *otvorenu evaluaciju* toka i ishoda nastavnog procesa i *otvorene kredencijale*, odnosno potvrde i uverenja koja nisu nužno vezana za institucionalnu administraciju [8].

2 Otvoreni udžbenici

Univerzalna deklaracija o ljudskim pravima UN definiše dostupnost besplatnog obrazovanja, barem onog osnovnog, kao jedno od elementarnih prava čoveka. Četvrti od 17 ciljeva održivog razvoja UN odnosi se na neophodnost pravičnog, inkluzivnog i kvalitetnog celoživotnog obrazovanja za sve. U tom smislu, otvoreni udžbenici mogu da budu presudan faktor demokratizacije obrazovanja i doprinesu smanjenju jaza između razvijenih zemalja i zemalja u razvoju. Jedan od preduslova je da se obezbedi njihovo lako pronalaženje i mogućnost prilagođavanja specifičnom kontekstu kako bi se prevazišle kulturne i jezičke barijere [9]. Kao što je već rečeno, to znači da nije dovoljno da neki udžbenik bude besplatan i postavljen na veb. On najpre mora da bude otvoren, tj. da se nalazi u javnom domenu ili da mu je dodeljena odgovarajuća vrsta licence za korišćenje. Najpoželjnije je da to bude *CC BY* licenca koja ispunjava sve zahteve predviđene 5P pravima. Pored toga, otvoreni udžbenik mora da bude dostupan za pronalaženje (engl. *findable*), tj. precizno opisan metapodacima i indeksiran u standardizovanom repozitorijumu, elektronskoj biblioteci ili bazi podataka.

Nesumnjivo je da OOR nude nove mogućnosti za rešavanje problema sa kojima se suočavaju đaci u zemljama nižeg ekonomskog statusa. Iako je neumesno porediti te probleme sa poteškoćama koje imaju učenici i studenti u razvijenim društvima, treba napomenuti da OOR kao ideja i kao praksa ima za cilj da pomogne i jednima i drugima. Drugim rečima, OOR treba svima da omoguće jednaka prava *na* obrazovanje, ali i *u toku* obrazovanja. Istraživanje sprovedeno na uzorku od oko 5.000 studenata koledža i univerziteta u SAD ukazalo je na problem visokih cena udžbenika koje su u toku samo jedne decenije porasle za 73%, tj. četiri puta više od stope inflacije u istom periodu [10]. Između 28% i 50% studenata, u zavisnosti od tipa visokoškolske ustanove, bilo je prinuđeno da zbog toga uzima dodatne zajmove, mnogi su se opredeljivali da ni ne kupe preporučene udžbenike, a nemali procenat studenata je čak i odustajao od studiranja. U zaključku studije, autori pozivaju studente, ali pre svega nastavnike i uprave fakulteta, da budu promoteri upotrebe OOR i razmotre mogućnost kreiranja novih, odnosno korišćenja i prilagođavanja postojećih otvorenih udžbenika.

2.1 Repozitorijumi otvorenih udžbenika

Kao što je već pomenuto, veliki broj univerziteta i neprofitnih organizacija prepoznao je važnost OOR i svoju ulogu u njihovom razvoju i popularizaciji. Pokrenut je veliki broj repozitorijuma sa ciljem da se udžbenici za sve nivoe obrazovanja učine javno dostupnim. Jedan od najobuhvatnijih izvora otvorenih udžbenika je svakako *Pressbooks Directory*, katalog koji sadrži preko 2.800 knjiga izrađenih na popularnoj platformi *Pressbooks*. U pitanju su otvorena izdanja preko 300 izdavača među kojima je i veliki broj univerziteta i visokoškolskih ustanova.

Open Textbook Library Univerziteta u Minesoti je biblioteka koja sadrži preko 900 udžbenika iz različitih oblasti nauke. Treba napomenuti da ovaj servis više ne prihvata postavljanje udžbenika kojima je dodeljena CC ND (engl. *No Derivates*) licenca. To znači da većina udžbenika iz ovog kataloga može besplatno da se preuzme i koristi, ali i da se preradi, prilagodi i dalje distribuira pod istom ili drugačijim licencama.

Kanadska organizacija *BCcampus* (*BC* od *British Columbia*) održava biblioteku od približno 400 naslova od kojih su neki preuzeti iz drugih otvorenih repozitorijuma. Većina udžbenika je delo

univerzitetskih profesora. Na veb-sajtu ove organizacije mogu se naći detaljna uputstva i priručnici o otvorenim udžbenicima za sve autore zainteresovane da svoje publikacije i materijale podele u režimu otvorenog pristupa i nastavnike koji žele da koriste postojeće otvorene udžbenike u svom radu i prilagode ih potrebama nastave koju održavaju.

Servis *OpenStax* Rajs univerziteta iz Hjustona sadrži manji broj naslova od prethodnih servisa, ali je vredan pomena jer je većina udžbenika interaktivna što pruža novu dimenziju učenju i podučavanju. Kao i u drugim digitalnim udžbenicima, udžbenici dostupni u ovoj biblioteci sadrže slike, grafikone i druge multimedijalne elemente, a dodatno su obogaćeni i zadacima za proveru znanja uz pružanje povratne informacije, kao i opcijama za podvlačenje teksta i dodavanje komentara.

Ovde treba pomenuti još dva korisna izvora iako nisu specijalizovana samo za otvorene udžbenike. Jedan je *OER Commons* koji održava neprofitna organizacija Institut za proučavanje upravljanja znanjem u obrazovanju, a drugi *MERLOT* Državnog univerziteta u Kaliforniji. Dodatni izvori recenziranih otvorenih udžbenika i mnogo korisnih informacija o OOR mogu da se pronađu preko metapretraživača *MOM - The Mason OER Metafinder* i veb-sajta mreže *Open Washington*.

2.2 Alatke za izradu otvorenih interaktivnih udžbenika

OOR i otvoreni udžbenici su u dosadašnjem tekstu opisani pretežno iz aspekta korisnika - učenika i studenata kojima je potreban kvalitetan i priuštiv materijal za učenje, i nastavnika koji žele da unaprede nastavu uključivanjem otvorenih sadržaja kao literature za svoje kurseve. Očigledno je da obrazovanje za 21. vek, pa tako i upotreba otvorenih interaktivnih udžbenika, iziskuje usvajanje novih informacionih kompetencija svih učesnika obrazovnog procesa. U slučaju nastavnika koji žele da se priključe pokretu otvorenog obrazovanja ne samo kao konzumenti, već i kao kreatori sadržaja i promoteri nove filozofije podučavanja, te kompetencije uključuju i poznavanje određenih tehničkih aspekata izrade otvorenih udžbenika.

Verovatno najpopularnija platforma za kreiranje otvorenih udžbenika je *Pressbooks* bazirana na sistemu otvorenog koda za kreiranje veb-sajtova *WordPress*. Ona omogućava izradu onlajn knjiga u interaktivnom HTML formatu i njihovo publikovanje, tj. preuzimanje u EPUB, PDF, XML, MOBI i drugim formatima koji olakšavaju naknadno menjanje i adaptiranje. Kao ilustracija funkcionalnosti platforme odabrana je knjiga *Principles of Microeconomic* jer je to ujedno adekvatan primer kako otvoreni udžbenik drugih autora može da se izmeni i prilagodi, u ovom slučaju nastavi na kursu koji se održava na Univerzitetu u Viktoriji. Odličnu polaznu tačku za sve koji žele da testiraju platformu *Pressbooks* i aktivno se priključe pokretu OOR predstavlja zajednica *Rebus Community*.

Moto projekta *Manifold* je „Akademski softver ne mora da boli“. U pitanju je platforma otvorenog koda za izradu obrazovnog materijala razvijena u saradnji sa nastavnicima Univerziteta u Minesoti i univerziteta CUNY. U udžbenike izrađene pomoću ove platforme mogu da se umeću interaktivni elementi, sirovi podaci za statističku obradu, kao i opcije za postavljanje komentara i diskutovanje o sadržajima opisanim u tekstu. Primer publikacije razvijene na platformi *Manifold*, a istovremeno i koristan priručnik o otvorenim udžbenicima i OOR je *The OER Starter Kit Workbook*.

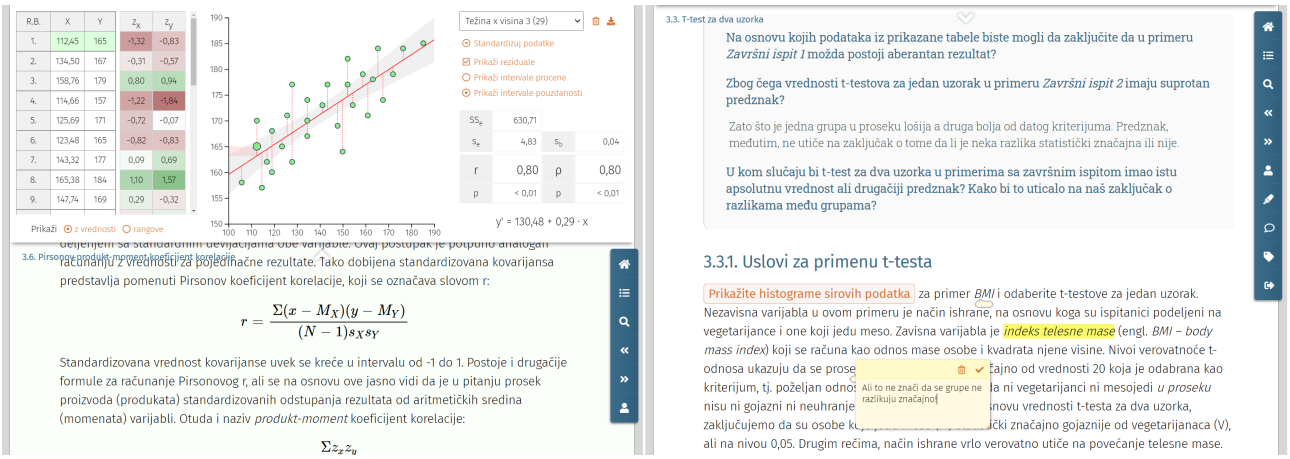
Za nastavnike i autore kojima je potrebna bolja podrška za interaktivne sadržaje, prikladan izbor za kreiranje otvorenih udžbenika mogao bi da bude paket *Bookdown*. Paket nudi svu fleksibilnost statističkog okruženja R i najpopularnijih programskih jezika. Slične interaktivne funkcionalnosti ima i veb-aplikacija *Jupyter Notebook*, posebno pogodna za izradu priručnika u kojima je potrebno u realnom vremenu praviti vizualizacije i izvršavati programski kod. Iako nisu u pitanju klasični otvoreni udžbenici, na ovom mestu treba pomenuti publikacije fondacije Petlja koje na dobar način ilustruju mogućnosti programskog jezika Pajton i platforme Džupiter za publikovanje interaktivnog

obrazovnog materijala. Pored navedenih, postoje brojne druge alatke i platforme za izradu otvorenih udžbenika kao što su *Scalar*, *GitBook*, *Fulcrum*, *Open Author* i *PubPub*.

3 Primer otvorenog interaktivnog udžbenika

Za potrebe kursa Uvod u statistiku na osnovnim studijama psihologije na Filozofskom fakultetu u Novom Sadu izrađen je interaktivni udžbenik pod nazivom Primena tehnika vizualizacije u bazičnoj statistici. Besplatno je dostupan svim zainteresovanim korisnicima pod uslovima CC BY-NC-SA licence kojom se ne dozvoljava komercijalna upotreba udžbenika i njegovih derivata. Pored želje da se polaznicima kursa obezbedi besplatna literatura prilagođena studijskom programu, motivacija za izradu udžbenika potekla je i iz potrebe da se studentima društvenih i humanističkih nauka približi gradivo koje često opažaju kao zahtevno i dosadno. Udžbenik je pionirski, donekle eksperimentalni projekat autora, tako da za njegovu izradu nije upotrebljena neka od postojećih, ranije opisanih platformi. Sav materijal je razvijen korišćenjem PHP i JavaScript jezika, a u izradi su upotrebljene besplatne JavaScript biblioteke: *D3* za interaktivno iscrtavanje grafikona, *jStat* za složenije statističke obrade podataka i *MathJax* za prikazivanje matematičkih formula. Udžbenik se hostuje na serveru Filozofskog fakulteta u Novom Sadu.

Udžbenik podržava različite oblike interakcije sa korisnikom. Tu su najpre interaktivni okviri koje sadrži svaki odeljak udžbenika (Sl. 1 levo). U njima se prikazuju vizualizacije i zadaci koje studenti treba da obave. Link za otvaranje okvira se automatski pojavljuje u vrhu ekrana kada čitalac dođe do dela teksta koji se odnosi na njega. U okvirima je moguće unositi podatke u tabele, iscrtavati i menjati grafikone, odrađivati jednostavne eksperimentalne vežbe i preuzimati prikupljene podatke. Drugi oblik interaktivnosti su kratka pitanja u tekstu (Sl. 1 desno) koja služe za proveru usvojenosti gradiva u toku čitanja. Osim toga, svako poglavlje sadrži interaktivni test znanja koji nudi povratnu informaciju o tačnosti datih odgovora i obrazloženje logike odgovaranja. Iskustvo interaktivnosti je dodatno pojačano opcijama za podvlačenje teksta, postavljanje obeleživača i umetanje komentara (Sl. 1 desno). Na kraju, korisnicima je omogućena pretraga udžbenika, a u svakom momentu im je dostupan i kratak sadržaj u kome je naznačeno koje poglavlje trenutno pregledaju.

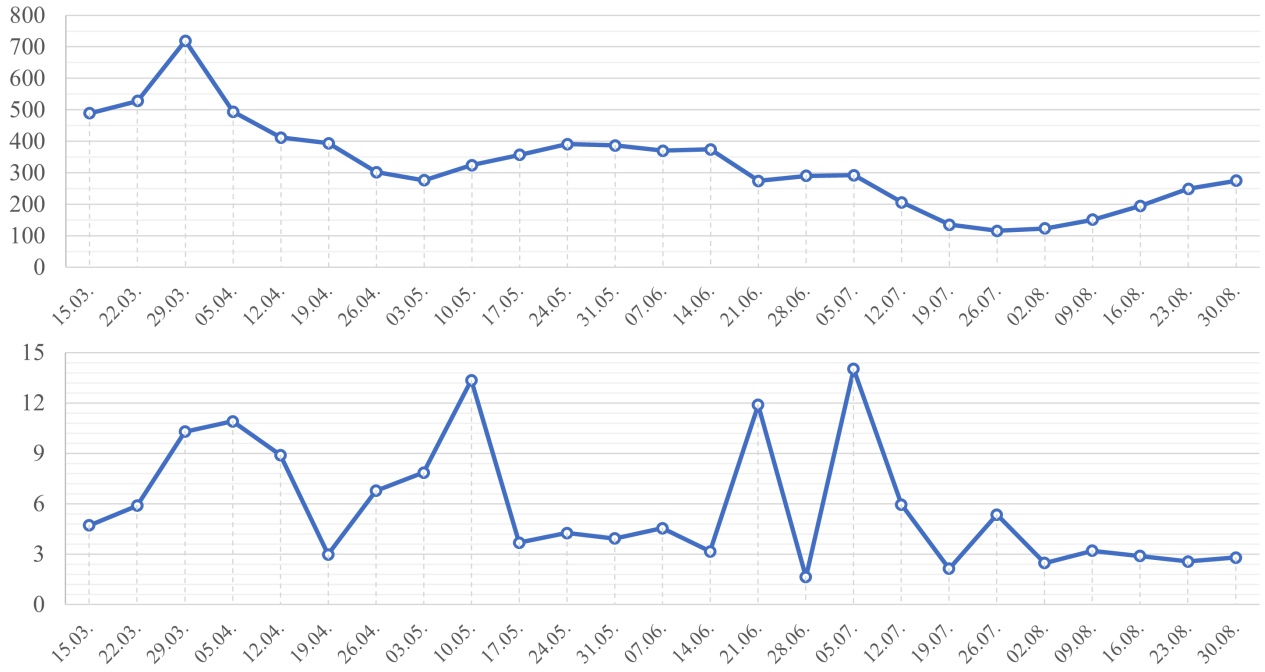


Slika 1 Interaktivni elementi udžbenika.

Bitna karakteristika i prednost onlajn udžbenika je mogućnost pribavljanja povratne informacije o njihovoj upotrebi na osnovu analize log datoteka. Na taj način se mogu izvesti korisni zaključci o ponašanju korisnika, npr. prepoznati zahtevni delovi gradiva na osnovu dužine zadržavanja ili važne teme na koje se korisnici često vraćaju. U periodu od marta do jula 2021. udžbenik opisan u ovom radu prosečno je posećivalo 50 korisnika dnevno. Kao što se može videti na Sl. 2, aktivnosti

korisnika približno su vezane za termine ispitnih rokova. Najviše poseta je zabeleženo početkom aprila kada je najveći broj studenata Odseka za psihologiju polagao ispit iz Uvoda u statistiku (Sl. 2 gore). Ova pravilnost je još uočljivija na grafikonu koji prikazuje prosečno trajanje sesija (Sl. 2 dole). Zadržavanje na stranicama udžbenika u proseku traje tek nekoliko minuta, ali ove vrednosti naglo rastu u periodima kada se studenti spremaju za polaganje ispita. O većem stepenu interakcije govori i podatak da se u istom periodu broj događaja (klikovi, pomicanja, preuzimanja, otvaranja okvira) povećava sa 5 do 8, na 10 do 15 po sesiji.

U kontekstu prednosti i načina korišćenja onlajn udžbenika bitno je pomenuti i tip uređaja na kojem korisnici pregledaju sadržaje. Čak 47% pregleda u analiziranom periodu obavljeno je sa mobilnih uređaja što ukazuje na potrebu da se obrazovni materijali prilagode različitim veličinama ekrana, naročito pametnim telefonima kao ključnim kanalom komunikacije mlađih generacija. Na kraju, pored pomenutih interaktivnih elemenata, prednost ovog i drugih digitalnih udžbenika u odnosu na klasične je mogućnost pretrage teksta i lakog kretanja kroz sadržaj. Najviše pregleda po korisniku imaju stranica sa koje se obavlja pretraga i stranica sadržaja udžbenika. Međutim, imajući u vidu prosečno trajanje sesija, ova informacija može da ukaže i na to da se onlajn udžbenik u većoj meri koristi kao jednostavan i uvek dostupan podsetnik nego kao izvor za dugotrajno posvećeno učenje.



Slika 2 Broj korisnika po sedmicama (gore) i prosečno vreme korišćenja udžbenika po sesiji (dole).

4 Budućnost otvorenih udžbenika (u Srbiji)

Prednosti korišćenja otvorenih udžbenika su nesporne: manji troškovi studiranja, veća fleksibilnost i dostupnost obrazovnih materijala, bogatije interaktivno i inkluzivno iskustvo učenja (posebno za tzv. „internet generaciju“ učenika), efikasnija diseminacija znanja, lakše umrežavanje i saradnja među nastavnicima, istraživačima i učenicima, jednostavnije ažuriranje i prilagođavanje literature. Osim toga, istraživanja pokazuju da se upotreba otvorenih udžbenika ne odražava negativno na uspeh studenata i na ostvarenje nastavnih ciljeva i ishoda [11]. Međutim, budućnost OOR zavisiće prvenstveno od uspešnosti rešavanja pitanja njihove održivosti. Pri tome nije reč samo o potrebi pronalaženja modela finansiranja i materijalne motivacije autora, već i obezbeđivanja adekvatne tehničke, informacione, organizacione, ali i političke podrške projektima otvorenog obrazovanja

[12]. U tom smislu, značajan podsticaj i korisna iskustva može da pruži pokret otvorene nauke čiji je potencijal prepoznat i u Srbiji, najpre usvajanjem nacionalne Platforme za otvorenu nauku, a potom i pokretanjem Nacionalnog portala otvorene nauke i više institucionalnih repozitorijuma. Ipak, nije opravdano očekivati da se na (univerzitetske) udžbenike prenese model finansiranja i obaveznog deponovanja primenjen na naučne članke nastale u okviru projekata podržanih od strane MPNTR i Evropske komisije. Pored činjenice da bi autori trebalo da se odreknu (barem dela) svojih potencijalnih prihoda, veliki izazov bi predstavljao otpor izdavača koji su više nego spremni da štite svoje finansijske interese. Ilustrativan primer su politizacija, polemike i tužbe vezane za aktivnost Fondacije „Alek Kavčić“ [13]. Naravno, u poređenju sa osnovnoškolskim, univerzitetski udžbenici plasiraju se na manje, izdeljeno i necentralizovano tržište na kome postoji potpuna sloboda izbora literature. Autonomija koju ovakvo tržište pruža autorima, ali i univerzitetima kao potencijalnim izdavačima, treba shvatiti kao podstrek primeni ideja OOR kojima će se omogućiti da pomenute slobode budu i privilegija studenata, a ne samo nastavnika.

Globalna primenjivost tipičnih modela finansiranja otvorenih udžbenika u SAD i Kanadi je sporna. To se posebno odnosi na zemlje sa niskim i srednjim prihodima u kojima ne postoje jake fondacije ili kompanije koje bi mogle da preuzmu ulogu donatora i sponzora otvorenog obrazovanja. Sa druge strane, iskustva razvijenih zemalja su korisna jer jasno ukazuju na važnost koju imaju visokoškolske ustanove u promociji ideje otvorenog obrazovanja, kao i na njihov potencijal da te ideje realizuju. Iskustva u izradi udžbenika predstavljenog u ovom radu govore da visokoškolske ustanove u Srbiji imaju neophodne resurse, ali da je potreban dodatni napor da se oni adekvatno iskoriste. Pojedini fakulteti, npr. Filozofski fakultet u Novom Sadu i Elektrotehnički fakultet u Beogradu, već poseduju repozitorijume besplatnih udžbenika koji bi lako mogli da se pretvore u istinski otvorene biblioteke. Uspešnost projekata kao što je grčki *Kallipos* pokazuje da u okviru postojećih modela finansiranja projekata, a uz pomoć kompetentnih bibliotekara, mogu da se iznađu rešenja za održivost otvorenih udžbenika. Posebno je važno da fakulteti i nadležne institucije posvete pažnju edukaciji nastavnika i studenata o prednostima otvorenog obrazovanja, ali i da porade na prilagođavanju legislativa novim modalitetima publikovanja i distribucije nastavnog materijala. Na većini fakulteta u Srbiji postoji obaveza objavljivanja monografija ili udžbenika kao uslova za izbor u zvanje redovnog profesora. Ako se uzme u obzir da svaka od tih publikacija treba i može da se koristi u nastavi, ovakva praksa se čini kao nepotrebno rasipanje resursa. U vezi sa tim, trebalo bi diskutovati i o vrlo osetljivom pitanju slobode studenata u izboru literature i prevenciji prakse nametanja obaveznih udžbenika.

Čini se da je razvoj besplatnih platformi za izradu i objavljivanje otvorenih udžbenika otišao dalje od trenutnog stepena prihvaćenosti, ali i poznavanja ideje OOR u akademskim krugovima. Čak i u SAD, državi u kojoj je pokret OOR najuticajniji, visok procenat nastavnika nije dovoljno upoznat sa principima i mogućnostima otvorenih udžbenika, a poseduje i pogrešnu percepciju ideje otvorenog obrazovanja [14]. Najčešće predrasude tiču se neopravdanog straha autora da će izgubiti prava nad svojim delom ako ga podele pod otvorenom licencom. Pojedini nastavnici izražavaju i sumnju u kvalitet slobodno dostupnih udžbenika što pokazuje da svoju ulogu u procesu obrazovanja gledaju iz pozicije ograničavajućeg autoriteta, a ne usmeravajućeg stručnjaka koji studentima treba da pomogne u proširivanju informacione pismenosti i sticanju veština evaluacije onlajn izvora. U tom smislu, interaktivnost otvorenih udžbenika ne treba da se shvati samo kao obogaćivanje teksta multimedijalnim sadržajima, već i kao kreiranje novog kanala komunikacije sa studentima. Na kraju, otvoreni udžbenici često se poistovećuju sa elektronskim, pa se tako kao prepreka za njihovu širu primenu navode rezultati istraživanja koji pokazuju da studentima više odgovaraju štampani udžbenici zbog mogućnosti podvlačenja, obeležavanja i lakšeg prelistavanja [15]. Pored toga što opisane otvorene platforme omogućavaju ovakvu vrstu interakcije, većina podržava i mogućnost štampanja na zahtev ili kupovine štampane verzije udžbenika po znatno nižoj ceni od komercijalnih.

Sve navedeno upućuje na zaključak da nastavnici, studenti, bibliotekari, rukovodstva fakulteta, ali i nadležne državne institucije moraju da ulože zajednički napor kako bi se očigledan potencijal OOR i već dostupne tehničke mogućnosti adekvatno iskoristili za realizaciju otvorene obrazovne prakse.

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KORIŠĆENJE OTVORENOG SOFTVERA U NASTAVI INFORMATIKE

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REZIME

Odabir softvera koji studenti informatike kod visokoškolskih ustanova svakodnevno koriste u nastavi je izuzetno važan. Pored ispunjenja funkcionalnih i tehničkih zahteva, softver koji se koristi u nastavi mora ispuniti i veoma važan treći zahtev: mogućnost slobodnog korišćenja. Softver koji se koristi u nastavi, ukoliko slobodan, studenti mogu koristiti i nakon studija u profesionalne svrhe. Korišćenje slobodnog i otvorenog softvera takođe upoznaje studente sa kulturom deljenja koda i prednostima koje ovaj vid razvoja donosi. U ovom radu biće opisane prednosti ovakvog pristupa izvođenju nastave na konkretnom primeru iz prakse – izvođenju nastave informatike na Departmanu za matematiku i informatiku Prirodno-matematičkog fakulteta u Novom Sadu.

Ključne reči: otvoren softver, slobodan softver, linux, nastava, edukacija.

1 Uvod - prednosti otvorenog softvera u nastavi

Korišćenje slobodnog softvera u nastavi ima nekoliko očiglednih prednosti, pogotovo za studente informatike. Mogućnost uvida u izvorni kod softvera koji student koristi je izuzetno dobro oruđe u edukaciji [3]. Studenti koje interesuju detalji implementacije mogu istraživati otvorene izvorne kodove i na taj način steći dodatno znanje o softveru koji koriste. Otvoren softver je takođe više prilagodljiv u odnosu na zatvoren (proprietary) softver i moguće su razne modifikacije po potrebi predavača ili studenata.

Još jedna prednost otvorenog softvera je problem upotrebnih dozvola odnosno licenci. Kod korišćenja zatvorenog softvera često se nailazi na razne probleme licenciranja. Za neke softvere licence su preskupe za visokoškolske ustanove a postoje i ekstremni slučajevi gde nije moguće dobiti odgovarajuću licencu kako bi se softver koristio u učionici. Kod otvorenog softvera ovakvi problemi ne postoje, studenti i nastavno osoblje mogu koristiti otvorene razvojne alate i u nastavi i za privatne potrebe. Ovakav pristup ima i još jednu veliku prednost za studente a to je mogućnost upotrebe istih razvojnih alata (npr. Eclipse) i po završetku studija. Na taj način studenti su po završetku studija spremni za industrijski razvoj softvera bez potrebe za upoznavanjem sa novim alatima.

Jedna od najvećih prednosti korišćenja otvorenog softvera je upoznavanje studenata sa kulturom otvorenog softvera [2]. Svakodnevnom upotrebom otvorenog softvera studenti se upoznaju sa osnovnim konceptima kao što su licence, razlike među licencama i prava i obaveze koje dolaze sa njima, korišćenje softvera za upravljanje verzijama koda (npr. Git), način komunikacije u velikim timovima za razvoj softvera, korišćenje mejling listi, issue tracker softvera i slično. Ukratko, studenti se, već u toku studija, upoznaju sa načinom na koji se softver razvija u velikim timovima, i na taj način stiču veoma vredno iskustvo koje bi inače teško stekli prilikom nastave. Slobodan softver svojim otvore-

nim pristupom razvoju i transparentnošću pri razvoju omogućava pojedincima (studentima) da steknu nezanemarljivo iskustvo u razvoju softvera na visokom nivou već u toku studija. [1] [5]

Pored upotrebe otvorenih razvojnih alata, nezamenljivo iskustvo je i upotreba otvorenih projekata drugih studenata, pojedinaca ili organizacija. Kroz razne kurseve/predmete na fakultetu, studenti se upoznaju sa načinima na koje mogu pronaći otvorene projekte, koristiti ih i isto tako doprineti tim projektima ili započeti svoje otvorene projekte. Studentima su baš ti otvoreni projekti (koliko god mali) izuzetno važni za karijeru, kao prvo iskustvo u samostalnom razvoju softvera i kao portfolio na osnovu kojeg mogu dobiti bolju priliku za zaposlenje.

2 Otvoreni softver u nastavi

U ovom delu diskutovaćemo upotrebu otvorenog softvera (razvojnih alata) u nastavi sa strane predavača. Neke od prednosti su već spomenute, a pored lakšeg upravljanja licencama i slobodne upotrebe bitno je napomenuti da je otvorenim softverom lakše i upravljati. Priroda otvorenog softvera je da ima jasno definisane otvorene interfejse kojima je moguće pristupiti na neki način. Ovo može biti slučaj i sa zatvorenim (proprietary) softverom, ali iz našeg iskustva češće je lakše upravljati otvorenim softverom.

U nastavi na Departmanu za matematiku i informatiku Prirodno-matematičkog fakulteta koristi se veliki broj otvorenih razvojnih okruženja kao što su:

- Eclipse okruženje za Java/Java EE i Web razvoj [1]
- Eclipse okruženje za C/C++ razvoj i paralelno programiranje
- Papyrus okruženje za UML modelovanje (bazirano na Eclipse projektu) [2]
- Spyder3 okruženje za Python razvoj [3]
- Jupyter okruženje za Python razvoj [4]
- Visual Studio Code za Web razvoj [5]
- Android Studio za Android razvoj [6]
- pgModeler za upravljanje i modelovanje PostgreSQL bazama podataka [7]
- WireShark za nadzor računarskih mreža [8]

Lista ovde pomenutih alata i razvojnih okruženja je naravno delimična, naveden je samo podskup korišćenih alata. Konkretno, razvojni alati predstavljeni u listi koriste se na Katedri za informacione tehnologije i sisteme, gde autor ovog teksta predaje kao asistent. Predmeti koji su u nadležnosti pomenute katedre su: Baze podataka 1 i 2, Računarske mreže, Razvoj poslovnih sistema, Proces razvoja informacionih sistema, Veštačka inteligencija 1, Razvoj mobilnih aplikacija, Prostorne baze podataka i drugi.

[1] https://www.eclipse.org
[2] https://www.eclipse.org/papyrus/
[3] https://www.spyder-ide.org/
[4] https://jupyter.org/
[5] https://code.visualstudio.com/
[6] https://developer.android.com/studio
[7] https://pgmodeler.io/
[8] https://www.wireshark.org/

Većina ovih razvojnih alata ima zatvorene alternative, poneke su čak nekada ranije bile korišćene na Departmanu ali nakon višegodišnje upotrebe otvorenih razvojnih alata možemo potvrditi da je ovde navedeni softver više nego adekvatan za upotrebu u nastavi (a i profesionalno). Pored ovih alata, gotovo svi kursevi koriste iz našeg iskustva nezamenljivu Moodle platformu za deljenje materijala i organizaciju kurseva.

Još jedna prednost korišćenja otvorenih razvojnih alata je što su često kompatibilni sa Linux operativnim sistemom. Korišćenje Linux otvorenog operativnog sistema u učionicama je od izuzetnog značaja i ima puno prednosti koje smo već pomenuli kao što su licenciranje, bolja podrška za stariji i slabiji hardver, i lakše upravljanje (između ostalog).

Naša računarska učionica koristi Fedora Linux [9] operativni sistem koji je odabran iz više razloga. Potpuna otvorenost samog operativnog sistema i dostupnost najnovijih stabilnih verzija razvojnog softvera u repozitorijumima ovog operativnog sistema je glavni razlog zbog kojeg koristimo baš ovu distribuciju Linux operativnog sistema. Neki od primera biblioteka/softvera koje se najčešće koriste i za koje želimo da koristimo najnovije stabilne verzije su OpenJDK i Python. Takođe, dobra podrška za hardver, aktivnost zajednice i aktivna upotreba baš ove distribucije u edukaciji [10] su još neki razlozi zbog kojih smatramo da je Fedora dobar izbor. Fedora Linux je u našem računarskom centru (sa 25 radnih stanica) u upotrebi od 2016. godine i do danas nismo imali velikih poteškoća sa upotrebom. Koristimo osnovnu Workstation verziju sa GNOME Desktop okruženjem a verzija operativnog sistema se ažurira jednom godišnje (pred početak semestra). Za upotrebu "kancelarijskog" softvera su takođe zaslužni otvoreni projekti kao što su Chromium, Firefox, Geany i naravno LibreOffice.

Još jedna sporedna posledica upotrebe Linux-a u nastavi je što se studenti sve češće odlučuju na upotrebu Linux operatvnog sistema (Fedora ili drugi) i na kućnim računarima što je važan korak unapred ka većoj upotrebi otvorenog i slobodnog softvera.

Na kraju, i dalje postoje načini za unapređenje našeg postojećeg sistema. U izvođenju nastave i dalje postoji mali broj komercijalnih alata koji se koriste u nedostaku dobre alternative. Na primer za modeliranje baza podataka uz pomoć ER dijagrama koristi se Oracle SQL Developer kao besplatan i Linux-kompatibilan ali softver zatvorenog koda. Takođe, ponekad postoji potreba i za korišćenjem veoma specifičnog softvera, na primer za konfiguraciju mrežne opreme kao što je MikroTik Winbox, kompatibilan samo sa Microsoft Windows operativnim sistemom, koji se u nastavi koristi uz pomoć softvera Wine. U ovakvim situacijama, gde je korišćenje komercijalnog softvera neizbežno, jedno od najboljih rešenja je razvoj novih alata otvorenog koda koji imaju traženu namenu.

3 Upravljanje otvorenim računarskim centrima

Upravljanje računarskim centrima/učionicama može biti naporan posao ukoliko ne postoji neka vrsta automatizacije. Neki od problema su: inicijalna instalacija softvera na sve radne stanice, konfiguracija svih računara, problemi ažuriranja verzija softvera, distribucija fajlova, nadzor studenata i slično.

Postoje razna oruđa koja se mogu koristiti za rešavanje ovih problema. Na primer, Ansible [11] ili Kickstart [12] se mogu koristiti za inicijalno podešavanje i instalaciju računara. Ansible se čak može koristiti i za kasnije upravljanje računarima. Naravno, ne možemo da ne spomenemo i iTALC [4] [13] otvoreni softver specifično napravljen za upravljanje učionicama.

[9] https://getfedora.org/

[10] https://labs.fedoraproject.org/en/python-classroom/

[11] https://www.ansible.com/

[12] https://docs.fedoraproject.org/en-US/fedora/rawhide/install-guide/advanced/Kickstart_Installations/

[13] https://sourceforge.net/projects/italc/

Naše rešenje za upravljanje učionicama je jednostavnije ali i dalje efektivno. Koristimo internu Python biblioteku koja je wrapper oko SSH protokola. Python biblioteka rc3-scripts [14] je otvorena i može se koristiti u bilo kojoj učionici sa Linux radnim stanicima. Jedini zahtev je mogućnost korišćenja SSH protokola.

Biblioteka rc3-scripts ima sledeće mogućnosti:

- Provera koji računari su uključeni
- Gašenje svih računara u učionici
- Korišćenje x11vnc [15] za monitoring svih računara u učionici
- Mogućnost izvršenja bilo koje bash komande na svim računarima (najčešće korišćena mogućnost)

Korišćenjem ove biblioteke rešen je velik broj problema upravljanja računarskim centrom. Moguće je automatski ažurirati sav softver, instalirati novi softver, ažurirati operativni sistem, pratiti ekrane svih studenata tokom testova i slično. Takođe, pošto je moguće izvršiti bilo koju komandu na svim računarima istovremeno (paralelno), postoje i naprednije mogućnosti:

- Korišćenje lokalnih torenata (uz pomoć aria2 [16] biblioteke) za efikasnu distribuciju velikih fajlova. Na primer: distribucija virtuelnih mašina za konferencije/radionice koje se održavaju u računarskoj učionici
- Distribucija fajlova sa katedre – glavnog računara na sve studentske računare (uglavnom sa HTTP Web serverom)
- Preuzimanje fajlova sa studentskih računara (SCP protokol ili rsync)

Za inicijalnu konfiguraciju i instalaciju softvera koristimo odličnu Linux distribuciju CloneZilla [17] koja nam omogućava da jedan podešeni računar iskoristimo kao obrazac za podešavanje drugih računara (kloniranjem hard diskova).

4 Zaključak i budući rad

Korišćenje otvorenog softvera i otvorenih razvojnih alata je od izuzetnog značaja u nastavi informatike. Studenti se upoznaju sa kulturom deljenja koda i razvoja softvera u velikim timovima što je nezamenljivo iskustvo u ranim fazama njihovih karijerama. U ovom radu prikazali smo neke prednosti ovakvog pristupa, kako i koji se otvoreni softver koristi u nastavi na Departmanu za matematiku i informatiku Prirodno-matematičkog fakulteta i kako mi upravljamo našim otvorenim računarskim centrom. Ovo iskustvo i znanje može biti primenjeno i na drugim institucijama i nadamo se da će naš primer podstaći i druge da koriste sve više otvorenog softvera u nastavi.

Što se tiče budućeg rada, uvek tražimo načine da unapredimo sistem koji smo opisali u ovom radu, kao što je na primer izrada specifične distribucije Fedora Linux operativnog sistema sa instaliranim svim potrebnim softverom za naše studente. Druga, možda važnija mogućnost je dodatna edukacija studenata o konceptima otvorenog i slobodnog softvera kroz radionice kao što su Linux Install dani, Fedora Release događaji i slično.

[14] https://github.com/nmilosev/rc3-scripts
[15] https://github.com/LibVNC/x11vnc
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Free IC Design in Education

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Abstract

One of the most important meetings that never happened was when King Theoden led his Riders of the Mark into a magnificent charge, releasing Minas Tirith from the siege, joining forces with King Aragorn of Gondor and winning the Battle of Pelennor Fields. About as impossible as that, not so many years ago, was the meeting of free software and open hardware at the nanoelectronics scale, down at the IC design level. Believe it or not, thanks to the many hours of many hard working engineers across the globe we are now able to design chips using nothing but the free resources: tools, PDK and IP alike. In this paper, we present our small contribution, mirrored in organizing analog and digital IC design courses at the Faculty of Electrical Engineering in Banja Luka, using the free and open source material.

Key words: CMOS, IC, chip design, analog, digital, EDA tools, free software, open hardware

1 Introduction

CMOS integrated circuit (IC) fabrication is the most sophisticated technology process commercially available on Earth. Therefore, its significance in the education of the next and, for that matter, every generation of electronics engineers is of paramount importance. Hence, it is the duty of educators in this domain around the world to bring IC courses to the universities in a manner that students actually get silicon proven experience. However, due to required funding and the complexity of legal paperwork that is not an easy task.

In the last year or so, a revolution in this domain is taking place, enabling us to do exactly that - have our students fabricate IC on silicon by removing both obstacles: funding and legal issues. This is done through the evolution of free electronic design automation (EDA) tools and open-sourcing a project design kit (PDK) In this paper we share some experiences of our own on organizing both analog and digital CMOS IC design courses at the University of Banja Luka. A retrospective overview of how we developed these programmes may be found in [1]–[5], by phases.

In section 2, we provide insight on why do we actually need the EDA tools and the PDKs by taking a look at what did take to create chips without these. Then, in section 3, we explain the shortcomings of the mainstream, industry standards tools and PDKs. In section 4, we describe the possibility of free and open ICs at all abstraction levels, as in free of charge and open to sharing with anyone every detail of the design and technology procedures. In sections 5 and 6, we present how analog and digital IC design courses are organized at the University of Banja Luka, respectively, utilizing the revolution at hand. Finally, a conclusion follows.

2 IC design, no tools, no PDK

Back when it all started, half a century ago and a bit more, with engineering legends breaking the ice in bipolar and MOSFET IC design, in the 60s and the 70s - there were no problems with IC design tools,

neither PDKs, nor intellectual property (IP) access; there were no problems simply because neither of those three components actually existed. Today, however, either of these three represents a sine qua non - and each one brings great benefits. To understand how they make IC designer life easier, let's take a moment to consider a testimonial from Y. Tsividis [6]:

> [..] to make analog circuits work in an unproven technology for such applications, we had to invent new schemes to circumvent the technology's limitations. [...] but there were no such techniques for analog MOS integrated circuits at that time. [...] there were no silicon foundries. The concept did not even exist as an idea at the time. So to verify our designs, we had to make the chips ourselves in the lab [...] Circuits were laid out manually, using a back-breaking process involving a light table, on top of which we would lay flat a "rubylith" sheet [...] With proper lighting, we would then photograph the result with a large reduction factor, and then photograph the result again with another reduction factor, to produce the final glass plate that was used as a mask in fabrication.

All that, while keeping in mind that the Integrated Circuits Lab (the "lab" mentioned in the quoted paragraph above), was actually privileged with access to SPICE, being developed at the time right next door, also at UC Berkeley. That said, let's assume there was a sort of a simulator (taking input with punchcards!), but drawing layout manually would still mean the IC designer would have to stand around a table a few meters across with (a sort of) pen and knife to draw both devices and interconnects, i.e. place and route". Then, that very same engineer, the IC designer, would have to take a chance at dealing with poisonous chemicals and matter at dangerously high temperatures, to get the design into a chip, i.e. to "harden" the RTL/schematic. The probability of all that working out is quite low, so many a try would have to be done for the very same project to actually see it operational at the end. And not only the amplifier.

Thanks to the development of the electronic design automation (EDA) tools (and, obviously, all other prerequisites) and appearance of the silicon foundry (fab, for short), instead of asking themselves: "Which knife is the sharpest?", or "Which fume will intoxicate me?", IC designers ask themselves things like: "Which chair is more comfortable?", or "Should I add a third monitor?"

3 IC design, no free tools, no free PDK

Very soon after the IC market exploded, the importance of simulators and, consequently, other tools was realized. Beside the semiconductor industry and all the consumer, industrial and military electronics markets dependent on it, that realization also created the industry of EDA tools specified for IC design.

Over the next several decades, the struggle to create a more efficient and a more effective tool, capable of following the Moore's law, i.e. processing the ever decreasing features, today well into one-digit nanometer numbers, took place. As a result, industry standard EDA tools in this domain are few and all are provided by large companies, well established vendors: Cadence, Synopsis and Mentor. All of them do provide discounts for both Higher Education institutions and startups, under certain limitations. Nevertheless, if one is to use these in a commercial environment, a significant budget per seat on a yearly basis must be assigned to a commercial license, making it beyond the reach of many.

The free tools have been around since the 80s, sure. However, due to mainly two reasons, these tools very soon became unusable in practice. First, it was not an easy job supporting newer and newer technology nodes, i.e. following the scaling dictated by Moore's law. Second reason requires a bit of context. To get the idea, we need to point out that, by this time (80s and 90s), silicon foundries were a common place, as well as circuit simulators and layout software tools, etc. Therefore, the process

described by prof. Tsividis has been made both more efficient and more effective. Primarily, efficiency came from the increased precision of device models used for simulation and effectiveness came from the professionals working in foundries, where ICs were made in larger batches. The Project Design Kit (PDK) is the glue that makes the simulation results resemble the silicon fabricated IC characterization in the lab. PDK of a process node holds device models fine tuned to the exact technology process node that is under way within the foundry. Hence, the IC designer may trust the results obtained through simulation, as it is highly probable that the circuit in silicon will yield the same behavior. Of course, for the EDA tool to be useful, it must be compatible with a PDK. Obviously, the information collected within a PDK is valuable. Very valuable. Hence, it is always subject to at least NDAs and sometimes quite limiting terms and conditions of use. In other words, even if there was the best EDA tool ever, unless a foundry decides they have interest in supporting the tool by providing a PDK compatible with that tool - the tool is useless. Now, the second reason why the free EDA tools haven't been in widespread use comes from the fact that most foundries that carried semiconductor's progress through node scaling haven't seen a reason to support free tools. It is worth mentioning the scalable CMOS (SCMOS), created by MOSIS, but this is limited to universities in the US and very, very mature nodes. Europractice allows multiproject wafers on this side of the ocean, they offer discounted prices and an abundance of PDKs - yet, neither with support for the free EDA tools.

Finally, let's assume that the free tools are usable enough to the point that we actually do a design in a very old technology node - these nodes do have educational value, after all. We can do that through the MOSIS service, or something similar. That design, it's layout and other technology-specific details are still subject to the NDA issued by the fab, further meaning the design may not be treated as open hardware. This limits it's educational potential heavily and, to conclude, renders the free tools - without a free PDK - not free tools (even though they do come with a license that is free of charge), since we are unable to make free hardware.

4 IC design, free tools, free PDK

The work on the free tools, taking them to the point to actually deliver a silicon proven design, has intensified about a decade ago, when the company efabless [7] had taken up the struggle. Leveraging plenty of tools from Open Circuit Design [8], supported by Tim Edwards for years and some other famous open-source tools, primarily ngspice [9], they created an online platform that designers may access remotely. The PDK issue was resolved by including technology nodes from XFAB in a manner that obscures the proprietary data. In this way, they enabled anyone to log in and use the tools and technology without signing the NDA personally and without fiddling with the tools configuration and installation. Still, the designs created in this way were no free open hardware. Nevertheless, they've proven that it is possible to create silicon ready designs using nothing but the free and open source tools [10]. More people joined forces producing further evidence that this is an important effort, the most prominent project being ASICOne [11]. We were fortunate enough to take part as well, and, among the first in the world, produce silicon ready designs using that methodology within an undergraduate course[3].

As emphasized in the previous section, all this effort invested in the tool development was still relaying on proprietary PDKs. Hence the revolution of open hardware at ASIC level started only after the missing link has been introduced in June 2020, by Tim Ansell, representing the Google efforts [12] in providing the first ever open source PDK of a CMOS technology node. Even though the 130 nm process appeared on the market back in 2001, it is still used in the area of research, small microcontroller development, and mixed signal embedded designs, i.e. IoT devices. Skywater Technology [13] was founded recently, through acquisition of Cypress' subsidiary, a foundry with extensive experience in IC fabrication. Therefore, the Skywater 130 nm (SKY130 [14]) process node, while open-sourced in 2020, is derived from a mature CMOS technology. On the other hand, while that original CMOS

technology has been used in design of many successfully manufactured IC in commercial purposes, the SKY130 PDK is not yet production ready. It is currently intended only for making test chips and prototype verification. Still, it is important to note that neither of those is guaranteed, at this point - i.e. this PDK is still a work in progress.

SKY130 is a 5 metal levels 180 nm-130 nm hybrid process node with internal input/output pins operable at both 1.8 V and 5 V. It includes MiM capacitors, inductors, one level of local interconnect and SONOS functionality. Therefore, SKY130 is quite a flexible technology, providing the IC engineer with a wide range of design choices. The foundry even leaves open the possibility of enabling further customization, through addition of specialized materials, such as Nb, Ge, V2O5, Carbon Nanotubes.

This marks the last brick needed for truly open hardware down at the nanometer scale.

5 Analog IC Design Course

Since the device physics is more tightly related to analog design, it makes sense to the analog design course first. The availability of the free PDK helps here, as well, even though circuit theory is the main topic of the course. The open access to all levels of the node allows presenting and sharing all the details of the fabrication, such as process stack diagram in Fig. 1 [14], as demonstrated in this paper.

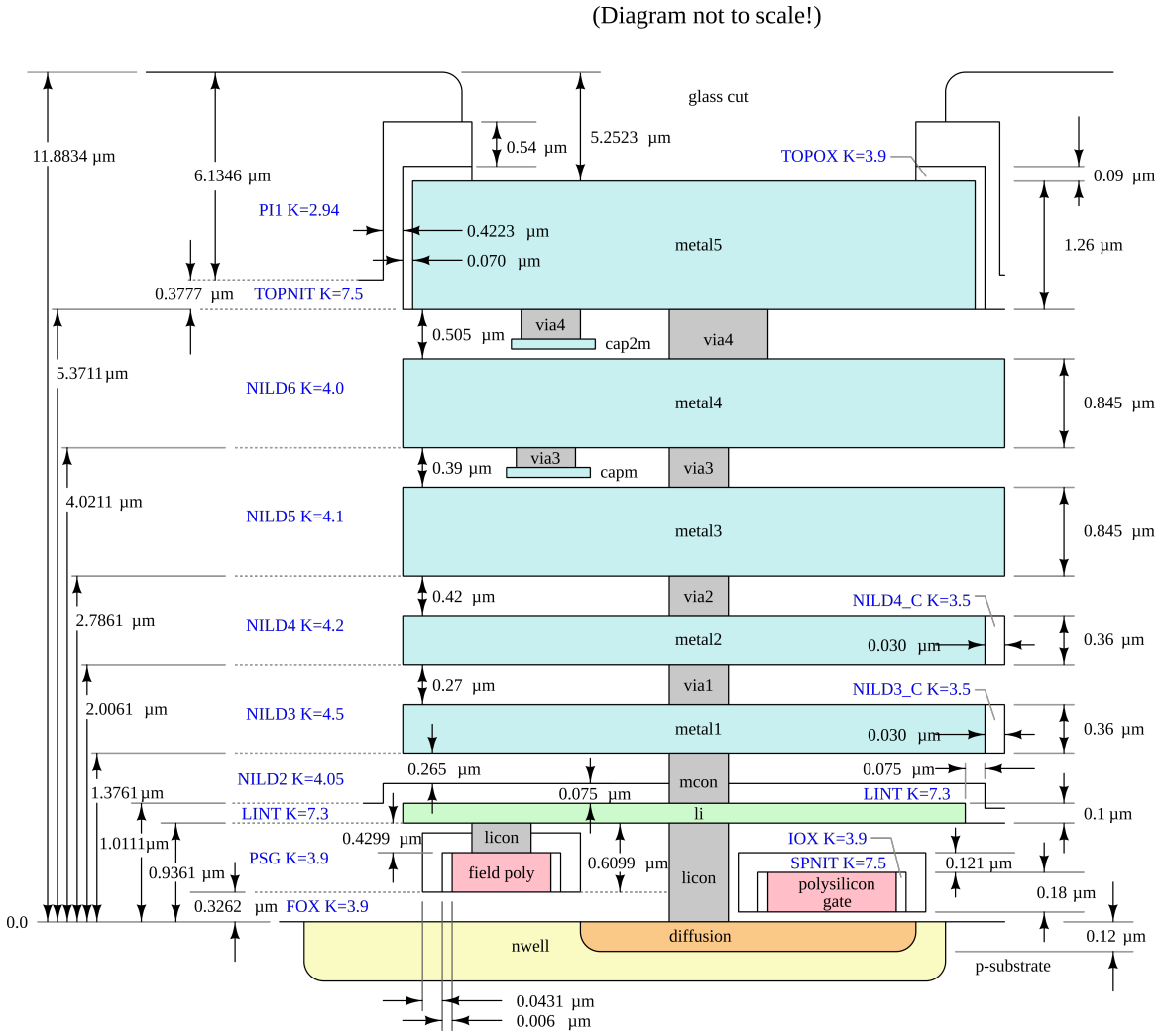

Figure 1: Process stack diagram [14]

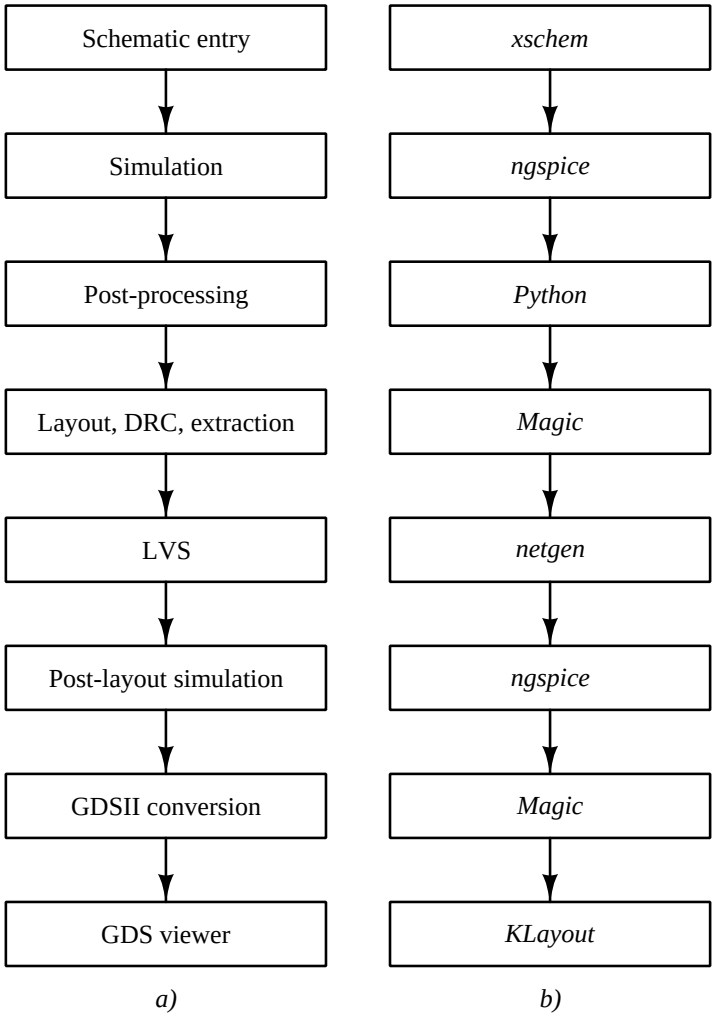

Figure 2: Analog IC design open source toolchain: a) general approach, and b) tools we applied

The toolset is different for analog and digital flows, so in this section the subset of tools we chose to use for analog circuit design is shown, Fig. 2. In the current iteration, the schematic entry is enabled by xschem [15]. For simulations, pre- and post-layout, nsgpice [9] is used. As a waveform viewer gaw [16] is fast and capable, but it is strongly suggested to have python installation handy, due to the requirements of certain simulation results processing and the agility found in countless libraries written in python. Layout is drawn in Magic [17], which provides a DRC in real time and parasitic extraction, while also converting the drawn layers into GDSII format for fabrication. LVS checks are done by netgen [18]. Finally, to make sure that GDS holds appropriate information, KLayout [19] may be used as a viewer.

Over the course of the semester, we first cover the frontend tools - beginning with the operating system; namely, at the Department of Electronics, this is the first course where students face Linux OS. Then we proceed to present basics of simulation, by working directly with the simulator, i.e. no GUI. The next stage is to discuss different device models, and learn how to manually process simple simulation results and show them graphically using python libraries. Only after the students get a grasp on the back end tools, we move to layout and LVS and talk further about DRC. Final stage of the course includes a project where a standard operational amplifier is provided as a template of very basic performance, the whole design is available in [5]. The students are tasked of improving that particular template to a given metric, e.g. to make it either more energy efficient, faster, higher magnitude, wider bandwidth, etc. There are other advantages of this course, but these are beyond the scope of this paper.

6 Digital IC Design Course

For the digital design course, we've decided to turn things the other way: we do the tools at the end, while working first on the system development first. Systems of processor core complexity may not be widely accepted as a subset of a VLSI dedicated course. Nevertheless, thanks to the vast offering of so many different classes of free IP of this level, we realized that it is actually possible to embed small steps into the computer architecture world within the digital design course. This has been demonstrated in practice, as we have been working with processor cores within this course for two years already and students' reactions are nothing but positive.

We provide thorough details on each of the cores taught in our recent publication [4], while here we only mention them: Hack [20], Sodor [21] and [22]; and point out that we have included a Chisel [23] hardware construction language in our curriculum, as well as that the latter two cores are RISC-V [24] compatible. In these efforts, resources available at the UC Berkeley courses webpages have helped greatly [25].

Once the design is settled from the computer architecture point of view, i.e. either we've reached the requirements or the time is simply up, we turn to the free tools for digital design flow That is a set of software tools used to transform the Verilog (emitted by Chisel in this case) netlist into a physical digital circuit, i.e. a set of IC layout masks in SKY130. The tools we used are the same collection used in [10]. Qflow [26] is a complete, open-source toolchain for synthesizing digital circuits starting from Verilog source and ending in physical layout for a specific target fabrication process. While the process is more detailed, we present a simplification describing only the major steps - shown in Fig. 3.

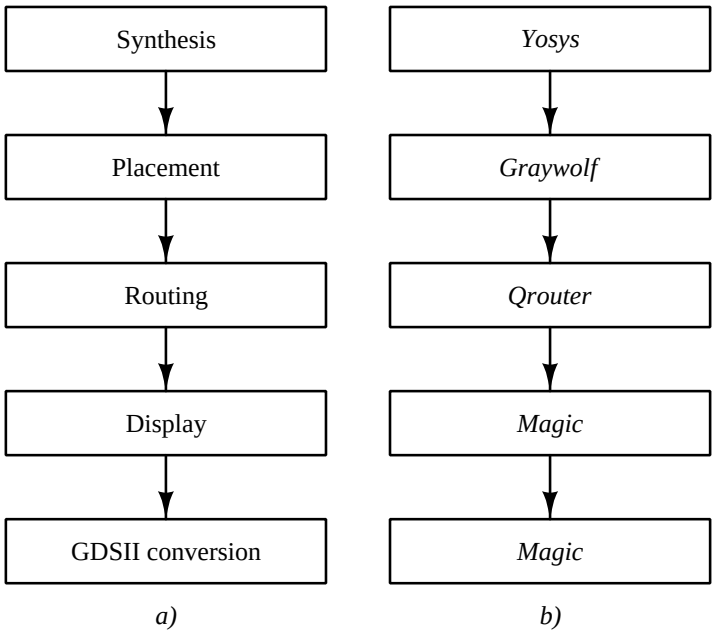

Figure 3: Digital IC design open source toolchain: a) general approach, and b) tools we applied

The first step in the automation process is to map the netlist onto a standard cells library. This step is done by yosys [27]. Next, the design is to be placed and routed. In shortest terms, this when the standard cells are spread across the available area, while grouped in blocks and interconnected (routed). Graywolf [28] is the member of the qflow toolchain that does the placement, while routing is performed by qrouter [29]. Finally, for layout inspection, DRC and GDS generation Magic [17] is used. Qflow, nor the provided PDK are not capable of creating a microprocessor that may compete with current 3 GHz+ multicore server processors, but these tools will successfully handle simpler designs that may be found in SoC all over the market - such as SPI, for example.

7 Conclusion

This is the point where all three requirement for free silicon meet: knowledge, tools and PDK, meaning that the age of open ASIC has begun. Further, both barriers have been removed, thus we may stand on the shoulders of giants to bring actual free silicon to our students. While having fabricated two analog designs using the free tools and a proprietary PDK, we hope to leverage our experiences and enable our students to fabricated completely free and open ASIC in future. In the next iteration of the courses, we hope to replace qflow with openLane and include openRAM into the curriculum.

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Izazovi u realizaciji nastave na predmetu osnovnih studija Programiranje mobilnih uređaja

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REZIME

Predmet Programiranje mobilnih uređaja je izborni predmet u pretposlednjem semestru osnovnih studija odseka Softversko inženjerstvo na Elektrotehničkom fakultetu. Zbog izraženog praktičnog karaktera predmeta realizacija nastave nameće veliki broj izazova. Format nastave mora biti odgovarajući za predmet praktične prirode. Tokom čitavog semestra izučava se *Android* platforma, ali jedan semestar ne pruža dovoljno vremena da se *Android* platforma obradi u potpunosti pa stoga treba napraviti adekvatan izbor oblasti. Učestale promene vezane za programiranje mobilnih uređaja takođe otežavaju organizaciju nastave. Predstavljanje *Kotlin* programskog jezika za preporučeni programski jezik za razvoj aplikacija za *Android* platformu dodatno opterećuje gusto zbijen program predmeta. Pokretanje aplikacija na *Android* emulatoru na računarima u fakultetskoj laboratoriji može biti suviše sporo u nekim slučajevima, dok bi obezbeđivanje fizičkog mobilnog uređaja za svakog studenta predstavljalo enorman trošak. Ocenjivanje studenata mora biti pažljivo koncipirano kako se ne bi narušila praktična priroda predmeta.

Ključne reči: nastava, programiranje, mobilni uređaji, android, kotlin.

1 Uvod

Svedoci smo sveopšte prisutnosti mobilnih uređaja [1]. Pametni telefoni, satovi, televizori, automobilski multimedijalni uređaji i ostali mobilni uređaji pronalaze primenu kako u privatnim tako i u poslovnim sferama života. Krajnji potrošači koriste raznolike aplikacije za mobilne uređaje kada god se dotaknu zabave, hobija, kupovine, prevoza, sporta, zdravlja, radnih obaveza itd. Masovna upotreba mobilnih uređaja stvorila je potražnju za programerima mobilnih uređaja čiji je zadatak da naprave date aplikacije. Ovakva izražena potreba tržišta jeste jedan od razloga za formiranje predmeta koji se tiče programiranja mobilnih uređaja.

Izborni predmet Programiranje mobilnih uređaja odvija se u sedmom semestru osnovnih studija odseka Softversko inženjerstvo na Elektrotehničkom fakultetu. Izbor poslednje godine osnovnih studija, tačnije sedmog semestra, za pozicioniranje predmeta je posledica povezanosti sa drugim predmetima koji predstavljaju preduslov za uspešno savladavanje gradiva [2]. Cilj predmeta, nalik sličnim predmetima na drugim univerzitetima [3], jeste sticanje praktičnog znanja iz oblasti programiranja mobilnih uređaja. Usled vremenskog ograničenja od svega jednog semestra na predmetu se izučava samo jedna mobilna platforma da bi istu bilo moguće što detaljnije obraditi.

Izabrana platforma jeste *Android* platforma zbog svoje velike zastupljenosti odnosno dominantnog udela na tržištu mobilnih uređaja [4, 5].

U nastavku rada biće navedeni najveći izazovi u realizaciji nastave na predmetu Programiranje mobilnih uređaja. Drugo poglavlje prikazuje poteškoće izazvane izabranim formatom nastave. Treće poglavlje predstavlja osvrt na odabir izučavanih oblasti programiranja mobilnih uređaja u cilju prilagođavanja predmeta za trajanje od jednog semestra. Izlaganje na temu uvođenja *Kotlin* programskog jezika u proces nastave dato je u okviru četvrtog poglavlja. Prepreke prilikom pokretanja razvijanih aplikacija u okruženju bez fizičkih uređaja u uslovima fakultetske laboratorije predstavljene su petim poglavljem. Šesto poglavlje definiše izazove i prikazuje osnovne informacije vezane za ocenjivanje studenata.

2 Format nastave

Programiranje mobilnih uređaja je mlada oblast trenutno u procesu intezivnog napretka. Posledica toga jeste izostanak kvalitetnog udžbenika smatranog za standardni i ustaljeni udžbenik za nastavu u oblasti programiranja mobilnih uređaja [6]. Izraženo učestale promene, kako proširenja novim elementima tako i unapređenje ili zastarevanje postojećih, smanjuju relevantnost tradicionalnog udžbenika i otežavaju održavanje *Power Point* prezentacija za nastavu.

Praktični deo nastave održava se zato na računarima u fakultetskoj laboratoriji u vidu izrade aplikacija za mobilne uređaje. Izvorni kod aplikacije sa elementima adekvatnim za izlaganje željene tematike piše se na licu mesta zajedno sa studentima na svakom času. Ovakav model nastave iziskuje od predavača više vremena za pripremu kao i dodatan napor tokom samog trajanja časa. Vreme utrošeno svake školske godine za pripremu časova obezbeđuje usklađenost predavanih materijala sa novinama u oblasti i preporučenim praksama. Period aktivnog učestvovanja studenata u nastavi prolongiran je dodatnim naporom predavača da tokom izlaganja gradiva u svakom trenutku priđe i pomogne studentima koji naiđu na prepreku.

Tumačenje unapred pripremljenih isečaka izvornog koda na *Power Point* prezentacijama nije format nastave prilagođen za predmet praktične prirode. Diskusija o izvornom kodu aplikacije izrađene pre početka nastave takođe nije dobar pristup jer najčešće dovodi do situacije u kojoj su studenti savladani velikom količinom informacija sa kojom se odjednom susreću. Format praktičnog dela nastave opisan u prethodnom pasusu, koji podrazumeva postepeno pisanje izvornog koda na licu mesta zajedno sa studentima, je odabran upravo iz ovih razloga. Kako bi studenti kasnije tokom samostalnog učenja mogli bolje da prate tok misli predavača i da se posevete nekom od koraka u razvoju aplikacije u većoj meri za potrebe nastave koristi se softver za verzionisanje izvornog koda. Izmene načinjene tokom nastave, zaokružene u dokumentovane logičke celine, čuvaju se na fakultetskom *GitLab* serveru. Na početku školske godine za svakog studenta na predmetu pravi se korisnički nalog za fakultetski *GitLab* server kako bi kasnije mogao da pristupa materijalima.

3 Izučavane oblasti

Usled ograničenosti trajanja nastave na samo jedan semestar nije moguće pokriti sve grane unutar oblasti programiranja mobilnih uređaja [7]. Najveći deo nastave posvećen je odabranim temama iz zvaničnog vodiča za programere *Android* platforme [8]. Izostavljanje nekih delova pomenutog vodiča moralo je biti načinjeno zbog toga što je njegov kompletan sadržaj preobiman za jednosemestralni predmet. Tako zbog nedostatka vremena u najvećoj meri nisu pokrivene oblasti animacije i grafike. Sigurnosni aspekti razvoja aplikacija za mobilne uređaje na niskom nivou

takođe se ne obrađuju zbog nedostatka vremena [9]. Teme koje se obrađuju opisane su u nastavku, a mogu se podeliti u tri celine tako da svaka celina odgovara tačno jednoj trećini semestra.

Nastava počinje obukom za korišćenje *Android Studio* razvojnog okruženja. Istovremeno objašnjava se uloga *Gradle* alata u procesu prevođenja i metod uključivanja eksternih biblioteka. *Material Design* smernice za korisnički interfejs pregledaju se paralelno sa upoznavanjem dostupnih komponenata grafičkog korisničkog interfejsa. Izrada prve *Android* aplikacije počinje lekcijom o aktivnosti kao komponenti *Android* aplikacije, životnim ciklusima i njihovoj važnosti. Demonstrira se upotreba resursa, fragmenata i navigacione komponente iz *Jetpack* skupa biblioteka.

Druga trećina semestra počinje predstavljanjem servisa kao komponente *Android* aplikacija. Zatim sledi lekcija o tehnikama višenitnog programiranja u okviru *Android* platforme. Izučava se rad sa datotekama i lokalnim bazama podataka. Injekcija zavisnosti putem *Hilt* biblioteke je poslednje obrađivana tema u drugoj celini.

Poslednja celina obrađuje prijemnike obaveštenja i pružaoce sadržaja kao komponente *Android* aplikacije. Rad sa senzorima pokreta, pozicionim senzorima i senzorima okruženja jeste deo jednog časa. Podučava se elementarno grafičko iscrtavanje korišćenjem `android.graphics.Canvas` klase. Rad sa kamerom i dohvatanje mrežnih resursa u skladu sa *REST* arhitekturom korišćenjem *Retrofit* biblioteke jesu poslednje obrađivane teme na predmetu.

4 Programski jezik *Kotlin*

Jedna od potencijalnih poteškoća prilikom učenja programiranja mobilnih uređaja jeste nužnost predznanja iz oblasti programiranja [10]. *Android* platforma se tradicionalno oslanja na *Java* programski jezik usled čega zahteva predznanje iz oblasti objektno orijentisanog programiranja. Studenti Elektrotehničkog fakulteta izučavaju paradigmu objektno orijentisanog programiranja u okviru dva jednosemestralna predmeta što predstavlja olakšavajuću okolnost. Jedan od ta dva predmeta zasniva se upravo na *Java* programskom jeziku. Poznavanje *Java* programskog jezika u velikoj meri olakšava realizaciju nastave iz predmeta Programiranje mobilnih uređaja. Zahvaljujući predznanju studenata nastava može odmah započeti izlaganjem specifičnosti programiranja mobilnih uređaja i koncepata *Android* platforme umesto osnovama *Java* programskog jezika.

Kompanija *Google*, koja stoji iza razvoja *Android* platforme, objavila je 2017. godine da *Kotlin* postaje programski jezik prvog reda za razvoj *Android* aplikacija. Počev od tada proširenja *Android* platforme novim elementima razvijaju se imajući na umu *Kotlin* programski jezik na prvom mestu dok se za *Java* programski jezik nadalje uglavnom samo pruža podrška. *Kotlin* je danas zvanično preporučeni programski jezik za izradu aplikacija za *Android* platformu.

Prelazak na *Kotlin* programski jezik u domenu nastave na predmetu Programiranje mobilnih uređaja predstavlja ozbiljan izazov. Upoznavanje studenata sa novim programskim jezikom zahteva izvesno vreme, a oskudica vremena je već dovoljno velika nevolja uzimajući u obzir širinu oblasti izučavane na predmetu Programiranje mobilnih uređaja. Razmatrana su dva pravca delovanja radi prelaska na *Kotlin* programski jezik. Prvi proaktivniji pravac delovanja jeste usputni inkrementalni pristup upoznavanju studenata sa *Kotlin* programskim jezikom tokom trajanja čitavog semestra. Usputni inkrementalni pristup ogleda se kroz postepeno izlaganje *Kotlin* programskog jezika u vidu nezavisnih inkremenata odnosno samostalnih elemenata u trenucima kada su dati elementi apsolutno neophodni za savladavanje gradiva na predmetu Programiranje mobilnih uređaja. Ovakav pristup može biti izvodljiv po pitanju vremenskih ograničenja, ali je upitno u kojoj meri će studenti savladati *Kotlin* programski jezik i koliko bi to moglo otežati razumevanje specifičnosti programiranja mobilnih uređaja i koncepata *Android* platforme. Drugi pravac delovanja bazira se na

uvođenju novog i nezavisnog predmeta na kojem se izučava *Kotlin* programski jezik. Uvođenjem kompletno novog predmeta studenti bi garantovano savladali *Kotlin* programski jezik, ali ovakav pristup otvara problem opravdanosti uvođenja takvog obaveznog predmeta. Kako se u nekoj od predstojećih školskih godina planira prelazak na *Kotlin* programski jezik neophodno je detaljnije izvršiti uporednu analizu prednosti i mana ova dva pravca delovanja.

5 Pokretanje aplikacija

Emulator dostupan u okviru softverskog paketa alata za razvoj *Android* aplikacija omogućava emulaciju različitih kategorija mobilnih uređaja u koje spadaju pametni telefoni, satovi, televizori i automobilski multimedijalni uređaji [11]. Nastava na predmetu bazira se primarno na radu sa pametnim telefonima kao jednim od predstavnika mobilnih uređaja. Usmerenost ka pametnim telefonima zasniva se na neoptimizovanosti ranih verzija emulatora [12]. Računari u fakultetskoj laboratoriji, gde se održava nastava, inicijalno nisu ispunjavali visoke hardverske zahteve ranih verzija emulatora čime su studenti bili prinuđeni da rade sa fizičkim uređajima. Pametni telefoni su izabrani kao fokusirana kategorija mobilnih uređaja jer većina studenata poseduje vlastiti fizički uređaj koji mogu koristiti za potrebe nastave. Pametni telefoni uglavnom pružaju i širi skup mogućnosti *Android* platforme u poređenju sa drugim kategorijama mobilnih uređaja.

Iskustveno se formirao zaključak da je studentima rad sa fizičkim uređajima svakako zanimljiviji nego rad sa emulatorom. Skup funkcionalnosti dostupan kroz emulator može uskratiti pojedine mogućnosti *Android* platforme u domenima kao što su senzori pokreta, detekcija dodira ekrana većim brojem tačaka, reprodukcija zvuka itd. Podaci dobijeni emulacijom senzora pokreta ne odgovaraju verno podacima kojima se generišu prilikom stvarnih pokreta. Emulator nema adekvatnu podršku za emulaciju dodira ekrana velikim brojem tačaka što je sputavajući faktor ukoliko aplikacija treba da detektuje broj tačaka dodira ekrana. Reprodukcija zvuka na emulatoru u uslovima fakultetske laboratorije nije moguća jer računari nemaju zvučnike.

Emulator ipak može biti prikladna zamena za fizički uređaj po pitanju bazičnih funkcionalnosti kao što je na primer rad sa komponentama grafičkog korisničkog interfejsa. Posebno treba napomenuti da je kompanija *Google* vremenom izvršila optimizaciju emulatora u velikoj meri tako da danas hardverski zahtevi emulatora ne predstavljaju problem ni za računare u fakultetskoj laboratoriji. Nezanemarljiv broj studenata upravo zato i koristi emulator na aktivnostima na kojima je to adekvatno.

6 Ocenjivanje studenata

Mehanizam ocenjivanja definisan je u skladu sa ciljem predmeta tako da se organizuje isključivo na računaru čime se naglašava važnost sticanja praktičnog znanja. Ocenjivanje se sprovodi kroz veći broj praktičnih aktivnosti, da bi studenti bili motivisani na kontinuirani rad, navedenih u tabeli 1. Aktivnosti za proveru znanja obuhvataju tri laboratorijske vežbe, dva kolokvijuma, ispit i odbranu projekta odnosno domaćeg zadatka. Prilikom svake provere znanja pred studenta se postavlja zadatak da napravi potpuno funkcionalnu aplikaciju koja predstavlja zaokruženu celinu. Ocenjivanje svih aktivnosti za proveru znanja vrši se uvidom u rešenje tokom same aktivnosti kada se ujedno obavlja i usmeno ispitivanje studenata. Nenultim brojem poena ocenjuju se samo oni delovi rešenja koji su potpuno funkcionalni čime su studenti primorani da se samostalno uhvate u koštac sa grešakama u aplikaciji. Pobuda za ovakav način ocenjivanja jeste želja da se kod studenata eliminiše strah od procesa otklanjanja grešaka.

Laboratorijske vežbe spadaju u grupu najlakših aktivnosti sa zadacima čija su rešenja najmanjeg obima. Vreme za izradu rešenja ograničeno je na dva sata. Laboratorijske vežbe su zamišljene sa namerom da podstaknu studente na što ranije moguću pripremu naredne teže aktivnosti. Tako prva laboratorijska vežba predstavlja aktivnost na kojoj se zahteva poznavanje komponenti grafičkog korisničkog interfejsa, aktivnosti kao komponente *Android* aplikacija i životnih ciklusa što je samo deo gradiva koji se kasnije proverava prvim kolokvijumom. Druga laboratorijska vežba pokriva oblasti servisa kao komponente *Android* aplikacija i višenitnog procesiranja na mobilnim uređajima koje su neophodne pri izradi drugog kolokvijuma. Poslednja odnosno treća laboratorijska vežba predstavlja pripremu za ispit, a tiče se oblasti prijemnika obaveštenja kao komponente *Android* aplikacije, senzora i grafičkog iscrtavanja.

Kolokvijumi spadaju u grupu srednje teških aktivnosti. Vreme za izradu rešenja ograničeno je na tri sata. Gradivo obuhvaćeno kolokvijumima oslanja se direktno na prethodeće laboratorijske vežbe. Prvi kolokvijum pored gradiva sa prve laboratorijske vežbe proverava i poznavanje resursa, fragmenata i navigacije među njima. Drugi kolokvijum proširuje skup oblasti pokrivenih na drugoj laboratorijskoj vežbi radom sa datotekama, lokalnom bazom podataka i injekcijom zavisnosti putem *Hilt* biblioteke.

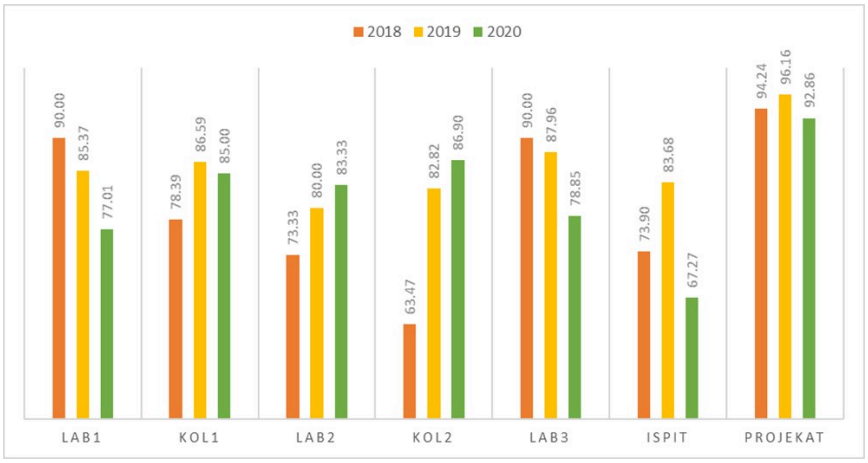
U okviru ispitnog organizuju se poslednje dve aktivnosti: ispit i odbrana projekta. Ispit spada u najtežu aktivnost sa zadacima čija su rešenja najvećeg obima. Vreme za izradu rešenja ograničeno je iz formalnih razloga na tri sata, ali studentima je dopušteno da nastave sa radom i nakon isteka tog roka. Prosečno vreme izrade rešenja je između četiri i pet sati. Ispit obuhvata celokupno gradivo predmeta. Pored gradiva obuhvaćenog svim prethodno navedenim aktivnostima ispit uključuje i pružaoce sadržaja kao komponentu *Android* aplikacije, rad sa kamerom i pristup mrežnim resursima. Aplikacija koju student treba da napravi na ispitu može sadržati sve elemente predavane tokom semestra. Odbrana projekta realizovana je kao modifikacija domaćeg zadatka. Uspešnom izradom modifikacije predatog projekta studenti potvrđuju da im je projekat poznat odnosno da su isti radili samostalno. Projektovano vreme za izradu rešenja projekta jeste sedam do četrnaest dana. Projekat, nalik ispitu, obuhvata celokupno gradivo predmeta ali se od ispita razlikuje po obimu. Aplikacija koju student pravi u okviru projekta sadrži značajno veći broj funkcionalnosti nego što je to slučaj sa ispitom.

Tabela 1, Pregled aktivnosti za proveru znanja

Naziv	**Vreme održavanja**	**Udeo u konačnoj oceni**	**Glavne karakteristike uobičajeno zadatih aplikacija**
Prva lab. vežba	4. nedelja semestra	3%	Jednostavna aplikacija sa aktivnostima, elementarnim funkcionalnostima, reagovanjem na promenu konfiguracije i bez perzistencije podataka.
Prvi kolokvijum	5. nedelja semestra	10%	Aplikacija sa jednom aktivnošću, fragmentima, navigacijom među fragmentima, reagovanjem na promenu konfiguracije i bez perzistencije podataka.
Druga lab. vežba	9. nedelja semestra	3%	Jednostavna aplikacija sa servisima i potrebom za višenitnim procesiranjem.
Drugi kolokvijum	10. nedelja	10%	Aplikacija za rad sa datotekama i mogućnošću

	semestra		perzistencije podataka u lokalnoj bazi podataka.
Treća lab. vežba	14. nedelja semestra	4%	Jednostavna aplikacija za obradu i iscrtavanje podataka dobijenih sa senzora.
Ispit	Ispitni rok	20%	Složena aplikacija koja može sadržati bilo koji element predavan tokom nastave.
Projekat	Ispitni rok	50%	Složena aplikacija sa svim predavanim elementima i velikim brojem funcionalnosti.

Prosečan uspeh studenata na skali od 0 do 100 poena u prethodne tri školske godine prikazan je u okviru slike 1 za svaku od aktivnosti za proveru znanja. Može se primetiti trend nešto slabijeg uspeha studenata na drugoj laboratorijskoj vežbi i drugom kolokvijumu pošto se ove aktivnosti za proveru znanja održavaju sredinom semestra kada su studenti generalno najopterećeniji. Najbolji uspeh studenti generalno ostvaruju na projektu odnosno domaćem zadatku jer imaju dovoljno vremena za njegovu izradu i mogu se posvetiti testiranju.



Slika 1 Prosečan uspeh studenata na skali od 0 do 100 poena na aktivnostima za proveru znanja

Prema mišljenju studenata predmet Programiranje mobilnih uređaja spada u grupu subjektivno težih izbornih predmeta jer je za uspešno savladavanje gradiva potrebno više vremena u poređenju sa drugim izbornim predmetima. Kategorizacija među teže izborne predmete je očekivana pošto predmet predstavlja spoj koncepata naučenih na prethodnim godinama studija i *Android* platforme. Ipak i pored toga studenti predmet smatraju interesantnim jer format nastave stavlja akcenat na praktičan rad kao i zbog toga što je znanje iz ove oblasti danas primenljivo. Krajnji ishod predmeta jeste da je student nakon uspešno položenog ispita osposobljen za samostalnu izradu potpuno funkcionalnih aplikacija za *Android* platformu.

7 Zaključak

U okviru rada izloženi su najveći izazovi u realizaciji nastave na predmetu Programiranje mobilnih uređaja. Predstavljeni su uzroci datih izazova kao i strategije kojima oni mogu biti prevaziđeni. Ustanovljeno je da nastava na računarima, u vidu izrade aplikacije za mobilne uređaje zajedno sa studentima, predstavlja najbolji format nastave u uslovima stalnih promena *Android* platforme, izostanku tradicionalnog udžbenika i praktične prirode predmeta. Ovakav format nastave sa druge

strane izuskuje dodatan napor od strane predavača. Prilikom odabira oblasti izučavanih na predmetu morale su biti izostavljene neke od tema vodiča za programere *Android* platforme. Objavljivanjem odluke da *Kotlin* postaje programski jezik prvog reda za razvoj *Android* aplikacija javlja se potreba za njegovim uvođenjem u nastavu na predmetu. Izazov uvođenja *Kotlin* programskog jezika još nije prevaziđen ali razmatraju se dva moguća pravca za njegovo prevazilaženje. Prikazan je pregled poteškoća pri pokretanju aplikacija u uslovima fakultetske laboratorije na koje se nailazilo tokom više godina držanja nastave na predmetu. Mehanizam ocenjivanja sa velikim brojem aktivnosti tokom semestra definisan je sa ciljem da se prevaziđe izazov kvalitetnog ocenjivanja studenata i motivacija studenata na praktičan rad.

Studenti iz oblasti programiranja mobilnih uređaja neretko pišu diplomske radove jer se predmet održava u pretposlednjem semestru osnovnih studija i pokriva interesantnu oblast. Tokom poslednje tri školske godine u proseku petina studenata, koji su pratili nastavu iz predmeta Programiranje mobilnih uređaja, svoje diplomske radove piše na neku temu iz ove oblasti. U sklopu diplomskih radova studenti najčešće realizuju aplikacije zabavnog karaktera, kao što su video igre, pošto im je to najzanimljivije.

Tokom nastave u narednim školskim godinama biće skrenuta pažnja na različite kategorije aplikacija nezabavnog karaktera pošto se trenutno studenti masovno fokusiraju na izradu aplikacija zabavnog karaktera. U nekoj od narednih školskih godina planira se i prelazak na *Kotlin* programski jezik koji je preporučeni programski jezik za razvoj *Android* aplikacija. Prelazak na *Kotlin* programski jezik biće veliki izazov jer u postojeći fond časova treba dodati koncepte programskog jezika *Kotlin* sa kojim se studenti nisu susretali na ranijim godinama studija.

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Učenje na daljinu – studija slučaja ETF-OL

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REZIME

Učenje na daljinu je odavno prisutno u ljudskom društvu. Razvojem Internet tehnologija i digitalizacijom društva olakšava se pristup ovim uslugama. Širokopojasni Internet je danas dostupan većini građana i bilo je pitanje trenutka kada će obrazovne institucije pored klasičnog pristupa nastavi ponuditi i učenje na daljinu. Pandemija COVID-19 virusa je ubrzala ovaj proces, tako da se većina nastave tokom 2020. godine odvijala uz korišćenje tehnologija i sistema za učenje na daljinu. U ovom radu je predstavljena jedna platforma ETF-OL kreirana na početku COVID pandemije, sa ciljem da olakša studentima i nastavnicima rad u novo-nastalim okolnostima. ETF-OL je sistem koji je prilagođen načinu rada sa studentima na Univerzitetu Crne Gore. Platforma se aktivno koristi od marta 2020. godine. Osnovna karakteristika joj je jednostavnost korištenja, tako da studenti i nastavnici na jednostavan način usvajaju i koriste ovaj sistem.

Ključne riječi: učenje na daljinu, on-line provjere znanja

1 Uvod

Sistemi za učenje i provjeru znanja na daljinu postoje već dugi niz godina [1], ali su bez obzira na to malo korišćeni u klasičnom obrazovanju. Dijelom zbog toga što su za njihovo uspješno korišćenje potrebni širokopojasni internet i odgovarajući hardver. Pojavom pametnih telefona i tablet uređaja, hardver je postao široko dostupan, tako da se danas može pretpostaviti da studenti raspolažu infrastrukturom neophodnom za efikasno učenje na daljinu.

Pandemija COVID-19 virusa je primorala većinu obrazovnih sistema da pređu na učenje na daljinu. U prvom redu se to odnosilo na nastavu (predavanja i vježbe) gdje je potrebno ostvariti audio i video komunikaciju koja se primarno koristi u jednom smjeru (komunikacija nastavnik $\rightarrow$ studenti) uz mogućnost obrnute komunikacije (studenti $\rightarrow$ nastavnik). Komercijalna platforma Zoom [2] je često korištena za ovu namjenu, iako su je pratile informacije da nije dovoljno bezbjedna [3, 4]. Pored nje treba pomenuti Microsoft Teams [5], Google Meet, [6], Big Blue Button [7] i Jitsi meet[8] platforme kao interesantne alternative Zoom-u.

U izradi ETF-OL platforme [9] autor je odabrao Jitsi meet kao videokonferencijsku platformu, jer se radi o open-source softveru, koji je moguće preuzeti i instalirati na lokalnim serverima.

Sastavni dio svake nastave pored predavanja i vježbi čine i provjere znanja. U većini slučajeva se za te namjene koristi Moodle [10] platforma. Iako su njene mogućnosti velike, radi se o složenoj platformi koja nije jednostavna za korišćenje i koja ima svoja ograničenja u koja se korisnici moraju uklopiti. Iz tog razloga je na ETF-OL platformi kreiran potpuno novi sistem za provjeru znanja koji je projektovan prema potrebama nastavnika i studenata na Univerzitetu Crne Gore.

Sistemi za provjeru znanja na daljinu nijesu naišli na dobar prijem. Većinom se nastavnici plaše da na ovaj način nije moguće obezbijediti regularnost ispitivanja. Drugi problem su zakonske norme. U

Slika 1: Prvi termin nastave

Zakonu o visokom obrazovanju Crne Gore [11] u članu 85 piše da „Nastava može biti organizovana i kao učenje na daljinu, a polaganje ispita održava se u prostorijama ustanove.” Ova formulacija ne prepoznaje predispitne provjere znanja (kolokvijume, testove, domaće zadatke i slično), ali se može tumačiti da su one dio nastave, te da se mogu izvoditi na daljinu. Dodatno, u članu 90 se ponavlja da „Student polaže ispit u prostorijama ustanove.”

Razvoj ETF-OL platforme počeo je 15.3.2020. godine. Prva video-konferencija održana je već 17.3.2020. Prvi termin nastave održane na ovoj platformi je bio 23.3.2020. godine. Nastavi, na dva predmeta, je prisustvovalo 40 studenata na jednom i 15 na drugom predmetu.

Razvoj web portala za podršku učenju na daljinu počeo je 23.3.2020. godine. Web portal, dostupan na adresi: https://bp.etf.ac.me/ol, je postao funkcionalan 25.3.2020. godine. Na slici 1 je prikazan pregled prvog termina nastave, zajedno sa pitanjima koja su studentima postavljana tokom nastave. Do sada je na ovoj platformi održano više od 1400 termina nastave.

Mogućnosti sistema za daljinsko učenje demonstrirane su zainteresovanim nastavnicima i saradnicima Elektrotehničkog fakulteta u Podgorici i Fakulteta za sport i fizičko vaspitanje u Nikšiću 27.3.2020. godine. Demonstraciji je prisustvovala i tadašnja ministarka nauke u Vladi Crne Gore.

Sistem je 16.4.2020. stavljen na raspolaganje studentima Pomorskog fakulteta u Kotoru, i koristi se

uglavnom za nastavu koju izvode nastavnici i saradnici sa Elektrotehničkog fakulteta.

Sistemu je dodat dio za online ispitivanje (testovi, kolokvijumi, domaći zadaci, ispiti...) Rad na ovom dijelu sistema započeo je 20.4.2020. Sistem za provođenje testiranja je postao funkcionalan 27.4.2020. Implementiran je studentski interfejs za pristup i izradu testa i nastavnički interfejsi za definisanje i pregledanje testova. Prvi testovi su organizovani 27.4.2020. Sistem za ispitivanje je trenutno dostupan ograničenom broj nastavnika, odnosno samo onim nastavnicima koji aktivno koriste ETF-OL sistem za izvođenje nastave. Iako su provjere znanja kreirane za potrebe učenja na daljinu, one se mogu koristiti i za organizovanje ispita u prostorijama fakulteta.

Posebna pažnja je posvećenja obezbjeđivanju regularnosti online ispitivanja. U sistem su ugrađene napredne i inovativne tehnike koje sa visokim stepenom pouzdanosti obezbjeđuju regularnost online ispitivanja i detektuju eventualne neregularnosti.

Prvi kolokvijum preko ETF-OL platforme održan je 15.5.2020. godine. Kolokvijumu je pristupilo 26 studenata, i niko nije prijavio negativno iskustvo u korišćenju ove platforme za ispitivanje. Prosječan broj osvojenih poena je bio 26 od maksimalno mogućih 40, što se u potpunosti poklapa sa rezultatima prethodnih generacija studenata koji su kolokvijum radili na klasičan način.

Za potrebe videokonferencijskog sistema iskorišćen je server HP ProLiant DL 360, generacije 9, opremljenom sa jednim 8 core procesorom, 16GB RAM memorije i dva SAS hard diska u RAID 1 konfiguraciji ukupnog raspoloživog kapaciteta 300GB. Server je nabavljen preko CS-ICT projekta 2016. godine. Operativni sistem servera je Oracle Linux 7.

Za potrebe web portala za pristup sistemu iskorišćen je server koji se koristi za podršku nastavi iz predmeta Baze podataka na specijalističkim studijama. Radi se o serveru HP ProLiant DL 380, generacija 4, koji je proizveden 2005. godine. Server je opremljen sa dva dvojezgrena procesora, 4GB RAM memorije i četiri hard diska (SAS, 146GB, 10000rpm) u RAID 5 konfiguraciji sa jednim rezervnim (spare) diskom. Na serveru je instaliran operativni sistem Ubuntu 14.04 LTS, Apache 2.4 web server, php 5.5, mysql 5.5, postfix mail server i drugi softver (Oracle XE 11g, postgresql…). Serveri se nalaze na Elektrotehničkom fakultetu Univerziteta Crne Gore.

Platforma ETF-OL je kreirana korišćenjem standardnog html-a, php okruženja i MySQL baze podataka.

2 Korisnici

Registracija korisnika je jednostavna. Na početnoj stranici, gdje je forma za prijavu korisnika je dat link za registraciju novog korisnika, slika 2. Traži se unos osnovnih podataka, nakon toga se korisniku šalje aktivaciona e-mail poruka, u njoj je link za postavljanje šifre i od tog trenutka student može da prati nastavu i učestvuje na provjerama znanja, na odabranom studijskom programu (i fakultetu). Sistem ne vrši provjeru da li je student zaista upisao godinu, prijavio predmete i slično. Do sada nije bilo primjera zloupotrebe ove, relativno slobodne, registracije a opravdanje za ovaj pristup je u tome što ni na klasičnoj nastavi u učionici nastavnik ne provjerava indekse studenata, već drži nastavu prisutnim osobama, pa čak i ako neko od slušalaca nije student tog studijskog programa. U trenutku pisanja ovog rada na sistemu je registrovano oko 2000 studenata i 27 nastavnika/saradnika.

Ne postoji posebna forma za registrovanje nastavnog kadra. Trenutno se nastavnici registruju na isti način kao i studenti, nakon registracije pošalju poruku autoru sistema i direktnom intervencijom u bazi korisnika on im dodjeljuje nastavnički status. Postoje dvije vrste nastavničkog statusa: osnovni i napredni. Osnovni status može držati nastavu, postavljati pitanja studentima tokom nastave, ali ne može kreirati i zakazivati provjere znanja. Provjere znanja su dostupne nastavnicima sa naprednim statusom, na zahtjev. Osnovni razlog za ovaj pristup je što provjere znanja studentima koji nijesu pratili nastavu preko ove platforme mogu biti stresne jer nijesu upoznati sa sistemom. Nastavnik ima

Slika 2: Registracija korisnika sistema

punu slobodu u kreiranju provjere znanja, a ta sloboda uz nedostatak iskustva u radu sa sistemom može rezultovati neadekvatno pripremljenim provjerama znanja, što ne bi išlo u korist studenata.

Primjer osnovnog nastavničkog interfejsa je prikazan na slici 3. Na slici 4 je dat primjer studentskog interfejsa (radi se o virtuelnom studentu). Na njemu su prikazani današnji termini i termini zakazani u narednih 10 dana. Pored termina nastave, student ima pristup rezultatima koje je ostvario na provjerama znanja.

3 Nastava

Nastavnik ima mogućnost zakazivanja termina nastave, postavljanja obavještenja studentima, kreiranja pitanja koja će postavljati prisutnim studentima, započinjanja i završetka nastave (slika 3).

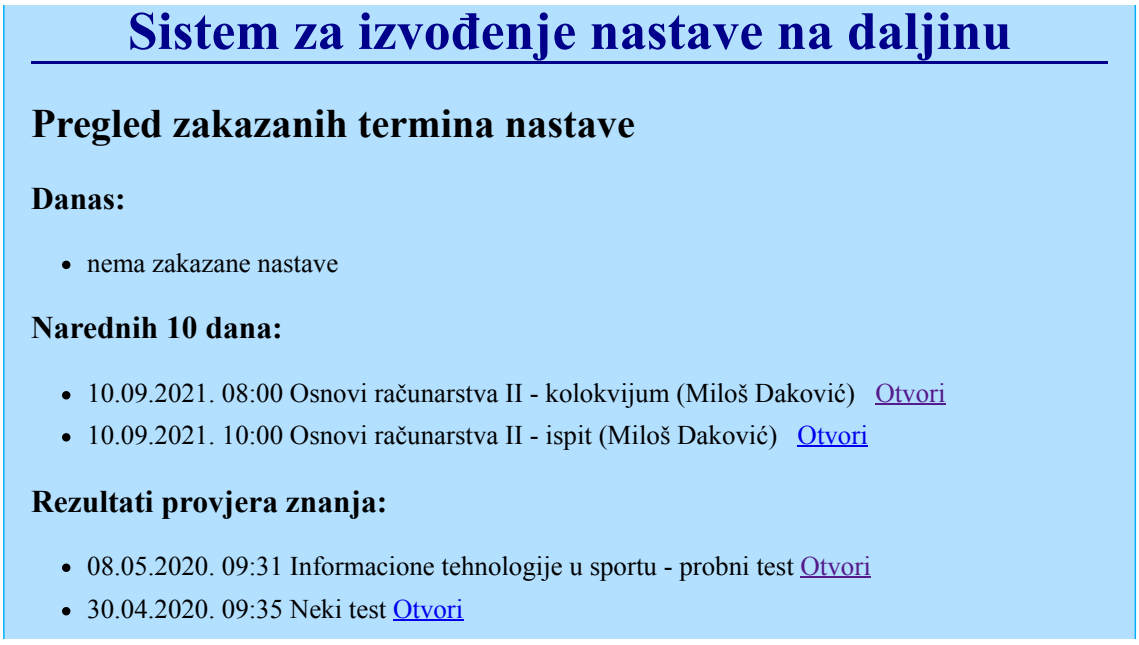
U toku, i nakon završetka nastave nastavnik može pogledati spisak prisutnih studenata proširen sa informacijama o tome kada je student došao na nastavu, koliko je vremena proveo na nastavi i slično.

Pored preporučenog Jitsi meet videokonfernecijskog sistema, platforma podržava i ostale načine izvođenja nastave (Zoom, Google meet…), odnosno sve sisteme kod kojih se studenti preko web linka mogu uključiti u nastavu.

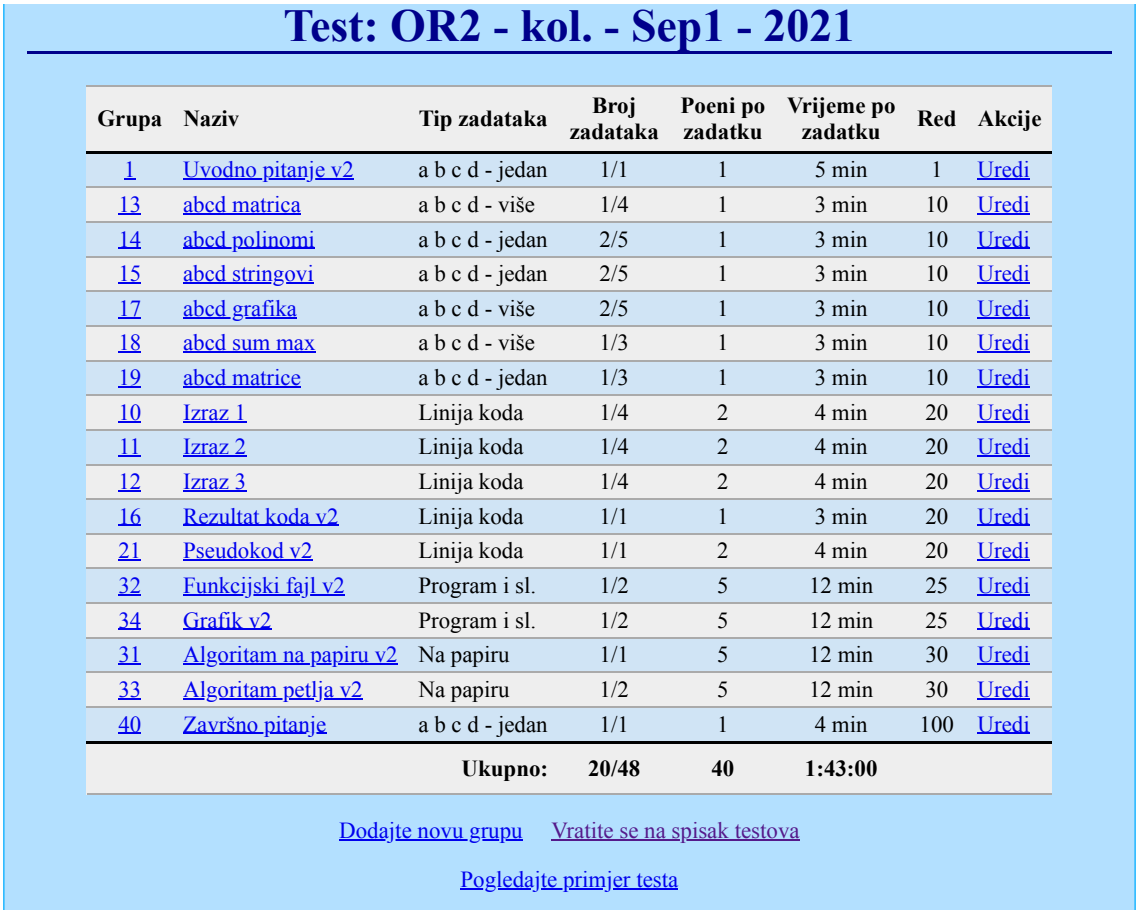
U nastavničkom interfejsu (slika 3) nastavnik ima pregled zakazanih obaveza koje su podijeljene u grupe: „Današnje obaveze”, „Naredni termini” i „Prethodni termini” (pri čemu se na osnovnoj stranici prikazuju samo termini u prethodnih 12 dana, a na zahtjev se može dobiti lista svih prethodnih termina nastave.

Studenti u svom interfejsu imaju pregled nastave zakazane za trenutni datum i spisak zakazanih termina u narednih 10 dana.

Slika 3: Nastavnički interfejs



Slika 4: Studentski interfejs



Test: OR2 - kol. - Sep1 - 2021

Grupa	Naziv	Tip zadataka	Broj zadataka	Poeni po zadatku	Vrijeme po zadatku	Red	Akcije
1	Uvodno pitanje v2	a b c d - jedan	1/1	1	5 min	1	Uredi
13	abcd matrica	a b c d - više	1/4	1	3 min	10	Uredi
14	abcd polinomi	a b c d - jedan	2/5	1	3 min	10	Uredi
15	abcd stringovi	a b c d - jedan	2/5	1	3 min	10	Uredi
17	abcd grafika	a b c d - više	2/5	1	3 min	10	Uredi
18	abcd sum max	a b c d - više	1/3	1	3 min	10	Uredi
19	abcd matrice	a b c d - jedan	1/3	1	3 min	10	Uredi
10	Izraz 1	Linija koda	1/4	2	4 min	20	Uredi
11	Izraz 2	Linija koda	1/4	2	4 min	20	Uredi
12	Izraz 3	Linija koda	1/4	2	4 min	20	Uredi
16	Rezultat koda v2	Linija koda	1/1	1	3 min	20	Uredi
21	Pseudokod v2	Linija koda	1/1	2	4 min	20	Uredi
32	Funkcijski fajl v2	Program i sl.	1/2	5	12 min	25	Uredi
34	Grafik v2	Program i sl.	1/2	5	12 min	25	Uredi
31	Algoritam na papiru v2	Na papiru	1/1	5	12 min	30	Uredi
33	Algoritam petlja v2	Na papiru	1/2	5	12 min	30	Uredi
40	Završno pitanje	a b c d - jedan	1/1	1	4 min	100	Uredi
		Ukupno:	**20/48**	**40**	**1:43:00**		

Dodajte novu grupu Vratite se na spisak testova

Pogledajte primjer testa

Slika 5: Primjer provjere znanja

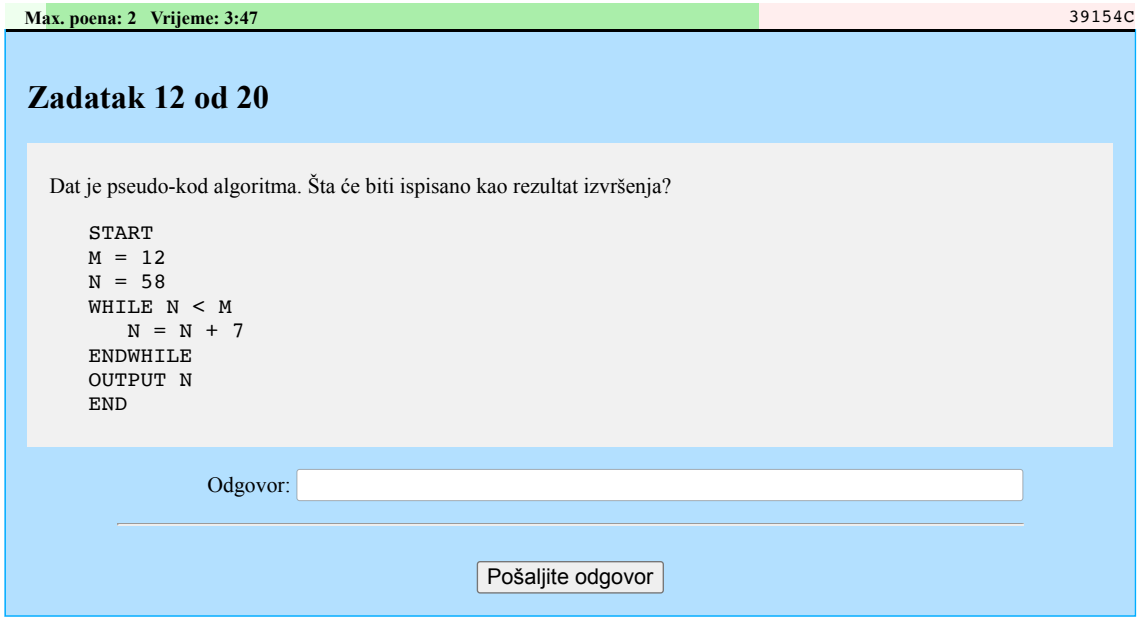
4 Provjere znanja

Nastavnik ima mogućnost kreiranja provjere znanja. Ona se sastoji od zadataka (pitanja) različitih tipova. Zadaci su podijeljeni u grupe. Podrazumijeva se da svi zadaci u jednoj grupi nose isti broj poena i da imaju isto vrijeme predviđeno za izradu. Nastavnik definiše koliko zadataka iz konkretne grupe će biti postavljeno studentima. U slučaju da u grupi ima više zadataka nego što se postavlja studentima, sistem će slučajnim izborom za svakog studenta odrediti potreban broj zadataka. Primjer jedne provjere znanja u nastavničkom interfejsu je dat na slici 5.

Svaka grupa zadataka ima i svoj red (numerička vrijednost) koja određuje redoslijed postavljanja zadataka. Nakon izbora zadataka iz svake grupe zadaci se postavljaju prema rastućem redu, pri čemu se u okviru svake vrijednosti reda zadaci slučajnoređaju.

U postavci zadataka, nastavnik može umetnuti slučajno generisane elemente. To se postiže pomoću `#!#` tag-ova u postavci zadatka. Postoje tri vrste ovih tagova:

- `#!#m-n#!#` generiše slučajan cio broj od m do n (uključujući obje granice)
- `#!#x.y-a.b-p.q#!#` generiše slučajan broj od $x.y$ sa korakom $a.b$ do $p.q$. Generisani broj može, a ne mora, imati decimalni dio. Na primjer: `#!#20.0-2.0-40.0#!#` će dati paran broj od 20 do 40, a `#!#0.5:0.05:0.7#!#` će dati slučajan broj iz niza: $0.5, 0.55, 0.6, 0.65, 0.7$.
- `#!#A-B#!#` ukoliko su A i B slova generiše slučajno slovo od slova A do slova B, na primjer: `#!#a-f#!#` će generisati slučajnim izborom jedno slovo iz niza a, b, c, d, e, f.



Slika 6: Primjer zadatka sa kratkim tekstualnim odgovorom

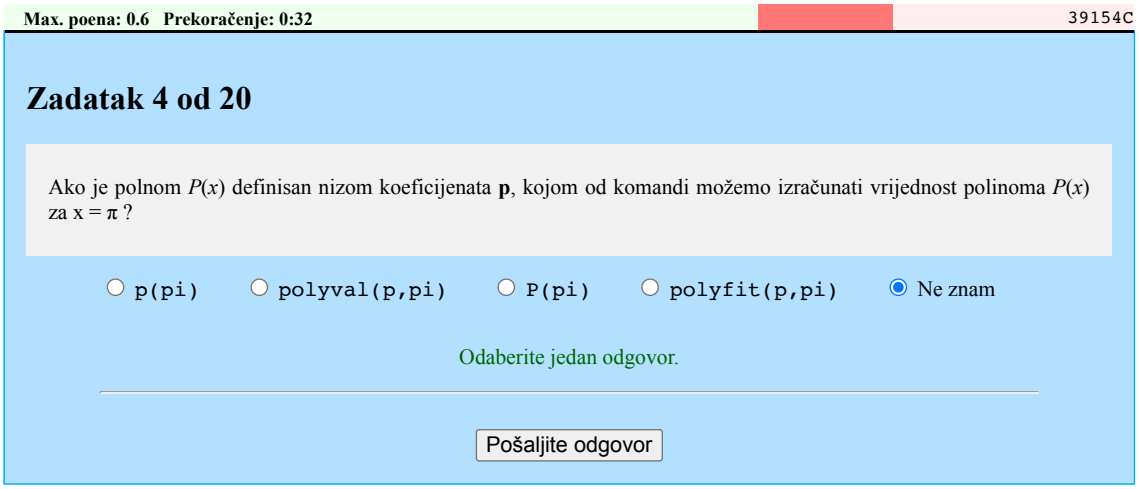
Na ovaj način nastavnik može sa jednom postavkom zadatka generisati mnogo različitih zadataka i time povećati regularnost izrade testa.

Za svaki test nastavnik može odlučiti da li će svi studenti raditi iste zadatke ili da svaki student ima slučajno generisan test. Vrijeme izrade se definiše za svaku grupu zadataka. Na nivou testa se definiše dozvoljeno prekoračenje vremena (u procentima). Prekoračenje je implementirano na sledeći način: ako je predviđeno vrijeme izrade zadatka 10 minuta, a dozvoljeno prekoračenje 50%, i broj bodova koje zadatak nosi 5, tada će u prvih 10 minuta student za tačno urađen zadatak dobiti maksimalnih 5 bodova, a tokom prekoračenja (dodatnih 5 minuta) maksimalni broj bodova opada od 5 do 0, linearno. Prilikom pregledanja zadataka, na nastavniku je da procijeni koliko bodova će dodijeliti studentu, a maksimalni broj bodova (vodeći računa o prekoračenju) mu je sugerisan kroz sistem. Na slici 7 je prikazan primjer zadatka gdje je student ušao u prekoračenje, tako da je maksimalni broj poena smanjen sa 1 na 0,6. Student prilikom izrade zadatka može pratiti vrijeme na traci na vrhu stranice. Zeleni dio je predviđeno vrijeme, a crveni dio prekoračenje (slike 7 i 8).

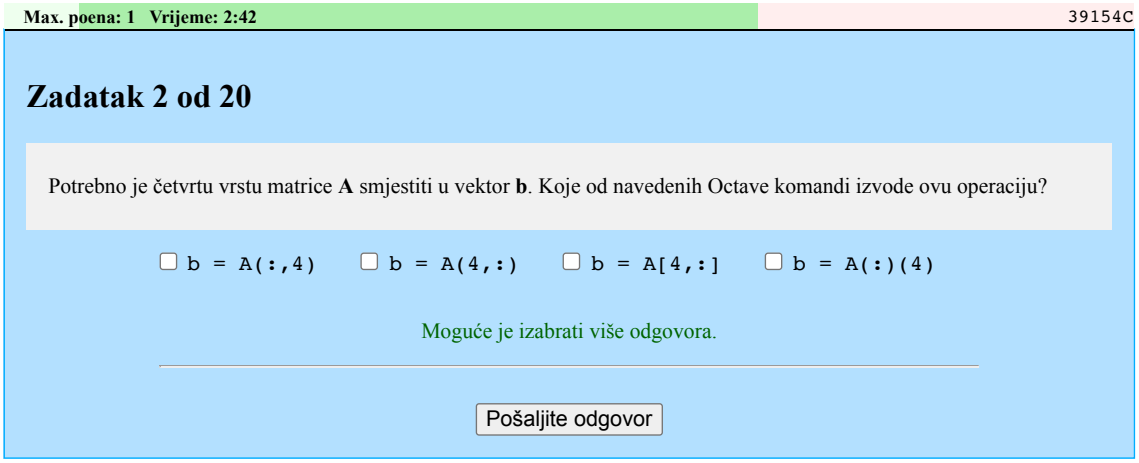
Preporučeno je da u uvodnom zadatku student dobije i sve potrebne informacije o strukturi provjere znanja, i da se na kraju testa postavi pitanje (koje ne nosi poene) gdje student može opisati eventualne probleme na koje je naišao tokom provjere znanja.

Sistem trenutno podržava devet tipova zadataka:

1. *Kratak odgovor.* Zadatak gdje student odgovara sa jednom linijom teksta. Primjer ovog zadatka dat je na slici 6.
2. *Duži odgovor.* Zadatak gdje veličina odgovora odgovara jednom pasusu teksta.
3. *Program.* Zadatak gdje student odgovara tekstom koji liči na program u bilo kom programskom jeziku (koristi se neproporcionalni font i vodi se računa o novim redovima).
4. *Jedna linija programskog koda.* Koristi se neproporcionalni font, a odgovor je kratak (u jednoj liniji).
5. *Odgovor sa više pasusa teksta.* Koristi se u slučajevima kada je odgovor duži, pa ga treba formatirati u paragrafe (pasuse).



Slika 7: Primjer zadatka sa ponuđenim odgovorima – jedan izbor

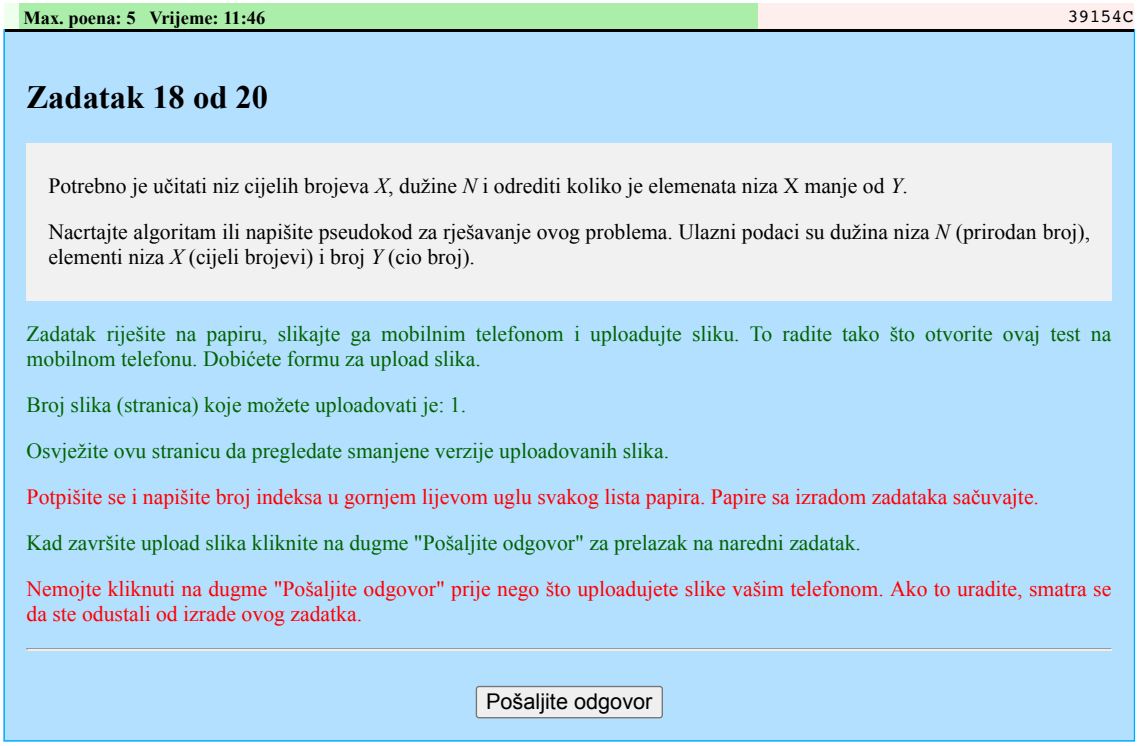


Slika 8: Primjer zadatka sa ponuđenim odgovorima – višestruki izbor

6. *Pitanje abcd - jedan odgovor.* Zadatak gdje student bira jedan od četiri ponuđena odgovora, a ima mogućnost i da odabere odgovor „Ne znam”. Kod ovih zadataka za svaki od ponuđenih odgovora se unaprijed definiše broj bodova (može biti i negativan) a ovi zadaci se mogu automatski pregledati. Na slici 7 je dat primjer ovakvog zadatka.

7. *Pitanje abcd - više odgovora.* Zadatak gdje student bira koji od četiri ponuđena odgovora, vrijedi za postavljeno pitanje. Može ne odabrati ni jedan, odabrati jedan, dva, tri ili sva četiri ponuđena odgovora. Kod ovih zadataka za svaki od ponuđenih odgovora se unaprijed definiše broj bodova (treba biti negativan za netačne odgovore) i ovi zadaci se automatski mogu pregledati. Slika 8 je primjer zadatka ovog tipa.

8. *Zadatak se radi na papiru.* Za izradu ovog tipa zadataka potreban je pametni telefon ili tablet sa aktivnom zadnjom kamerom. Student zadatak radi na papiru, a sistem mu otvara mogućnost da fotografiše izradu i pošalje sliku na pregledanje. Primjer zadatka ovog tipa je dat na slici 9. Nastavnik definiše maksimalni dozvoljeni broj slika. Slike se prenose u punoj rezoluciji, tako da upload slike, kod manjih brzina prenosa podataka može potrajati nekoliko minuta. Web interfejs na pametnom telefonu/tabletu aktivira zadnju kameru, preuzima sliku i šalje je bez pamćenja na korisničkom uređaju. Studentima se preporučuje da sačuvaju papire sa izradom zadataka, ukoliko fotografija ne bude dovoljno kvalitetna, mada se u praksi to, do sada, nije dešavalo.



Slika 9: Primjer zadatka koji se radi na papiru

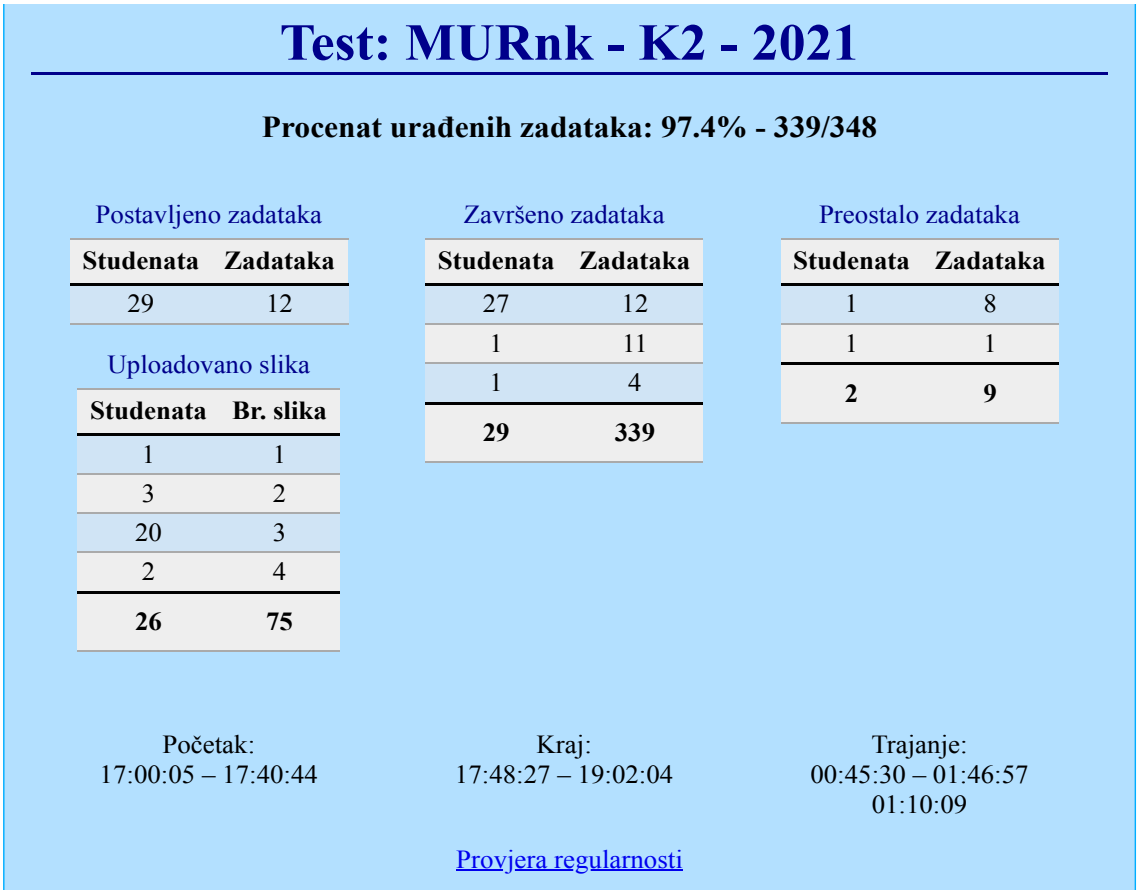
9. *Zadatak sa uploadom fajlova.* U ovom slučaju odgovor na zadatak je fajl (u formatu: pdf, doc, c, txt,…) ili više fajlova koje student kreira na svom računaru i kroz sistem ih šalje nastavniku na pregledanje.

Radi lakšeg pregledanja zadataka nastavnik može svakom zadatku dodijeliti dvije JavaScript funkcije. Prva funkcija vraća tačan odgovor na postavljeno pitanje. Ulazni argument joj je niz slučajno generisanih elemenata zadatka. Druga funkcija ima svrhu da automatski pregleda zadatak. Ulazni argumenti su joj odgovor studenta i niz slučajnih vrijednosti, ako su korišćene u postavci zadatka. Funkcija vraća decimalan broj od 0 do 1, koji se množi sa brojem poena da bi se dao predlog ocjene. Algoritam pregledanja u potpunosti definiše nastavnik u tijelu funkcije za pregledanje.

Nastavnik može u realnom vremenu pratiti test. Na slici 10 je dat primjer informacija koje su nastavniku dostupne u toku i nakon završetka testa. Nastavnik pregleda jedan po jedan zadatak za sve studente koji su radili test. Na taj način je olakšano pregledanje i ujednačavanje kriterijuma pregledanja.

U ETF-OL sistem je uključen i inovativni podsistem za praćenje regularnosti izrade zadataka. Sistem koristi sve dostupne informacije koje studentski uređaji šalju da bi heuristički, kroz niz testova nastavniku predložio parove radova na koje treba obratiti posebnu pažnju. Na nastavniku je da donese odluku šta raditi u tim slučajevima i da provjeri da li ima elemenata koji ukazuju na neregularnost. Dosadašnja iskustva su da sistem jako rijetko griješi. Iskustva su pokupljena tako što je studentima gdje postoji sumnja na neregularnost značajno smanjen broj poena, i nakon toga, prilikom pregleda radova, kada se suoče sa činjenicama i pitanjima studenti su priznavali neregularnosti u izradi testa .

Sistem za provjeru znanja se može koristiti ne samo za on-line rad, već i za provjere znanja u prostorijama ustanove (fakulteta), pri čemu se podrazumijeva da studenti ispit rade uz upotrebu računara i sa pristupom Internetu.



Slika 10: Praćenje provjere znanja

5 Zaključak

Platforma za učenje na daljinu ETF-OL je razvijena i implementirana u Crnoj Gori, te se za korišćenje ovog sistema angažuju samo lokalni resursi. Sav Internet saobraćaj se odvija u grancama Crne Gore. To otvara mogućnost, da se u budućnosti, kroz pregovore sa crnogorskim Internet provajderima ovaj saobraćaj tretira drugačije u odnosu na klasični Internet saobraćaj. Platforma ima mogućnost integracije sa drugim sistemima (na primjer sa komercijalnom Zoom platformom i sličnim sistemima). ETF-OL platforma je projektovana da ispuni specifične zahtjeve nastavnog procesa na Univerzitetu Crne Gore, uključujući i provjere znanja: domaće zadatke, testove, kolokvijume i ispite.

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xSample: A FREE, USER-FRIENDLY APP FOR COLLECTING EXPERIENCE SAMPLING DATA

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ABSTRACT

In this paper, we introduce xSample, a free, open-source platform that our lab developed to use in experience sampling studies. The experience sampling method (ESM) belongs to the group of ambulatory assessment techniques and presents a novel assessment tool in (social) sciences. Human-computer interaction (HCI) as a multidisciplinary field focuses on the design of computer technologies and interaction between humans and computers. The fast development of smartphones enabled methodological advancements and the development of smartphone apps suitable for ESM. This enables researchers to collect various behavioral measures, like the number of phone calls, text messages, GPS data, in addition to data collected using ESM. We provide a brief overview of xSample features as well as the pros and cons of using smartphone-based apps for ESM.

Keywords: ambulatory assessment, experience sampling method (ESM), smartphone-based apps, xSample app, human-computer interaction (HCI).

1 Introduction

Moving survey research from lab to online setting provided researchers with several benefits [1]. Van Selm and Jankowski [2] report that online surveys enable access to more diverse populations. A recent report done by Pew Research Center revealed that as of 2015, 84% of American adults use the Internet, while in the population of older adults, which is the fastest-growing group of Internet users, 58% are using it [3]. Online data collection also reduces the biases of the researcher being present in the lab together with the participant and decreases the cost and time necessary to collect data [4]. Online data collection also reduces human errors and standardizes administration, and is proven to be of the same quality as traditional methods in terms of reliability and validity [5].

Development and increase in online survey research took a parallel path with technological advancements. Smartphones are amongst the fastest-changing devices and their usage in psychological research is increasing stunningly [6]. Technical characteristics of smartphones, like memory capacity, processors, operating systems, onboard sensors, different connectivity options, GPS tracking, visual and audio output, haptic and motor output, the possibility of recording visual, audio, and haptic signal, call logging, data usage tracking, etc. (for a detailed overview see [6]) are making smartphones very attractive research tool in social sciences and psychological studies. Thus, searching through Elsevier's database "Science Direct" - either within the title or abstract - with the following keywords, ("experience sampling" OR "ecological momentary assessment" OR "ambulatory assessment") in the last 10 years (from 2011 onwards), and limiting this search to articles (research and review) and book chapters, yields 1034 results. Searching through all databases of publisher EBSCO with the same keywords, again in the last 10 years, and limiting research to academic journals only, yields 6932 results. Assuming that these databases are not

overlapping it means that, in the last decade, at least two full articles (or book chapters) relying on ESM methodology were published on average per day - by these two publishers only. Experience sampling methodology appears to blossom, indeed.

1.1 Experience sampling method

The experience sampling method (ESM, [7]) presents a novel assessment tool in social sciences and psychological research [8, 9]. The ESM method is used to collect data on everyday behavior, emotions, and cognition and allows researchers to gain insight into the dynamics of people's cognitive and emotional processes, and characteristics influencing these dynamics [10]. The ESM is also referred to as the daily diary method [11], ecological momentary assessment [12], event sampling [13], and intensive longitudinal assessment [14]. The ESM belongs to the broader group of techniques known under the umbrella term ambulatory assessment techniques [8, 15], which are used also to collect data on verbal behavior [16, 17], to obtain reports on various physiological states [18, 19], etc.

The ESM offers several advantages compared to other assessment methods. The first is an increased ecological validity, as ESM offers very direct and more valid insight into people's mental and behavioral patterns [9, 20]. It enables us to study people in their "natural habitat", thus, allowing us to understand behavior and factors influencing our behavior which is not available when using retrospective questionnaires or artificial manipulations [7, 15]. Additionally, real-life contexts are diverse and less constrained than laboratory settings, allowing us to observe a wide range of people's responses [21]. Repeated measurements in different contexts allow researchers to understand variability in mental states and psychological constructs, and to disentangle sources of variances using multi-level modeling [22]. Repeated measurements also reduce assessment error and improve the reliability, validity, and transparency of individual pattern assessments [20].

In ESM, participants are providing self-reports similar to diary studies, but different from typical self-report, here participants are proactively triggered at various points throughout the day [23]. Participants do not have to rely on their long-term memory to reconstruct past events or experiences, and data collection is primed to those particular events that are of interest to the researcher [24]. Another advantage is the possibility to overcome typical drawbacks of self-reports, like socially desirable responding, acquiescent or extreme responding [25, 26]. Since respondents answer to the items at the moment (or very close to it) ESM enables reduction of recall bias, and available evidence suggests that the accuracy of responses collected using ESM is substantially higher than with traditional retrospective methods [27, 28].

ESM enables the assessment of experiences, behaviors, thoughts and emotions, and moment-to-moment changes in mental states. In a typical study, a respondent is asked to complete a short questionnaire, usually, a couple of minutes, in response to beep prompts. Typically, respondents are triggered randomly, in an unpredictable random time sampling protocol, but event sampling is also used [13]. ESM studies cover a range of different question types, Likert-type scales, open-ended questions, visual analog scales, checklists, etc.

On the flip side, ESM has some drawbacks. First, it is very time-consuming and demanding for the participants [22]. Study protocols include repeated daily assessments for at least 7 consecutive days, which can create a significant burden for respondents, despite assessments being kept as brief as possible. Second, although some studies suggest good compliance [29], other scholars report that compliance with the research protocol can be jeopardized because subjects are completing the study during the day, without the presence of the researcher [22]. Third, there is a possibility of selection bias, as respondents can miss assessment as a response to their current mood. Nevertheless, recent findings suggest that time of the day predicts non-response stronger than mood [30]. Finally, the order and the content of the questions, and repeated assessment can induce the reactivity of the respondents [22]. Therefore, it is important to balance questions and carefully select the items [20].

2 Human-computer interaction (HCI) in social sciences

Recent methodological advancements are challenging researchers to move beyond lab experiments to understand how people behave and function in everyday, real environments. Human-computer interaction (HCI) or human-machine interaction (HMI), or man-machine interaction (MMI) as a multidisciplinary field focuses on the design of computer technologies and interaction between humans and computers. In the field of HCI, the fast development of smartphones enabled methodological advancements and the development of smartphone apps suitable for ESM.

2.1 Advantages of smartphone-based ESM

The usage of HCI and smartphones in scientific research (especially ESM) has several important advantages. The first is (flexible) control over the whole process of data collection, as researchers can overview the whole process of data collection in real-time and record behavioral data like movement and communication. Second, based on the completion time we can determine whether respondents were skipping or inattentively completing questions [24].

Another advantage is its cost-efficiency since long-term studies of everyday behavior and collecting a rich body of data without the researcher's intervention is enabled, which reduces the work needed. As already said, ESM allows for studies of increased ecological validity. By using smartphones, we have relatively easy access to a variety of behavioral data without asking participants to report on them and without constant observation. Thus, using smartphones for ESM offers unobtrusive data collection and enables context reconstruction. Furthermore, using smartphones to collect ESM data enables researchers to collect and analyze data in real-time, which allows us to identify respondents who do not comply with the study protocol, participants' drop-out, or some technical problem [24]. Moreover, ESM offers a possibility to embed logic in the order of the questions.

In psychology, the ESM proved to be a valid assessment method of very different outcomes, e.g., those related to mood dysregulation [31], anxiety [32], substance-use disorders [33], premenstrual disorders [34], and psychotic-like experiences [35].

2.2 Challenges in smartphone-based ESM

- *Programming*. Although for researchers who have the technical knowledge to program an ESM study in freely available software packages, study costs and technical requirements are reduced, accessible tools for researchers without programming skills are still lacking [36].
- *Study equipment.* Another challenge is the cost of the study since the equipment used for ESM can be high. Therefore, researchers consider using the participant's own devices during the study [24].
- *Heterogeneity of platforms.* Furthermore, the large number of different devices developed by different manufacturers creates another challenge: variations in both hardware and software components. Thus, the software used for ESM has to be flexible enough to accommodate and support different devices. The development of smartphone devices is extremely fast, thus imposing new challenges and requirements for developers of ESM apps.
- *Technical characteristics of smartphones.* Although each generation of smartphones has improved technical characteristics, there are still significant differences in their performances. Memory capacity, battery duration (especially when using GPS data), limited-accuracy sensors, and interference of different apps (third-party application intervention) may cause difficulties in functioning and influence the quality and the accuracy of collected data [6, 37].
- *Biases in sampling and difficulties in participant recruitment.* Despite the growing popularity of smartphones and their widespread use, some data suggest that adoption of smartphones is slower in people of lower SES, coming from developing countries, introverted, mentally ill, older people, etc [38]. Moreover, a bias in sampling will also

happen because certain people might perceive data collection via smartphones as intrusive, and fear for their privacy [6].

- *Participant behavior*. The quality of the collected data depends on the responsibility of the participants. Namely, respondents can forget to recharge smartphones, change the device during data collection, or lend their smartphone to someone else (someone else's behavior is tracked in those situations), or even purposely change their behavior because they know they are being studied. Another challenge is the fact that a lot of people have two smartphones, one using for their work, and another using outside their working hours which creates biases in behavioral data collected or even restricts data collection to certain days in the week or time during the day [6, 37]. Additionally, device ownership influences the behavior of respondents. If participant uses a study-specific device it influences the quality of the data - participants might feel uncomfortable using unknown device and carrying several devices can influence participant's behavior [24].
- *Sensor usage.* Despite being highly relevant for assessment of participants' behavior, sensors are still relatively rarely studies thoroughly [36]. For the app developer, sensor development is very costly, while on the user side, its usage and recording imposes some requirements because participants also have to be very familiar with the features their smartphone is offering or carrying additional devices collecting sensor data such as bracelets, fitness trackers, etc.
- *Data management and analysis.* The amount of data collected using smartphones and their complexity pose a new challenge to researchers. To adequately analyze and interpret collected data, researchers have to gain expertise in complex multilevel analysis, signal processing, feature extraction, machine learning, and pattern recognition [6].
- *Ethical issues*. Using smartphones for data collection imposes certain difficulties in maintaining the privacy of respondents participating in the study. Although most of the apps do not record the content of the calls, text messages, and e-mails, the majority of smartphone apps collect GPS data, call logs, and the logging of sensors. Collected data may allow for inferences of participants' gender, life stage, marital status, home address, etc, thus making absolute anonymity very difficult to achieve [6].
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2.3 Essential features of smartphone ESM apps

Several features are essential for high-quality data collection. First, an app should offer researchers the possibility to design a questionnaire using a variety of item types. The app should offer a choice between multiple-choice, open-ended questions (text, numbers), multimedia audio, video, images, sliders, etc. Furthermore, branching logic is a very useful feature, so that based on previous responses, a researcher can decide what will be the next question a respondent will see. This feature positively influences a completion rate, as respondents are only asked to respond to questions they should see. An adequate app should also be able to collect GPS data and collect data on the movement of respondents.

The app should offer a possibility to have reliable reminding system, as this is one of the most important features of ESM. Several different types of reminders are possible: fixed dates, rolling dates (e.g., every Saturday at 1 PM), and random times which are used in most ESM studies. In addition, a system reminding the respondent should be reliable and available when the phone is offline, thus, the majority of smartphone apps are using push notifications. Push notifications are mobile alerts that are visible even on locked screens, accompanied by sound or vibration. A good smartphone app should be able to collect data when offline. Offline data collection is highly important since a good-quality internet connection is not possible all the time or when using mobile data is expensive. Finally, a high-quality smartphone app should be safe and offer security for collected data. Thus, data should be stored on safe servers, and respondents should be aware of what kind of data is collected and what safeguards are.

3 About xSample

xSample is an open-source smartphone android-based ESM app developed by the Laboratory for research of Individual differences at the Faculty of Philosophy, University of Belgrade. The app is quite configurable, user-friendly, and does not require programming knowledge. xSample is freely available to researchers. Researcher conducting a study are given credentials to access the platform free of charge and can set up their study. It serves as a research tool for tracking the emotions and actions of respondents.

3.1. Structure of the xSample platform

After logging in, a researcher can configure items that will be displayed to the respondent (i.e., "poll" section in the platform) and information about the participants (i.e., "examinee" section in the platform). In the "poll" section, the researcher first should create a survey that will be administered i.e., labels the survey, adds disclaimer text if wanted, and sets the number of days. Additionally, a number of polls that will be administered during one day of ESM is set, as well as poll periods and reminders (random or fixed). After that, the researcher creates items, that is, selects a type of the item (multiple-choice, open-ended questions, sliders, visual stimuli), enters the text of the item, possible answers (if an item is a close-ended question), select whether the item will be displayed only in the first period during the day, and selects the poll to which the item will be assigned (if several polls are created). The researcher can determine the order of the questions, how often to run trials. The app also allows for branching logic. The app uses push notifications and respondents can be reminded to complete the survey at predetermined or random times.

In the "examinee" section, an ID number of the respondent is mandatory, while gender, age, education, and name are optional fields. The ID number is created by the respondent using the instructions for generating the code provided by the researcher (preferred option) or the ID number can be assigned to the respondent by the researcher. Only respondents with IDs that are entered into the platform can take part in the survey. Each respondent has to be assigned to the poll in which they will participate (by selecting it from the drop-down menu if several surveys are existing in the platform).

3.2. Functionality of the xSample app

In terms of functionality, xSample covers several important features, like sensor logging, triggering, and branching. Specifically, the app allows tracking the number of incoming and outgoing calls and the number of text messages exchanged, but the content of the conversation is hidden to researchers. That is, the data about the calls and messages are restricted only to the amount of mobile traffic, not to its content. Researchers also can analyze GPS data and data collected using Google fit app. The app also gives the amount of internet data usage in bytes. Researchers also have the possibility to provide their participants with feedback on the moods and emotions they experienced throughout the survey. To create feedback, a researcher has to select items that will be used for it, and the algorithm calculates the score representing the mood and/or emotions of the respondents compared to the reference group, i.e., respondents participating in the study. To sum up, functionality features available in xSample allow researchers to collect data of similar quality like other available apps[24].

3.3. xSample and participants

To be able to participate in the study, a respondent has to download the xSample app from the Play market on their android device. Internet connection is necessary during the download of the app and during the last period of the day when data is stored on the server. The respondent has to accept terms and conditions to be able to continue using the app. Upon opening the app, the respondent has to enter their personal code, and the app is ready to use. Respondents are reminded to answer the survey in each poll period by push notifications. Questions are displayed to the respondents one by one and the app records their answers and their response times. If a survey is

administered several times during the day, after the first and subsequent period(s) responses are stored locally on the phone, while after the last period in the day, data is sent to the server. It is also possible to have the same respondent participating in several surveys (their personal code can be connected to several surveys in the platforms). In that case, upon opening the app on their device, the respondent chooses between available surveys. Respondents also can easily withdraw from the study by uninstalling the app from their device, after which the questionnaire is not delivered to the respondent nor are sensor data collected.

3.4. xSample data security

Collected data is stored on the central server where it is completely secure. Data is used exclusively by the researchers conducting the study. Collected data is easily downloaded in .csv format and pre-prepared adequately for multilevel modeling (i.e., all daily entries for each respondent are organized in rows, while responses to items and other data are organized in columns). Researchers have information about the date and time when responses were collected for each period of the day, and items are downloaded including their labels.

4 Conclusion

By making the xSample application freely available to researchers, we aimed to promote and facilitate the adoption of ESM. The xSample app is an easy-to-use platform that allows researchers to design an ESM study without the need of having programming knowledge. The variety of question types, reminder types, censor data that are collected, and push notifications are features that satisfy the majority of requirements of a high-quality ESM study. For the time being, the xSample is designed to be an app used solely for research purposes, that is, only users registered by researchers can use the app and participate in an active survey. This feature allows researchers to have high control over the usage of the app and the quality of the data collected.

However, we have to highlight some drawbacks of the app as well. First, due to financial restrictions, for now, the app runs only on the Android operating system. Another drawback is that, due to privacy issues, the app does not allow for tracking the usage of internet data while using most common communications apps like Viber, WhatsApp, Signal, Messenger, etc. This makes researchers blind to the significant part of verbal communication that respondents make during the day.

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Free Software in Speech Technology

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Abstract

Speech Technologies are becoming increasingly important with the increased penetration of smart devices in our every day lives. They also are indispensable for allowing the digital and social inclusion of people with disabilities. Free software has always played an important role in speech technology research and real-world deployment in general. This is even more true today with the development of deep learning based systems. With this speech technology is continuing to catalyse the advancement and proliferation of free software and with that open and reproducible science.

Key words [speech technology, free software, open source software, speech synthesis, speech recognition, speaker recognition]

1 Speech Technology

Speech technology relates to the technologies designed to duplicate and respond to the human voice [1]. It includes a large range of different fields including: speech synthesis, speech recognition, and speaker recognition and verification. Speech technology allows:

1. speech based communication with electronic devices
2. conversion of speech to other forms of information and *vice versa*, such as: text, images, actions / movements, and neural activity.

Speech technology is important for the general public. It allows the creation and deployment of speech enabled devices and thus improves our daily interaction with technology. Some examples include handling a mobile phone while driving and handling smart devices in the household. These technologies are also a core element of the increasingly ubiquitous virtual assistants. Speech synthesis also enables the conversion of textual content into speech, facilitating easier consumption: audiobooks, news / web portals, and e-mail.

Speech technology is also important for people with disabilities. Speech synthesis empowers screen readers that allow the blind and visually impaired to use computers and smart devices. Assistive augmentative and alternative communication (AAC) devices use speech synthesis to give a voice to the deaf and dumb, and the speech impaired. Sign language devices can levy speech recognition to convert speech to sign language for the deaf.

The field of speech technology has always been well-supported by free software. Various speech toolkits have been released by research institutes and advanced by the community. Some of these offer commercial level performance. The paper lists a number of available free software packages for two speech technologies: text-to-speech (TTS) synthesis and automatic speech recognition (ASR). The list is by neither meant to be exhaustive or representative. It is mainly to be used for further exploration of the available free software packages in each of the subfields.

2 Free Software for Speech Synthesis

There are several paradigms in text-to-speech synthesis:

- articulatory synthesis – based on modelling the anatomy and physiology of the vocal tract,
- formant synthesis – based on the filter-source model for shaping the speech signal,
- concatenative synthesis – based on the concatenation of short audio recordings of natural speech,
- parametric synthesis – based on statistical and machine learning models of the speech signal dynamics,
- deep learning based synthesis – based on advanced neural network architectures for speech synthesis.

Four of these five paradigms, except formant synthesis, are covered with free software packages.

VocalTractLab [2] is an articulatory speech synthesizer. It also can be used as a tool to visualize and explore the mechanisms of speech production with regard to articulation, acoustics, and control. The project also has a development version on GitHub [3].

The early concatenative synthesis systems used short speech segments based on diphones, i.e. inter-phone transitions from the stable state of the first to the stable state of the succeeding phone. One of the free software synthesisers supporting diphone synthesis was MBROLA [4]. The Festival Speech Synthesis System supports both diphone and the more advanced unit selection synthesis that is based on larger segments, and was used in most commercial TTS systems before the wide adoption of deep learning models [5].

The Hidden Markov Model/Deep Neural Network (HMM/DNN) based Speech Synthesis System (HTS) [6] is the primary free software used for parametric speech syngvthesis, both in research, as well as commercially. RH Voice [7] that is built on top of HTS, is a free software product that is used as a screen-reader on Windows, Linux and Android by many users with disabilities.

Deep learning based synthesis is a very hot topic in speech research. In fact, most recent papers either include official implementations available as free software, or have been implemented by the community. One of the largest offerings of a variety of latest TTS models is Coqui-AI TTS [8]. A successor of Mozilla TTS, it offers over 20 pretrained language models, and has a vibrant and very active developer community. Another big package is the ESPnet: end-to-end speech processing toolkit [9]. It offers implementations of state-of-the-art synthesis models as well as pretrained models ready for use. Examples of single model implementations are: NVIDIA's Tacotron 2 And WaveGlow v1.10 For PyTorch [10], DeepVoice 3 [11], and Transformer-TTS [12].

3 Free Software for Speech Recognition

As in synthesis, there are several paradigms in automatic speech recognition (ASR):

- template based – the original ASR approach still viable for simple small-vocabulary single-word small-footprint systems. Based on comparison of input words to stored word templates,
- parametric - based on statistical and machine learning models, and
- deep learning - based on advanced neural network architectures.

All paradigms have free software support.

Template based ASR is straight-forward to implement using existing Python libraries, e.g. DTW: Dynamic Time Warping Python Module [13]. Some example systems available online are "DTW* applied to isolate word speech recognition" [14], and "Simple word recognition using dynamic time warping" [15].

Parametric ASR models can be divided in models based on Hidden Markov Models (HMMs) and those based on Weighted Finite State Transducers (WFSTs). The HMM Toolkit (HTK) [16] is one of the most used packages for ASR. Although it was primarily used for speech recognition, it was also applied to HMM based speech synthesis (HTS), character recognition and DNA sequencing. CMUSphinx [17] and PocketSphinx [18] were both based on HTK and were used in real-world applications and commercially. The Julius: Open-Source Large Vocabulary Continuous Speech Recognition Engine [19] is also a free software that was based on HTK and used for real-world ASR.

The Kaldi Speech Recognition Toolkit [20] is an advanced WFST based platform. It comprises high performing models and is actively developed by a big community. Kaldi is deployment ready for use in real-world applications. It has been used by other packages, such as the VOSK Speech Recognition Toolkit [21].

Deep Learning ASR, not unlike TTS, is a hot topic in speech research. Both Coqui-AI and ESPnet offer ASR support. Coqui Speech-to-text (STT) [22] is a fast, multi-platform, deep-learning toolkit. It boasts over 80 pretrained models for over 50 of the world languages, as well as state-of-the-art performance. Like it's TTS counterpart, it is a successor of Mozilla's Project DeepSpeech [23]. An up-and-coming framework that offers ASR is the SpeechBrain all-in-one speech toolkit[24].

4 Free Software for Speaker Recognition

Speaker recognition has also been offered in free software packages. Amongst them we can mention SPEAR: A Speaker Recognition Toolkit based on Bob [25], as well as the ALIZE Speaker Recognition Platform offering commercial grade speaker recognition [26]. SpeechBrain also includes speaker recognition and it's worth keeping an eye on in the future [24].

5 Conclusion

Free software remains to play an important part in speech technology research. Moreover, free software frameworks are becoming increasingly important for real-world deployment of speech technology, even in commercial speech systems. With this speech technology is one of the fields that is continuing to catalyse the advancement and proliferation of free software and with that open and reproducible science.

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TOWARDS FAIR PRINCIPLES FOR OPEN HARDWARE

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Abstract

The lack of scientific openness is identified as one of the key challenges of computational reproducibility. In addition to Open Data, Free and Open-source Software (FOSS) and Open Hardware (OH) can address this challenge by introducing open policies, standards, and recommendations. However, while both FOSS and OH are free to use, study, modify, and redistribute, there are significant differences in sharing and reusing these artifacts. FOSS is increasingly supported with software repositories, but support for OH is lacking, potentially due to the complexity of its digital format and licensing. This paper proposes leveraging FAIR principles to make OH findable, accessible, interoperable, and reusable. We define what FAIR means for OH, how it differs from FOSS, and present examples of unique demands. Also, we evaluate dissemination platforms currently used for OH and provide recommendations.

Keywords: computational reproducibility, FAIR, free software, FOSS, open data, open hardware, open science, open-source.

1 Introduction

Open science emerged as a movement to make scientific research available to broad audiences, from professionals to the general public [1, 2, 3]. In particular, scientific publications, data, physical samples, and software should be made transparent and accessible whenever possible [4, 5, 6]. The movement, helped by community-driven efforts such as the Turing Way [7] and Global Open Science Hardware (GOSH) [8], includes practices like open access to published research, releasing software as Free and Open-Source (FOSS), and experimental instruments as Open-Source Hardware or Open Hardware (OH).[1] These open practices aim to facilitate scientific verification, reuse, and collaboration and to inspire trustworthiness in science.

Software and hardware have been an integral part of scientific research and are increasingly recognized in academic journals and conferences that often encourage their dissemination upon publication. FOSS is, by definition, software that "respects users' freedom and community," which means that it adheres to four essential freedoms: to run the program, to study how the program works, to redistribute copies, and to distribute the modified copies (commercially or non-commercially) [9, 10]. OH is defined as a "physical artifact, either electrical or mechanical, whose design information is available to, and usable by, the public in a way that allows anyone to make, modify, distribute, and use" it [11, 12]. It represents a set of design and legal principles and can refer to a wide range of objects such as computers, scientific instruments, 3D printed furniture, physical constructions, and robots. In practice, OH is commonly

[1]In this paper, we use a common OH abbreviation, however FOSH (standing for Free and Open-Source Hardware) is also occasionally used.

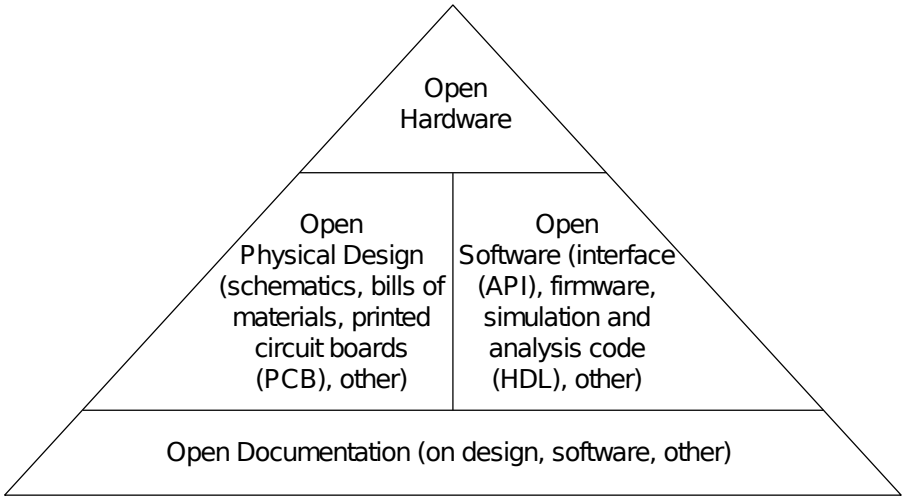

Figure 1: Components of OH (inspired by OSHWA [15, 16]).

captured as digital schematics and drawings with design instructions and a license that allows a reuser to construct and put it to use.[2]

The OH concept was modeled on free software, which led to many issues as software and hardware are fundamentally different and comply with different standards and design principles [13]. Reported challenges of OH reuse include high costs in its construction, imprecise documentation, and complex licensing [14, 15, 16, 12]. In particular, the cost of reusing OH can be high as it implies building custom-made physical artifacts at non-negligible expenses, while in contrast, the cost of reusing FOSS is often marginal.[3] Even slight imprecision in OH description, such as resistor power in schematics, can lead to an unintended final product and a failed investment. Also, OH licenses are complex and have the added risk of patent infringement because OH specifications encompass various artifacts, including design schemes and simulation codes [15]. Because of these issues, reusing or reproducing a study based on OH can be particularly challenging. Reproducibility refers to "obtaining consistent results using the same input data, computational steps, methods, and code, and conditions of analysis" [18, 19, 4, 20]. The need for reproducibility led to a surge of research and development, making scientific work more streamlined, but the challenges of OH reuse still remained.

In this paper, we propose an application of FAIR principles [21] that could help alleviate the complexities in OH dissemination and reuse. We modify FAIR principles to incorporate the needs of OH users. Moreover, we examine current dissemination platforms and evaluate their effectiveness for OH. Our recommendations support open-source values and practical implementations that make OH more discoverable, reusable, and transparent. They should be of interest to OH users, scientists, and repository managers.

2 Open Hardware: background, use cases, and challenges

We can distinguish three components of OH digital form: physical design, software, and documentation (Fig. 1). The physical design includes mechanical drawings, connectivity diagrams (schematics), bills of materials, printed circuit boards (PCB), layout data, and more. The software component may include HDL (hardware description language) source code, which is used to simulate and validate the design's intended functionality while allowing architectural exploration and comparing variations of

[2]In this paper, we examine OH used for research, which in addition to the design component typically includes software.

[3]OH can be highly profitable [14, 17]. For example, opening Arduino OH and FOSS created significant revenue of $56.8 M per year (https://growjo.com/company/Arduino).

a base design. The software component may also include software firmware (drivers) that operate the hardware, an open interface to the hardware, and an open implementation covering a set of tools to create and test a design. Finally, the documentation component offers information on assembling and running the OH. Understanding the structure of OH helps us grasp the complexity of its capture, dissemination, and reuse.

The use of OH in science has been recognized internationally by researchers and institutions. The nonprofit Open Source Hardware Association (OSHWA) fosters technological knowledge of hardware, promotes its development, and maintains certification. The increased popularity of OH is demonstrated by the significant rise of certified projects over a single year (64%, from 977 on August 24, 2020 to 1601 on July 19, 2021) [22]. It is estimated that a national OH policy in Finland (with a funding mechanism that supports OH development) would provide 90% in savings compared to the cost of proprietary hardware [17], which is in line with the EU findings [23]. The first official government document with a strategy for FOSS in research for 2021-2024 was released in July 2021 by the French Ministry of Higher Education, Research, and Innovation [24]. Another example is the European Organization for Nuclear Research (CERN) introducing a policy to publish its experimental hardware in open access journals and invest in OH initiatives [25].

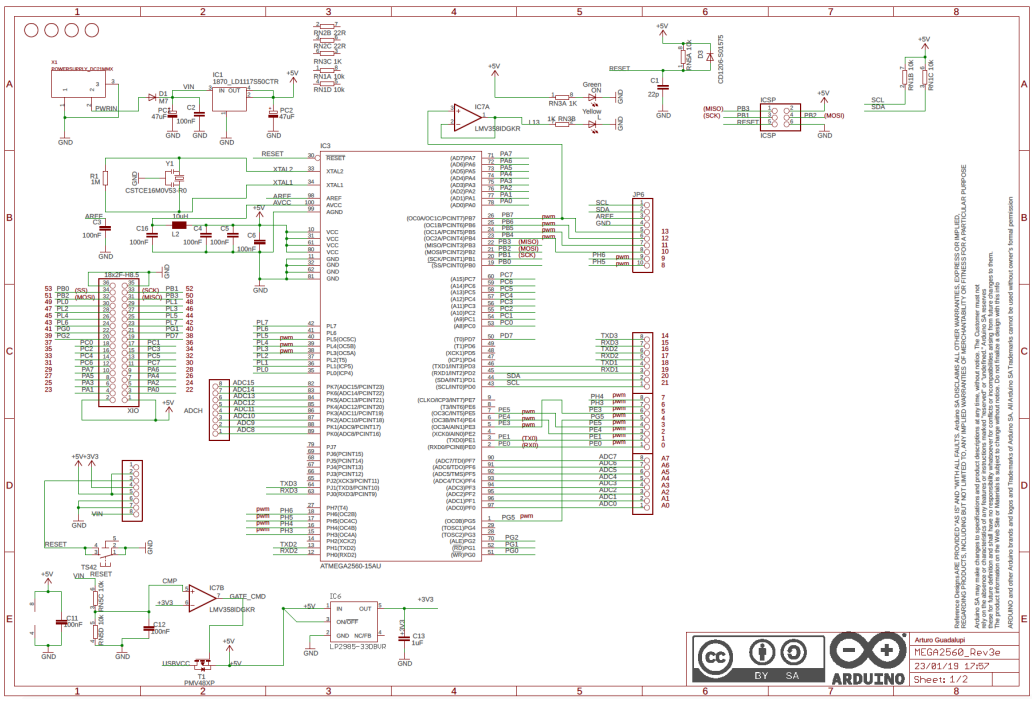

Figure 2: Arduino MEGA 2560 Schematics licensed under CC BY SA license [26]

An example of a highly successful and widely used OH design is the Arduino MEGA 2560 microcontroller board (screenshot of the design file shown in Fig. 2). With the open design file and its permissive license, a replica (Fig. 3 right) of the original printed circuit board (Fig. 3 left) can be produced and legally sold around the world [26]. However, the copies cannot contain the Arduino name and logo as the trademark is protected. The trademark can be used if a company becomes an official manufacturer, such as Smart Projects in Italy, SparkFun in the USA, and Dog Hunter in Taiwan/China [27]. These boards are easily programmable and able to receive input (e.g., read input from a light sensor) and generate output according to a custom algorithm (e.g., if a room is dark, turn on the light) at a low price (e.g., MEGA 256 board costs at most 35 EUR [28]). In addition to simple applications, Arduino boards have been extensively used in scientific research [17, 29], including as part of other OH designs [30, 31, 32].

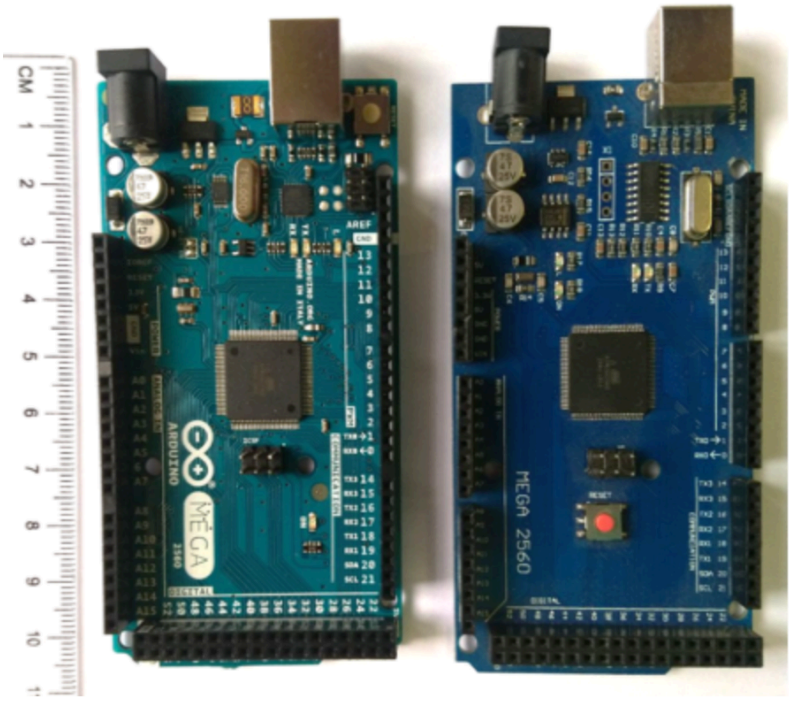

Figure 3: Comparison of the original Arduino MEGA 2560 board produced in Italy on the left, and a derived MEGA 2560 board produced in China based on the open design (see schematics at Fig. 2). Photo Credit: N.M.

To illustrate the challenges of OH dissemination and reuse in scientific research, we examine three published studies that used OH: Actifield device for measuring movements of laboratory rodents [30], a non-contact thermometer to prevent the spread of the contagious diseases [31], and an electronic board BioAmp EXG Pill for measuring signals in the human body such as electrical heart potentials or electrocardiogram (ECG) [32].

Three dedicated licenses were applied for the BioAmp EXG Pill design, software, and documentation, as mandated for OSHWA certification (Tab. 1). Projects disseminated through HardwareX journal are assigned the same license for both hardware and software components: for the thermometer, a CC BY-SA license was applied, and for the actifield device, a GNU GPL license was used. The CC license is mainly intended for work regulated by copyright law (e.g., for books, music, photographs, articles) and therefore is less suitable for software and OH. On the other hand, the GNU GPL license is widely used for FOSS, but it is ineligible for OH. The documentation was licensed under CC BY in all use cases, but some differences emerged. For example, the actifield device and the thermometer HardwareX articles provide more details for further OH reuse due to the article template requiring information such as build and operation instructions, validation and characterization, and the bill of materials [33]. Another advantage of dissemination through specialized journals such as HardwareX is the application of persistent identifiers. Although OSHWA also provides unique identifiers, information on their persistence is not available.

The Open Science Framework (OSF), as a common choice for disseminating OH design files, was used for the actifield and the thermometer studies. However, while the actifield data contain structured OSF metadata (e.g., license, registration DOI, tags), the thermometer data deposit lacks structure and has only two folders with code and images. On the other hand, the BioAmp EXG Pill data deposit provides metadata on GitHub (e.g., keywords, license) but without a persistent identifier. Interestingly, some of the actifield data are not shared but available "on reasonable request" [30] even though the study was published in an open-access journal. This presents another complexity in its reuse as the

Use case		Actifield device [30]	Thermometer [31]	BioAmp EXG Pill [32]
Main dissemination channel		HardwareX journal		OSHWA
Licenses	Physical design	GNU GPL	CC BY-SA	CERN-OH
	Software			MIT
	Documentation	CC BY		
Design files repository		Open Science Framework (OSF)		GitHub and dedicated website
Identifier		persistent identifier (journal/ OSF DOI)		OSHWA unique identifier
Metadata		OSF and article metadata	article metadata	OSHWA metadata

Table 1: OH use-case examples

study had closed data, open design files, FOSS, and open documentation.

From the examined use cases, we identify the following challenges of OH reuse: (1) choosing adequate licenses for its design, software, data, and documentation, (2) identifying a dissemination channel (e.g., OSHWA, HardwareX, GitHub, or other), (3) organizing, separating and interlinking resources (e.g., if software and hardware are used for the same purpose researchers tend to choose the same license), and (4) providing detailed metadata and documentation on OH to be reusable, modifiable, and reproducible. Some of these challenges have been previously reported [13, 15, 14, 16, 12] but not fully addressed in practice. In addition, establishing a specialized repository for OH dissemination has not been examined. In the following, we elaborate on the identified challenges.

2.1 Licensing hardware and software

The separation of physical and software components of OH has been advised with the instruction to use traditional software licenses for firmware and code loaded in programmable electronic devices [34, 11, 35]. However, schematics with a graphical circuit representation can fall between the analog design and software code categories. They are not solely a connectivity diagram and can serve for circuit simulation and even produce data as, for example, in the Simulation Program with Integrated Circuit Emphasis (SPICE) [36]. Further, a complexity can emerge when OH is a part of another OH, such as for example, in the non-contact thermometer (licensed under GNU GPL) containing an Arduino UNO unit licensed with Creative Commons (CC BY SA) license [31]. Therefore, licensing OH can be a complex procedure requiring an application-oriented approach rather than defining a common framework [23].

Specialized licenses for the OH design component include the CERN Open Hardware License (CERN OHL) with three sharing mechanisms (strongly reciprocal, weakly reciprocal, and permissive), Solderpad, based on the Apache software license, and Tucson Amateur Packet Radio (TAPR) license, adapted from the GNU General Public License. The Solderpad license maintained by the Free and Open Source Silicon Foundation (fossi-foundation.org), has also been recommended as a software license [37]. Although hardware licenses have existed for about a decade, some of the most successful OH designs (e.g., Arduino) are licensed under Creative Commons (CC) Attribution Share-Alike 2.5 (released in 2005 before the establishment of OH licenses).

2.2 Dissemination channel selection

The precondition for OH reuse is that one can access its complete design (i.e., open-source code) [37]. Public availability of OH is beneficial as sharing provides a firm base for democratic participation in production and reuse [38], especially in response to global crises such as the COVID-19 pandemic [39,

40]. In response to a growing need for medical devices [39], HardwareX journal launched a Special Issue on COVID-19 medical hardware [41] presenting, for example, an open-source solution for non-contact temperature measurement [31].

However, there is no universally used repository for open hardware [13]. The three most common dissemination methods are the Open Hardware repository (ohwr.org), git-based repositories (e.g., GitHub, GitLab), and via dedicated journals (i.e., HardwareX, Journal of Open Hardware, Journal of Open Engineering). Certified hardware is typically hosted on GitHub, but some are shared on Google Drive or personal and producer websites and indexed at OSHWA [42]. HardwareX accepts a variety of repositories for sharing OH and FOSS, including OSF, Mendeley Data, GitHub, and Zenodo.

Researchers and developers commonly use GitHub to share, store and version their code, data, design files, and documentation. It is based on a well-known distributed version-control system, Git, used for collaborative work in the software developer community. There are numerous benefits of using git-based platforms such as GitHub, GitLab, and BitBucket, but some precautions are warranted. For instance, the current list of officially offered licenses at GitHub does not include any OH licenses. In addition, there is neither a uniformly applicable curation policy nor metadata. FSF constantly evaluates popular repositories and does not encourage using GitHub for several reasons, including the incomplete licensing practice and the use of proprietary software on the platform [43]. On the other hand, git-based repositories, including GitHub, are free of charge, convenient to use [4] and effective for version control and collaborative development [5, 44]. They seamlessly incorporate advanced tools like workflows, software testing, and persistent identifiers [5, 44]. GitHub has built-in support for repository citations as of August 2021 [45]. Furthermore, git-based platforms can enable FAIR-compliant resource sharing with additional efforts from OH depositors. For instance, the lack of metadata can be bridged with rich documentation in readme files.

Zenodo, Dataverse, and other similar repositories mainly used for sharing publications, data, and software, can also be employed for OH dissemination. Zenodo even supports a deposit type such as Physical Object in the general "Other" category. The main disadvantage of Zenodo is that it does not incorporate software or hardware licenses. Dataverse, on the other hand, specializes in the dissemination of data, meaning that licenses would need to be applied manually. However, both repositories mint a unique identifier DOI, are free to use and have a long-term preservation commitment.

2.3 Level of documentation detail

Hardware is generally less documented than software, even though consistent documentation is crucial for complete and accurate OH [13, 46]. Bonvoisin et al. referred to the completeness of OH documentation in terms of the freedoms of FOSS: freedom to study can be exercised by the schematics publication (see Fig. 2 for Arduino MEGA 2560); publishing documents in editable format can support the freedom to modify; freedom to make can be practiced by the publication of bill of materials and assembly instructions, and the selection of appropriate license can grant freedom to distribute. In addition to these principles, it is proposed that documentation of OH should incorporate guidelines for participation, degree of maturity of the shared OH (i.e., design, prototype, full product), and the status of the community (e.g., active or not active) [13]. Although setting an OH documentation standard has been considered critical [13], it has not materialized, to the best of our knowledge.

Structured metadata presents an essential aspect of the overall project documentation, especially machine actionable metadata, which is integral to FAIR principles. We address OH metadata in the following section.

3 FAIR principles for open hardware

In order to facilitate high-quality research dissemination in the information age, a set of FAIR principles emerged to improve the findability, accessibility, interoperability, and reuse of digital assets. The guidelines emphasized machine-actionability and data management with minimal human intervention due to the ever-increasing complexity and volume of data. The FAIR principles have since been widely recognized and employed in many data repositories and data archiving warehouses. Even though they were primarily intended for data sharing, they found an application in sharing of software code [44, 20], as code availability was identified as an essential component of scientific reproducibility [4, 47]. We argue that OH is the next frontier for FAIR principles.

The first FAIR principle, or *Finable*, mandates that "data and metadata should be easy to find for both humans and computers" [7]. OH should be identified with a unique ID. OSHWA certifies open hardware designs and provides a unique identifier, which is not persistent but can be used for this purpose, and commonly used DOIs can be a viable alternative. *Accessibility* mandates access to the resource, potentially with authentication or authorization. It means that OH needs to be retrievable using its digital record via an open, free, and universally used protocol, such as HTTP. The protocol should allow for authentication and authorization when necessary. *Interoperability* means that "data needs to be integrated with other data" and that it "needs to interoperate with applications or workflows for analysis, storage, and processing" [7]. Last, the *Reuseable* principle mandates that "metadata and data should be well-described so that they can be replicated and/or combined in different settings" [7] for optimal reuse. OH should be described with machine-readable metadata, which is critical for automatically discovering resources on the web. An ongoing Field Ready project (2021-2023) aims to develop and maintain metadata standards for OH.[4]

Since FAIR principles have been proposed and applied to research data and software, their implementation on OH, which incorporates both, should be attainable. Some aspects of FAIR can be reused from previous work, though there are gaps that need to be addressed for each principle, and an interpretation for OH should be more clearly provided. In Tab. 2 we show an application of FAIR principles, using "hardware" to denote the digital description of OH (as shown in Fig. 1).

Findability for OH may be implemented with unique identifiers and specific metadata similarly to its implementation for research data and software. Regarding accessibility, we note that infrastructure for OH dissemination remains a challenge as OH files are currently often (disassembled and) shared at multiple places. For interoperability, we emphasize the use of standard knowledge representation and cross-referencing of all required components of OH. Finally, the reusable principle calls for adequate licenses and provenance for all components of OH. Here, we propose a new sub-principle (R2) mandating an explicit dependency tree of OH to other required components, which may include a dependency on other hardware (Tab. 2). The sub-principle was modeled on the FAIR for research software framework and further expanded it to a physical realm by adding a reference to available components required for successful OH reuse.

Similar to research data which may not always be released as open data, some specific caveats exist when working with OH. First, source code can be FAIR and shared even if it has proprietary dependencies. For example, the most common source code at the Harvard Dataverse research repository is proprietary [48]. Similarly, hardware components can comply with the FAIR principles even with proprietary dependencies. Second, some OH medical diagnosis and treatment designs may be limited to research purposes only. Therefore, appropriate regulations and legislation for designs with the intended medical application need to be specified before their dissemination [39].

[4] https://sloan.org/grant-detail/9626

Table 2: FAIR principles for data [21], research software [49], and open hardware (proposed, modifications are underlined).

Data (www.go-fair.org)	**Research software [49]**	**Open Hardware (proposed)**
	Findable	
F1. (Meta)data are assigned a globally unique and persistent identifier	F1. Software is assigned a globally unique and persistent identifier	F1. Hardware is assigned a globally unique and persistent identifier through OSHWA or a trusted repository, such that each hardware design and software versions have unique identifier
F2. Data are described with rich metadata (defined by R1 below)	F2. Software is described with rich metadata	F2. Hardware is described with rich metadata (defined by R1 below)
F3. Metadata clearly and explicitly include the identifier of the data they describe	F3. Metadata clearly and explicitly include the identifier of the software they describe	F3. Metadata clearly and explicitly include the identifier (DOI or OSHWA) of the hardware they describe
F4. (Meta)data are registered or indexed in a searchable resource	F4. Software is registered or indexed in a searchable resource	F4. Hardware is registered or indexed in a searchable resource through OSHWA or a registry
	Accessible	
A1. (Meta)data are retrievable by their identifier using a standardized communications protocol (the protocol is open, free, and universally implementable, and to allow for an authentication and authorization procedure, where necessary)	A1. Software is retrievable by its identifier using a standardized communications protocol	A1. Hardware is open and retrievable by its identifier using a standardized communications protocol (the protocol is open, free, and universally implementable, and to allow for an authentication and authorization procedure, where necessary). OH files should be stored cohesively on a repository infrastructure (rather than in multiple disjointed locations), which support long-term hardware stewardship.
A2. Metadata are accessible, even when the data are no longer available.	A2. Metadata are accessible, even when the software is no longer available	A2. Metadata is accessible, even when the hardware is no longer available.
	Interoperable	
I1. (Meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.	I1. Software should read, write or exchange data in a way that meets domain-relevant community standards	I1. Hardware uses a formal, accessible, shared, and broadly applicable language for knowledge representation used in both academia and industry (and enabling their collaboration).
I2. (Meta)data use vocabularies that follow FAIR principles	I2. Software includes qualified references to other objects.	I2. Hardware uses vocabularies that follow FAIR principles
I3. (Meta)data include qualified references to other (meta)data		I3. Hardware includes cross-references (to own software, data, documentation) and qualified references to other objects (e.g., software, data, documentation).

Table 2: FAIR principles for data [21], research software [49], and open hardware (proposed, modifications are underlined).

Data (www.go-fair.org)	**Research software [49]**	**Open Hardware (proposed)**
	Reusable	
R1. (Meta)data are richly described with a plurality of accurate and relevant attributes (with a clear and accessible data usage license, detailed provenance, whilst meeting domain-relevant community standards).	R1. Software is richly described with a plurality of accurate and relevant attributes	R1. Hardware is richly described with a plurality of accurate and relevant attributes that reflects its complex structure compliant with the OSHWA definition (with clear and accessible usage licenses, to be applied on each of the components and compatible with the dependencies, detailed provenance on all components (bill of materials, assembly instructions and other), whilst meeting domain-relevant community standards).
	R2. Software includes qualified references to other software	R2. Hardware includes qualified references to other hardware and available components (that would enable reuse).

4 Related research

The CURE-FAIR (CUrating for REproducible FAIR data and code) RDA (Research Data Alliance) working group [20] investigated the current landscape for the adoption of best practices for computational reproducibility by acquiring recommendations and challenges from both literature and the community. The report highlighted the importance of openness and provided some key remarks including FAIR and beyond-FAIR challenges for reproducibility using FOSS, which are also relevant for OH.

Applying FAIR principles from research data to software turned out to be non-trivial due to the software complexity and unsteadiness [50, 49]. Moreover, qualities beyond FAIR such as maintainability of the software, version control, quality control, computational efficacy, and others have been identified as valuable [44, 20]. OH adds to this complexity as, for example, schematics can be seen as both design file and software, and can even produce data. It has been suggested that before defining EU policies on OH and adopting OH widely, appropriate guidelines for OH concerning existing industrial standards should be introduced [23]. Progress has already been made in Germany where the Association of Open Source Ecology Germany (OSEG), in collaboration with the German Institute for Standardization, has carried out a project that aims to develop standardization for OH termed DIN SPEC 3105 [51, 52].

The need for reuse and enhanced findability of existing OH designs has been recognized and addressed in the literature [53]. Ezoji et al. conclude that there is a need for good documentation practices that would enable reusability. We believe that applying FAIR principles to OH and adopting good reproducibility practices would enhance the reuse of existing OH designs in research and the industry. Besides code availability, an in-detail description of the software, its environment, and hardware requirements should be available to enable reproducible outputs [47].

5 Conclusions

The paper provides a perspective on leveraging FAIR principles for the dissemination of scientific OH. Considering contemporary science motivations, from research reproducibility to open collaboration,

we believe that applying FAIR principles to OH would be a significant step forward, making it documented, finable, accessible, interoperable, and reusable on the web. Thus, it would improve OH curation and its recognition as a complete scientific output. In addition, effective OH dissemination would aid reproducibility on a higher level, beyond the computational part of the study process. FAIR cannot guarantee complete openness of hardware, working functionality, and reproducibility, but it would undoubtedly facilitate it and provide venues for further research across disciplines. Incorporating FAIR principles in the dissemination of scientific OH and adopting best practices such as free OSHWA certification would provide a solid ground for reproducible and reusable research results.

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FREE SOFTWARE FOR ANALOG AND DIGITAL DESIGN

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Abstract

This paper presents an overview of free and open-source software tools for analog and digital design, with emphasis on integrated circuit design. Software tools are essential to harness the full potential of modern CMOS processes, and to enable the design of increasingly complex chips in the first place. Features and limitations of existing software tools are reviewed, as well as missing tools and features important for complex chip design. Some thoughts on improvement of existing, and arguments for development of new, tools are given. Most of the suggested improvements and development of new tools refer to analog design flow because it is not complete, and in its current form cannot be used for the design of high-performance chips. A major obstacle in using free and open-source software tools for chip design is the lack of support from foundries. Problems with foundry-provided process design kits in proprietary formats are discussed, and possible solutions are suggested.

Keywords: [open-source, EDA, integrated circuits, analog, digital.]

1 Introduction

Few years after the very first monolithic integrated circuit was made by Robert Noyce in 1959, Gordon Moore has made a prediction in 1965 that complexity will exponentially increase ”at least for 10 years”. Exponential trend has been sustained for more than 50 years, resulting in unparalleled growth of complexity and performance of integrated circuits. It has been a long journey from humble 2250 transistors in Intel 4004, designed in 1971, to tens of billions of transistors in 2021, an increase in number of transistors of more than seven orders of magnitude in 50 years!

Early on, increasing complexity of integrated circuits was welcomed - more transistors could be integrated into a single chip, reducing the overall system size, cost and power consumption. Exponential growth eventually became a problem, as number of transistors overwhelmed engineers, and it became clear that new methodologies and tools are needed. New design methodologies were needed to cope with exponentially increasing chip complexity and to take full advantage of CMOS scaling. Software tools were needed to help engineers focus on design, and automate it as much as possible. Automation was important not just to free engineers from tedious and error-prone tasks, but to make the design and verification of complex chips possible at all.

In late ’70s Conway and Mead have observed that all CMOS design rules, across process nodes and different foundries, can be expressed in terms of integer multiples of lambda units, where lambda is usually half of the minimum feature size [1]. Introduction of lambda-based rules has enabled the design of scalable, process independent, designs and has triggered a VLSI revolution.

Cells designed with lambda-based design rules are not optimal, but are portable across foundries and process nodes. They can be designed once and reused in any CMOS process - Conway formulated that such designs have a ”timeless quality”. Due to phenomenal pace of CMOS process development in 80s and 90s, in many cases better performance could be achieved by porting a lambda-based design

to a new process by simple geometry scaling, than optimizing for an existing process.

Another big step in VLSI revolution was separation of chip design and manufacture. Semiconductor foundries, as they were first called by Mead, are providing manufacturing services to fabless chip design companies. The importance of this concept can be seen from the fact that most of the companies in the semiconductor business are fabless. An excellent read on VLSI revolution is Lynn Conway's personal accounts of events that triggered VLSI revolution is [1].

Fast forward forty years into 2021 many things have changed. Cost and complexity of advanced CMOS nodes has has left only a few foundries following Moore's law to 10 nm and below. Other foundries have stopped development of new nodes, trying to enhance the yield and enrich existing processes with new devices - a concept which is sometimes called "more than Moore".

Demand for lowest chip area and power consumption, increasingly complex design rules, and slower pace of process development have made lambda-based cell design less attractive. Instead of using scaled cells in all process nodes, foundries usually provide a library of digital cells optimized for a given process. Digital designs are synthesized from description in a hardware description language (HDL), such as Verilog or VHDL, or some higher level of abstraction. In a sense, not much has changed, only the "timeless quality" of a design has shifted from lambda-based layout to a more abstract representation in HDL.

Complexity of analog designs has also increased over time - not as dramatic as in digital designs - but still in orders of magnitude. Most CMOS processes are optimized primarily for digital circuits, and analog designs have to "fit in". This creates unique challenges for analog designer because analog/RF circuits don't always benefit from process scaling. Scaled processes offer transistors with higher operating frequency, but at reduced supply voltage and lower intrinsic gain, having detrimental effect on analog performance. In RF designs, area of integrated inductors does not scale with process at all because inductance is determined solely by geometry of windings.

Software tools are essential to harness the full potential of advanced CMOS processes and cope with design complexity. Following sections present an overview of FOSS tools for analog and digital design flow. Overview covers only a portion of available tools, which are most representative in authors opinion, and highlights missing tools or features.

2 Digital Design Flow

Modern digital design flow relies on many software tools to generate a chip layout from a given design. A majority of digital chips are built using libraries of standard cells provided by a foundry. In rare cases, where minimum delay or power consumption are imperative, digital circuits are designed on a transistor level - full custom design. Full custom digital design relies on analog design flow to accurately capture timing and power information, and is very time and resource consuming. As the nature of full custom digital design limits its scope to small designs, or critical parts of larger designs, it will not be considered as a part of digital flow in this paper.

Digital design can be roughly partitioned to logic and physical design phase. In a logic design phase the design is synthesized - design is read-in from a given description, optimized for specified goals, and mapped to a set of available logic gates and sequential elements available in a given standard cell library. Physical design tool takes the synthesized design netlist, and performs iterative place and route (PnR) until design goals are satisfied. Finally, placed and routed design layout is extracted for parasitic resistance and capacitance, timing model is generated, and timing constraints are verified.

Digital circuit can be described at various level of abstraction, from gate level, through register transfer logic (RTL), to abstract descriptions on algorithmic level. Gate level description is rarely used, as it locks the design to a specific standard cell library and process, and is time consuming, hard to debug

and maintain.

Most designs are implemented on RTL level, usually in Verilog or VHDL, where design intent is explicitly stated, while implementation and optimization details are left to synthesis tool, according to specified constraints. Design intent in RTL encompasses specifying signal types, digital logic equations, state machine states and transitions, placement of pipeline registers etc. Synthesis tool deals with details of implementation and optimization, such as common subexpression elimination, resource duplication to satisfy fanout constraints, timing and area, state machine encoding, pipeline retiming etc. Output of synthesis tool is a netlist of gates from a given standard cell library.

Various higher levels of abstraction are also used in digital designs. One of prominent FOSS high level hardware description languages, developed at UC Berkeley, is Chisel [6]. Chisel is based on Scala language with many extension classes, which are used to translate the design to an intermediate representation, optimize it, and emit a Verilog code for synthesis. It is an abstract HDL, in the sense that it can infer signal types, and that it is more expressive than Verilog or VHDL, but is not abstract on algorithmic level. Chisel has attracted a lot of attention in academia and industry because design generators, ranging from block level to full SoC, have been written in it.

Algorithmic level abstraction tool, also called high level synthesis (HLS), takes design intent description in C/C++ (SystemC) or other high level language, and generates all logic equations, state machines, pipeling etc. automatically according to specified constraints. For example, to design a FIR filter, designer only provides filter coefficients and uses a C/C++ library function - the HLS tool takes care of details, such as constant multiplier design, pipelining etc. To the best of author's knowledge, there aren't any widely used algorithmic level digital design FOSS tools.

Simulation of complex digital designs is essential for development and verification. Verilog designs can be simulated with Icarus Verilog [7], while VHDL designs can be simulated with GHDL [8]. Both Icarus and GHDL can simulate any valid language construct, including timing delays and behavioral code. Orders of magnitude faster simulation of Verilog code is possible with Verilator [9] if only a synthesizable subset of Verilog is used in a design. Verilator transforms synthesizable Verilog to optimized C++ code, which can be compiled and used as any software component. Common use case for Verilator is to generate a cycle/bit accurate C++ simulator for CPUs or DSP blocks.

Regardless of whether the digital design is specified in Verilog/VHDL or some higher level tool, eventually it has to be synthesized to standard library gates. Digital design has been made truly vendor-agnostic by standardizing:

- Logic function, timing and power are specified in Liberty library (.LIB) files, containing tables of delay, rise and fall times, and power vs loading capacitance.
- Process information and simplified abstract views of gate layouts are provided in Library Exchange Format (.LEF). Simplified abstract views are derived from layout by keeping only the cell boundary, pin locations and routing blockage information. Complete cell layouts are needed only for LVS, DRC or tapeout.
- Cell placement and design routing is kept in a Design Exchange File (.DEF).

Most foundries provide standard digital libraries under NDA, with SkyWater being a notable exception. SkyWater is providing open-source PDK for a 130 nm CMOS process [10], which can be used in open-source digital flow.

OpenROAD project [2] has produced a complete FOSS digital flow called OpenLane [3] by putting together available tools and developing new ones. OpenLane is not the first complete FOSS digital flow, but is actively maintained and has gained significant attention.

Design flow in OpenLane consists of design exploration outer loop and synthesis exploration inner loop. Design exploration loop evaluates a complete - synthesized, placed and routed - design. During synthesis exploration the design is repeatedly synthesized with various options, and result of each synthesis run is processed by static timing analysis tool OpenSTA to evaluate its performance.

Synthesis in OpenLane flow is performed by Yosys+ABC [4]. Yosys is currently the most complete open-source synthesis tool, which can synthesize a Verilog design, optimize and map to gates from a given Liberty library. It has been used to synthesize complex digital systems, and is considered to be a robust tool.

However, some features are missing in Yosys. VHDL support requires an external proprietary tool, but work is ongoing to provide open-source alternative. More importantly, advanced synthesis options, such as pipeline retiming, physically aware synthesis, clock domains, support for SDC constraints, etc. are missing. These advanced features are important to achieve better quality of results, comparable to prorietary tools.

Floorplanning, placement, clock tree synthesis, optimization and global routing of synthesized design is performed by OpenROAD applications. Optimizations performed during physical design phase are not only related to cell placement and routing, but also gate resizing to satisfy design constraints. Placed and routed design is exported to design exchange format (DEF).

When design exploration is finished, parasitic resistances and capacitances of routed design are extracted with SPEF Extractor [5], saved in a Standard Parasitic Exchange Format (SPEF) and used for final STA check. SPEF Extractor is a Python script which takes library LEF and design DEF files and calculates parasitic resistance and capacitance of routing. Algorithm used for RC extraction is simple, straight forward, and is likely to produce low accuracy results, so more work, or another extractor, is needed to match the accuracy of proprietary tools.

Design rule check (DRC) is performed by Magic, while the layout versus schematic check is performed by netgen. If there are no errors the design is exported to GDSII file, which is used for chip fabrication.

The described digital flow is complete, in a sense that a FOSS tool exist for every step from RTL to chip layout in GDSII. It is incomplete in a sense that some tools are not adequate for complex designs, and should be improved or replaced.

3 Analog Design

Standardization of library formats for digital design (LIB, LEF, DEF) has enabled a true vendor-agnostic design flow. Such standardization does not exist for analog design flow, and foundry-provided process design kits are usually tied to one vendor. Process design kits contain device model decks used for simulation, parametrized primitive device layouts, physical verification (DRC, LVS) rules and process information for parasitic extraction, all of which are needed in analog design flow.

Circuit simulation is a first step in the analog design flow. One of the best known open-source simulator is SPICE, developed at UC Berkeley. SPICE circuit simulator was revolutionary at the time it was introduced. It provided robust algorithms for solving electrical circuits, and an extensible framework to add new device models and analyses. Perhaps most importantly - authors have made the SPICE source code publicly available. open-source derivatives of SPICE, such as Ngspice [11], are still actively developed.

Last version of SPICE released by UC Berkeley (SPICE3F5) was improved and extended over the years, requiring changes of netlist syntax. Changes of netlist syntax were necessary to support convenience features, such as variables and expressions, and core features, such as model binning, new device types and analyses. Myriad of SPICE-like simulators, both FOSS and propietary, expanded the

original SPICE netlist syntax independently, resulting in many incompatible dialects - SPICE Tower of Babel. Proprietary extensions, for example ”A” behavioral devices in LTSpice, are another source of incompatibility. To make matters even more complicated, some proprietary simulators are using proprietary netlist languages.

Incompatible netlist formats, either SPICE dialects or proprietary languages, pose a major problem in using FOSS circuit simulators. To the best of author’s knowledge, there is no technical reason why that must be the case. Most device models, such as BSIM, PSP, etc., are developed by a third party and are freely available. Therefore, model decks for any simulator, i.e. in any netlist format, convey the same information - the only issue seems to be how to read-in model parameters from a netlist.

A possible solution for netlist language incompatibilites is to standardize a netlist language for circuit simulation. Standardization is a colossal effort, and would probably be affected by conflicting interests, so it might take a very long time, if ever, to complete. A step in the right direction would be to develop an unified intermediate representation of analog netlists, and parsers for existing netlist languages, which would decouple simulator front-end from a simulator core. Short-term solution, or rather a duct tape to hold the design flow together, would be to make a translator of netlist in proprietary netlist language to flat SPICE netlist. Flat SPICE netlist would elliminate any issues with hierarchy, parameter evaluation, conditional expressions, etc. and should enable the use of FOSS simulators with already existing PDKs. From a technical point of view, such translators should be feasible, but whether there would be any legal issues is beyond the scope of this paper and author’s expertise.

For an analog circuit netlist to be truly vendor-agnostic, non-standard or behavioral devices should be modeled with Verilog-A instead of using simulator specific custom devices, or (mis)using controlled sources by exploiting some simulator specific implementation. Therefore, Verilog-A support is of paramount importance for circuit simulators, even for core device models. For example, BSIM6 is provided only as a Verilog-A model, in contrast to earlier versions of BSIM.

Support for compiling and dynamic loading of Verilog-A models is a standard feature in proprietary simulators. In principle, Verilog-A models could be used instead of built-in models, effectively decoupling the simulator core from models and thus providing ultimate flexibility. Although possible, such approach is not used for core models due to performance penalty of using automatically generated code, but is useful for custom Verilog-A models. FOSS circuit simulators, such as Ngspice, Qucs and Xyce, rely on a tool called ADMS for compiling a Verilog-A code.

ADMS is a tool which reads a Verilog-A model and outputs code based on rules and code templates given in XML. Processing a Verilog-A model involves parsing, building an abstract representation, which usually requires algebraic manupulations, calculation of derivatives and optimizations, such as node collapsing. Abstract representation is then used to generate simulator-specific code from provided templates. Generated code can be compiled to a shared library, which can be dynamically loaded by Ngspice to add support for new models.

Dynamically adding new device or behavioral models to simulator via compiled Verilog-A code provides ultimate flexibility and is a very important feature. However, ADMS does not support all of Verilog-A constructs, which poses a limitation on which devices or behavioral models can be added. Furthermore, ADMS is not actively developed nor maintained, and is likely to remain that way. In author’s opinion, revival of ADMS development, or a new implementation, should be one of priorities for analog design flow to progress.

Simulator architecture and mathematical formulation can have a significant impact on code maintenance and development, as well on performance and scalability. SPICE derivatives, such as Ngspice, are still using legacy progamming paradigms and code base. For example, SPICE requires that each device model provide a separate function for each type of analysis. Analysis-specific device model function is then responsible for calculating MNA contributions by calling a numerical integration rou-

tine NIntegrate, provided by simulator core. Although used in SPICE derivatives for decades, there are advantages and drawbacks of such approach.

Advantage of requiring that device model provide a separate function for each analysis type is that mathematical formulation and implemenation could be optimized for a specific analysis. As a side effect, it simplifies simulator development since it delegates matrix fill-in to device models. An obvious disadvantage is that introducing a new type of analysis would require updating all device models with a new function. A not-so-obvious disadvantage is that direct matrix fill-in by device models, which rely on simulator-provided numerical integration, couples simulator core algorithms with device models. Such copling complicates development of either simulator core or device models, as any changes might have unforeseen effects and require changes in a large code base.

Direct matrix fill-in hides important details from a simulator, which might be needed in certain types of analyses. For example, mathematical formulation of harmonic balance (HB) analysis requires that a circuit is partitioned to linear and non-linear parts. Separating linear from non-linear branches is difficult when a device model provides only numerical values for matrix fill-in. Similar problems arise in other types of analyses, such as periodic steady state (PSS) analysis and its small signal variants. Aforementioned difficulties could be, in principle, solved within legacy SPICE framework, but it would require more hacking the existing code than developing new features, and making code increasingly difficult to maintain and develop.

Demand for increased integration and low power has resulted in SoCs which contain digital, analog, mixed signal, RF and power converters on the same chip. Harmonic balance and periodic steady state, followed by corresponding small signal and transfer function, analyses are essential for development of such SoCs. Lack of HB, PSS and corresponding small signal and transfer function analyses is a major obstacle for designing highly integrated SoCs.

Besides FOSS SPICE circuit simulator derivatives, there are simulators using modern object oriented programming paradigms and mathematical formulations. Xyce [12] is an open-source simulator developed at Sandia National Laboratories. It is not a SPICE derivative, but a new implementation written in C++, using advantages of object oriented programming paradigm to allow easier development, adding new features, and code which is maintenable in the long term. Mathematical formulation used in Xyce is different than the one used in SPICE. Instead of relying on device models to perform numerical integration and fill-in MNA matrix, as is the case in SPICE-based simulators, Xyce uses Differential-Algebraic Equation (DAE) formulation. DAE formulation, used in Xyce and some proprietary simulators, requires that device models only provide branch contributions and their derivatives, while numerical integration and MNA matrix fill-in is handled by the simulator core algorithms.

SPICE-derivatives and DAE-based simulators eventually solve a system of equations determined by MNA matrix and right-hand side, and it may seem that DAE formulation is a minor reformulation of SPICE algorithms. However, this is not the case - DAE formulation is a major improvement for several reasons. In DAE-based simulators device models are just that - they provide information about branches, calculate branch currents, charges and their derivatives from given terminal voltages - nothing more or less. Everything else - numerical integration, analysis specific circuit partition, MNA fill-in etc. is handled exclusively by the simulator core. This in effect decouples the development of device models and simulator algorithms and analyses. Any improvement in simulator core, such as new analysis type, or a new ODE integration algorithm, does not require any change in device models, and is immediately available. In contrast, implementing a new type of simulation in SPICE-derivatives would require that a new function is provided for each device model.

Device models for DAE-based simulators are available in NXP SiMKit [13], an open-source library providing PSP and other models. Besides an open-source version of SiMKit, there is a proprietary versions of SimKit which can be used with Cadence Spectre and Keysight ADS. SiMKit uses an API

which allows the simulator to dynamically load and query the library for available device models, instantiate a device model with given model parameters, and use it to calculate branch contributions. Such API is general enough to be considered as a good candidate for all models in DAE simulators.

Analog, mixed signal and RF circuits are sensitive to physical implementation effects, and designers go to great lengths to ensure that circuit layout does not degrade performance. Physical implementation effects can roughly be divided into two categories:

- parasitic resistance, capacitance, inductance and inductive coupling,
- geometry-dependent effects that alter the device model.

In almost all parasitic extraction flows inductors and transformers are treated as black boxes, and extraction of only parasitic resistance and capacitance results in acceptable accuracy most of the time, which is also used in digital design flow. Geometry-dependent effects are not extracted at all in digital design flow, since only routing parasitics are extracted. Effect of any geometry-dependent effects are expected to be captured in Liberty library files, either from analog simulation of extracted cells, or from silicon characterization. Accurate extraction of analog, mixed signal and RF circuit layouts cannot rely only on parasitic RC extraction because geometry-dependent effects can have significant impact on performance.

To eliminate, or at least minimize geometry-dependent effects analog designers use many layout techniques, some of which are:

- common centroid layout to minimize the effects of process gradients,
- same source-drain orientation of matched devices to elliminate mismatch due to MOSFET chirality caused by ion implantation at an angle,
- avoididng routing metal, and blocking dummy filler, over poly in matched transistors and resistors to avoid device mismatch due to hydrogen trapping,
- placing dummy devices (resistors, MOS, capacitors) around matched devices to equalize density-dependent effectcs, such as etcing bias, metal dishing etc.,
- placing sensitive circuits, which rely on device matcing, in the middle of the chip to minimize mismatch due to mechanical stress of seal ring, dicing and bonding.

Although all of the above listed effects are well known, and some of them are quantified in foundry-provided process documentation, they are not considered by any device model nor extracted by parasitic extractor. However, some important geometry-dependent effects are included in transistor models, but are not extracted by FOSS parasitic extractors. These effects are well proximity effect (WPE) and length of diffusion effect (LOD).

Well proximity effect captures the change in NMOS device model due to proximity of N well, caused by ion scattering during well implantation. Matching of asymmetrically placed transistors is severely degraded by proximity of N well, and can cause a costly chip re-spin if it is not caught by simulation of extracted circuit with effects of WPE.

Mobility of carriers in MOS transistors is affected by compressive mechanical stress, degrading mobility of carriers in NMOS and enhancing it in PMOS. Stress-dependent mobility is used in many advanced processes to enhance MOS performance by deliberately introducing mechanical strain in

the channel. Mechanical stress is also dependent on the distance from the channel to the nearest shallow trench isolation (STI), equal to the length of source or drain diffusion, hence the name length of diffusion. Difference of LOD lenght in matched devices, and corresponding change of mobility, can result in as much as 20% mismatch in drain current - an error that is unnaceptable in analog design. This LOD-dependent current mismatch cannot be simply trimmed because it is temperature dependent, ultimately resulting in poor performance and chip respin. Device current mismatch could be caught by simulation of extracted circuit, if LOD effects are extracted.

To summarize, RC-only extraction is not adequate for analog, mixed signal and RF designs - geometry-dependent effects have to be extracted as well. Extraction of geometry-dependent effects is a major feature missing in FOSS extractors, and should be considered as an important future improvement.

Another very important feature for RF design, missing in FOSS extractors, is parasitic blocking. It is common for RF devices to be modeled with extrinsic model - it includes intrinsic parasitics of semiconductor device and extrinsic parasitics of local interconnects. Extrinsic model is of great importance for RF desingers, because they can optimize the device size to achieve design goals without having to draw a layout for each device size. Without extrinsic model, designer would have to estimate the local interconnect parasitics and include them as ideal elements, find a candidate device size from simulation, draw a layout and extract it, just to see that parasitic estimate was not correct. To say that optimizing an RF circuit performance without extrinsic model is very tedious and time consuming is an understatement.

Extrinsic device models are great - but there is a problem: they already include local routing, which would be double-counted by parasitic extraction, producing an incorrect extracted circuit. Simply removing the device layout and treating it as a black box does not solve the problem either, because it would exclude the parasitic capacitance from local interconnect to layout drawn by designer, and underestimate parasitics. The only solution is to instruct parasitic extractor to block extraction of certain layers in certain cells, which have already been accounted for in the device model. This feature is present in most proprietary parasitic extractors, but is missing in FOSS extractors.

Even in parasitic extractor does its job perfectly - accurately extracts layout parasitics and geometry-dependent effects, and properly performs parasitic blocking - the resulting netlist of top level design is usually too big for simulation with available resources in a reasonable time. Netlist size problem is usually solved (?) by partitioning the top level design, mixing extracted netlists of critical blocks with schematic, or even behavioral models, of supporting circuits. Putting aside that such approach is error prone, and does not really simulate the whole chip, there are cases where the netlist is still to big. The reason for excessive netlist size it that parasitic extractors generate circuits with too much details, possibly filtering out only very small parasitic resistors (mili Ohms) and capacitors (atto Farads).

Parasitic reduction tools take an extracted circuit netlist and create an equivalent circuit with specified tolerance at maximum frequency of interest. Reduction of extracted circuit size can be dramatic, by more than order of magnitude, without compromising simulation results accuracy. Smaller netlist results in faster simulations, and in some cases enable the simulation to be run at all, especially on top level or large blocks. To the best of author's knowledge there aren't any FOSS parasitic reduction tools available.

Electromagnetic simulators are also missing from FOSS desing flow, with one notable exception - ASITIC [14]. ASITIC is not a general purpose electromagnetic simulator, but rather a magneto- and electro-static simulator for supported geometries. It is free, but is not open-source, and it has been used in both academia and industry for more than twenty years. At the time ASITIC was introduced CMOS processes were mostly used for digital designs, and phrase "CMOS RF" was considered as oxymoron. In such historical context ASITIC was an invaluable tool for CMOS RF pioneers, and many others to follow even into mm-Wave. Last release of ASITIC was in 2001, and it is long overdue for an update.

Many things have changed since the last release of ASITIC - thick metal options are common in CMOS processes, modern CPUs have with powerful SIMD instructions, and desktop PCs have more cores than servers twenty years ago. To illustrate the point, some proprietary EM simulators simulate an inductor in full wave mode over a broad frequency range, from DC to beyond self resonant frequency, in less time than it takes ASITIC to simulate the same inductor at a single frequency. Furthermore, proprietary EM simulators can simulate an arbitrary geometry provided in GDSII file. Having in mind that the design of all RF, microwave and high speed IO circuits rely on EM simulation, lack of FOSS EM simulator is a significant drawback.

While on the topic of high-performance RF, microwave or high speed IO, required performance has long surpassed the raw (uncalibrated) peformance of CMOS. Digital circuits have benefited from each generation of scaled CMOS nodes, reducing the power consumption and area, while increasing operating frequency and scale of integration. Process scaling has not been so generous to analog/RF circuits - constant field CMOS scaling has resulted in reduced supply voltage, and consequently reduced available voltage swing and dynamic range. Going into deep sub-micron nodes, mismatch of close to minimum transistor size cannot be considered as a perturbation of a process corner, but rather a large deviation, having detrimental effect on performance and yield. If transistors of minimum, or close to minimum, channel length cannot be used in a given process due to excessive mismatch, there is no point of using it - an older, and more stable CMOS node could be used, at lower cost as well.

Key to using an advanced CMOS node to its full potential is digital calibration, correction and assistance. For example, spurios free dynamic range (SFDR) of RF D/A converter without any digital calibration is determined solely on transistor matching, proportional to inverse square root of device area, in a given CMOS process. High resolution D/A converters require large transistors, resulting in large area, high power consumption and/or limited maximum frequency, to achieve desired SFDR without using digital assitance [15]. Mixed signal simulations are essential for design and characterization of digitally assisted analog/RF circuits.

Currently available mixed signal simulators support only basic simulations - DC, AC, transient, and there is not a single simulator supporting mixed signal PSS simulations. In principle, digital circuits can be simulated on transistor level with available simulators, but in reality it is not feasible due to excessive number of transistors. There have been hacks to perform PSS with digital circuits by compiling Verilog code with Verilator and using it within Verilog-A module [15], but this is not a general approach. Future improvents of FOSS circuit simulators could consider using Verilator for mixed-signal PSS simulation in a general manner.

4 Conclusion

An overview of free software for analog and digital design has been presented in this paper. In general, FOSS digital design flow is in much better shape than analog. One of the reasons is that file formats for digital design are standardized, while PDKs for analog design are usually locked to one vendor. Besides an overview of available FOSS tools, some thoughts on possible improvements and missing tools are also given. Hopefully these thoughts will contribute to future directions of development.

Development of EDA tools for chip design requires specialized knowledge and a lot of resources. It is interesting to note that many tools used in FOSS digital and analog flow were developed by individuals or projects outside of universities. Shift of FOSS tool development from universities to individuals/projects might be explained by pressure to publish papers. Some form of academic recognition for development of FOSS tools might restore interest at universities.

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OTVORENI SOFTVER ZA VEŠTAČKU INTELIGENCIJU

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REZIME

Razvoj veštačke inteligencije tokom poslednje decenije omogućio je primenu u mnogim oblastima. Otvoreni softver za veštačku inteligenciju je osnovna pretpostavka za dalji napredak, dostupnost i masovnu primenu. U ovom radu dat je kratak pregled aktuelnih otvorenih softvera iz oblasti veštačke inteligencije, njihov uporedni pregled i primeri primene.

Ključne reči: otvoreni softver, slobodan softver, veštačka inteligencija, mašinsko učenje

1 Uvod

Veštačka inteligencija predstavlja jedan od ključnih pokretača za napredak nauke i inovacija u mnogim oblastima. Motivacija za primenu veštačke inteligencije obuhvata širok dijapazon praktičnih problema od rešavanja visoko složenih računarskih zadataka koji se odlikuju kombinatornom eksplozijom do inteligentne automatizacije procesa kojom se ostvaruje veća produktivnost. Međutim, da bi sve ove napredne tehnike zaživele u praksi, licence otvorenog softvera imaju presudan značaj, kako bi ove metode postale široko dostupne, i kako bi bila omogućena njihova nadogradnja, prilagođavanje i eksploatacija (što je osnovna ideja otvorenog i slobornog softvera u opštem slučaju).

U ovom radu dat je pregled nekoliko aktuelnih otvorenih softvera za veštačku inteligenciju i njihovih primena kako bi se demonstrirali glavne ideje i trendovi u ovoj oblasti.

2 Pregled aktuelnih softvera

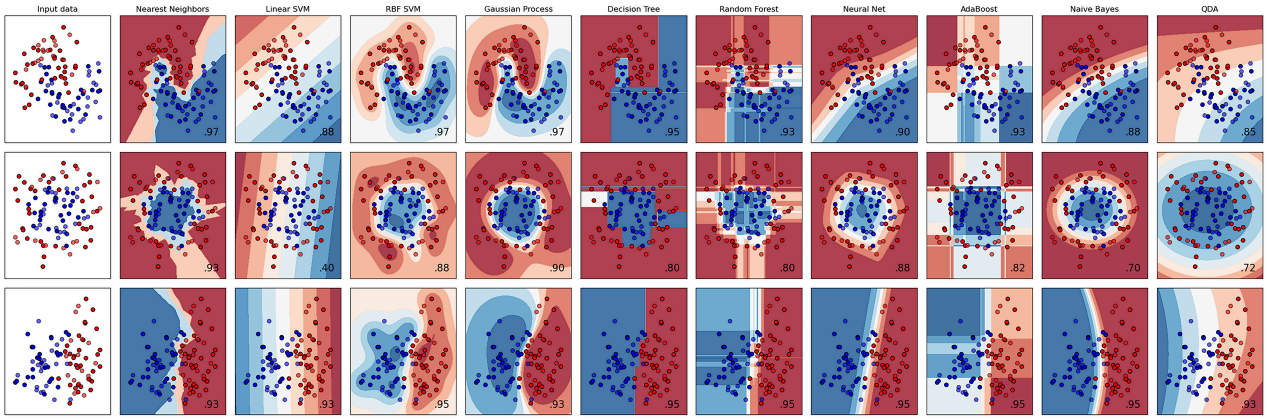
U ovom poglavlju dat je kratak pregled nekoliko aktuelnih otvorenih softvera iz oblasti veštačke inteligencije. Pregled nije sveobuhvatan i potpun, ali daje osnovni uvid u glavne kategorije softvera, njihove mogućnosti, vrstu licenci i mogućnosti primene, kao i drugi slični radovi [1]. Ove informacije mogu biti od koristi prilikom izbora softvera za konkretne projekte i njegovu primenu.

2.1 Scikit Learn

Scikit Learn [2] je softverska biblioteka u programskom jeziku Python koja sadrži skup alata za mašinsko učenje. Podržava algoritme za klasifikaciju, regresiju, klasterizaciju, pretprocesiranje podataka, evaluaciju i selekciju modela. Napravljena je pomoću srodnih Python paketa kao što su NumPy (višedimenzionalni nizovi), SciPy (matematičke metode), Matplotlib (grafici i

vizuelizacija) i Pandas (tabelarna struktura podataka za mašinsko učenje tipa *data frame*). Zahvaljujući intitivnom dizajnu brzo se uči i lako se koristi, pri čemu zahteva predznanje programskog jezika Python, prethodno navedenih biblioteka, statistike i generalno poznavanje algoritama i procedure primene mašinskog učenja.

Scikit Learn ima jednostavnu sintaksu karakterističnu za programski jezik Python, a zahvaljujući efikasnoj integraciji NumPy-a sa bibliotekama za numeričko računarstvo napisanim u programskom jeziku C, ostvaruje dobre performanse prilikom izvršavanja. Međutim, i pored dobrih performansi na relativno malim skupovima podataka, nije predviđen za rad sa velikom skupovima podataka (BigData). Na slici 1 prikazana je vizualizacija poređenja različitih algoritama za klasifikaciju napravljena pomoću Scikit Learn softvera. Kompletan izvorni kod primera je dostupan na adresi https://scikit-learn.org/stable/auto_examples/classification/plot_classifier_comparison.html



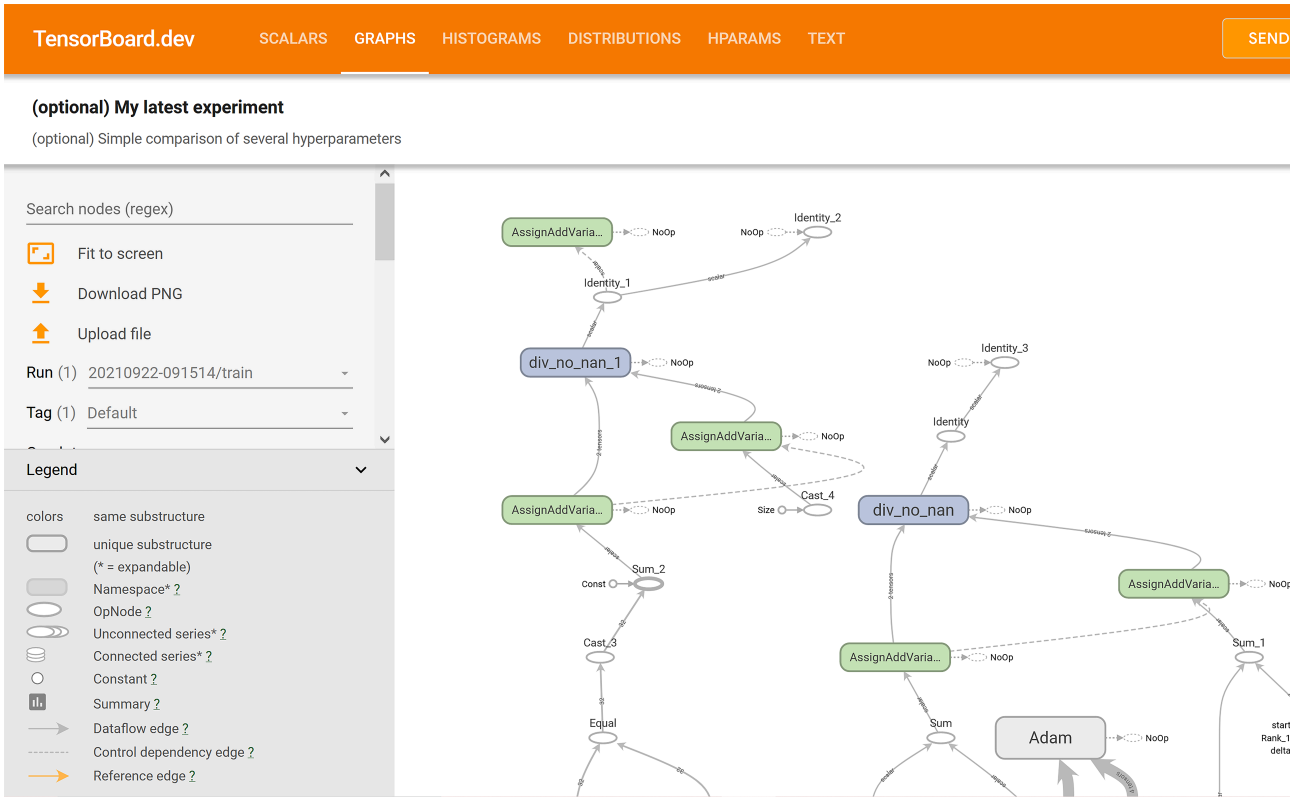
Slika 1. Vizuelizacija poređenja klasifikatora pomoću softvera Scikit Learn
Izvor: https://scikit-learn.org/stable/auto_examples/classification/plot_classifier_comparison.html

2.2 Tensorflow

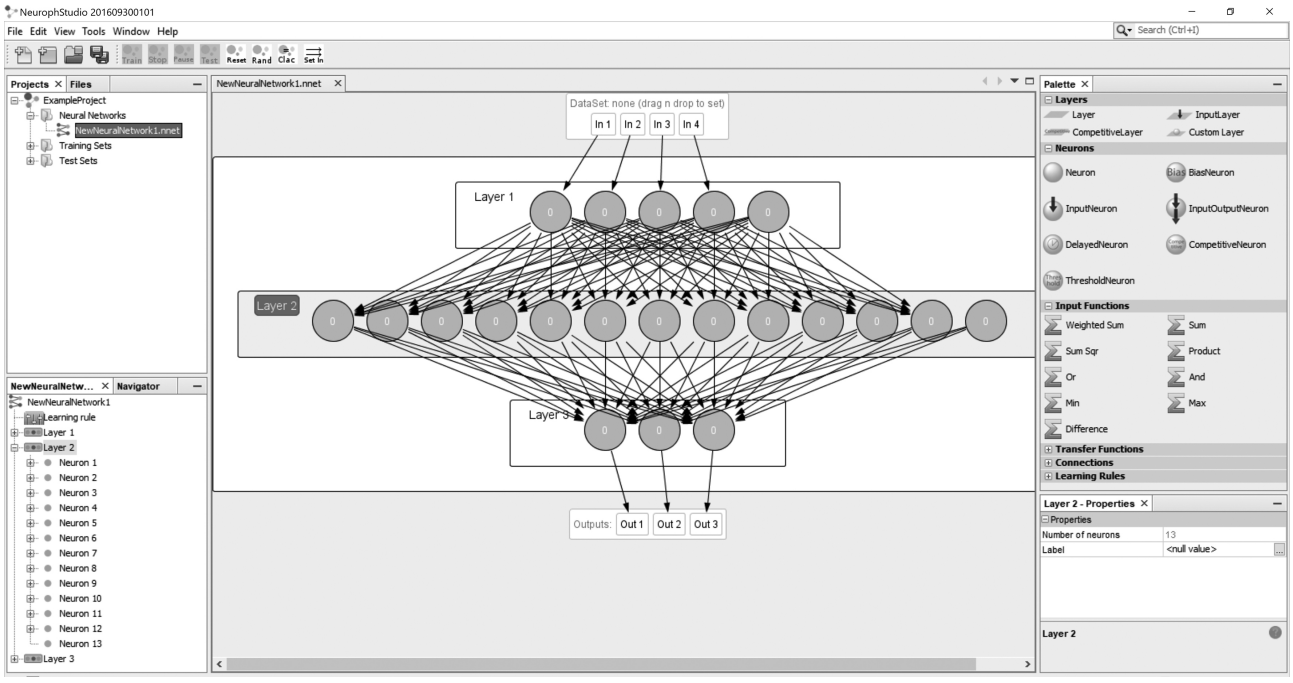
Tensorflow [3] je softverska platforma koja obezbeđuje biblioteku i alate za duboko učenje. Podržava izvršavanje modela dubokog učenja visokih performansi na specijalizovanim grafičkim procesorima (GPU) kao i distribuirani rad sa velikim količinama podataka. Jezgro sistema je napisano u C++, a programerski interfejs u Python-u koji obezbeđuje jednostavno korišćenje. Pored osnovnog programskog interfejsa koji podrazumeva direktan rad sa tenzorima i grafovima, ima i programski interfejs kroz softverski okvir (frejmvork) Keras koji značajno pojednostavljuje rad sa modelima dubokog učenja. Takođe, obezbeđuje alat za vizualizaciju i dijagnostiku modela TensorBoard. Na slici 2 prikazana je slika ekrana za Tensorboard alata na kojoj se vidi graf modela dubokog učenja kreiranog pomoću Tensorflow-a.

2.3 Neuroph

Neuroph [4] je edukativni softver za neuronske mreže napisan u programskom jeziku Java. Sastoji se od Java biblioteke softverskih komponenti za neuronske mreže i alata sa grafičkim interfejsom koji sadrži simulator, vizualne alate za rad sa neuronskim mrežama i interaktivne edukativne primere. Podržava osnovne algoritme za neuronske mreže i koncipiran je tako da bude jednostavan za korišćenje za početnike i da zahteva minimum predznanja. Na slici 3 je prikazan glavni prozor integrisanog vizuelnog razvojnog okruženja za veštačke neuronske mreže Neuroph Studio koje je deo Neuroph softvera.



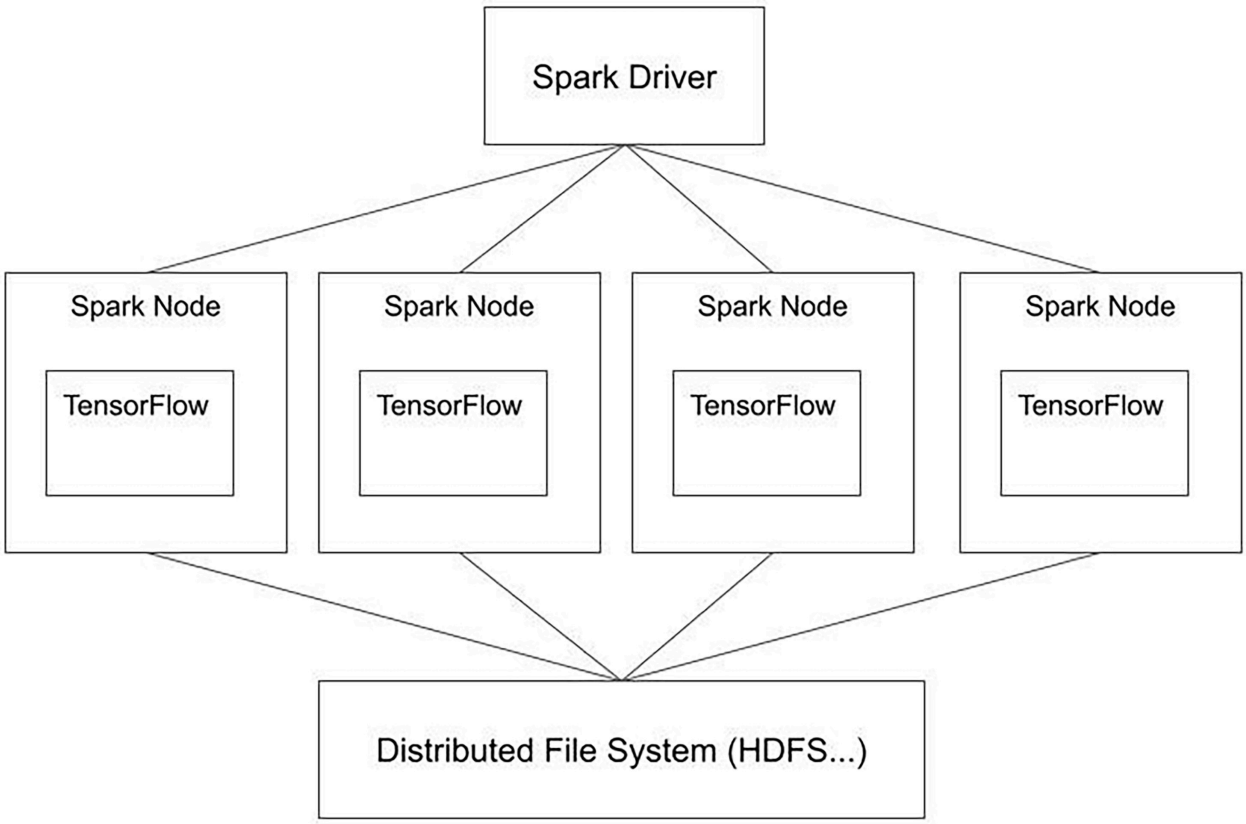
Slika 2. Slika ekrana alata za vizuelizaciju modela dubokog učenja TensorBoard



Slika 3. Glavni prozor razvojnog okruženja za neuronske mreže Neuroph Studio

2.4 Apache Spark

Apache Spark [5] je platforma za distribuirano procesiranje velikih količina podataka. Ima programski interfejs u programskim jezicima Java, Scala, Python i R. Pored izvršavanja zadataka opšteg tipa u distribuiranom okruženju, postoji i proširanje kroz biblioteku MLLib koja sadrži često korišćene algoritme mašinskog učenja za klasifikaciju, regresiju i pretprocesiranje podataka. Apache Spark se koristi i kao distribuirana infrastruktura za izvršavanje drugih sistema npr. Tensorflow (slika 4). Dostiže visoke perfromanse u odnosu na slične sisteme, jer koristi memoriju (a ne disk) za skladištenje i procesiranje podataka.Slika 4. Arhitektura za distribuirano izvršavanje Tensorflow modela na Spark sistemu.



Slika 4. Arhitektura za distribuirano izvršavanje Tensorflow modela na Spark sistemu

2.5 Uporedni pregled

U tabeli 1 je dato uporedno poređenje otvorenog softvera u odnosu na programski jezik, oblast veštačke inteligencije, potreban nivo predznanja (na osnovu iskustva autora) i vrstu otvorene licence.

Tabela 1. Uporedni pregled otvorenog softvera za veštačku inteligenciju

Naziv softvera	Programski jezik	Dominantna oblast veštačke inteligencije	Potreban nivo predznanja	Licenca
Scikit Learn	Python	Mašinsko učenje	Srednje	BSD 3
Tensorflow	Python, C++	Duboko učenje	Napredno	Apache 2.0
Neuroph	Java	Neuronske mreže	Osnovno	Apache 2.0
Spark	Java, Scala, Python, R	Big Data	Napredno	Apache 2.0

3 Primeri primene

U ovom poglavlju navedeno je nekoliko primera projekata koji koriste otvoreni softver za veštačku inteligenciju koji su predstavljeni u prethodnom poglavlju, kako bi se sagledao značaj i mogućnosti za praktičnu primenu.

Alpha Fold [6] je projekat koji koristi Tensorflow i omogućava predviđanje 3D struktura proteina sa visokom tačnošću. Predviđanje struktura proteina je aktuelni istraživački izazov u poslednjih 50 godina i ima potencijal da ubrza istraživanje u svim oblastima biologije.

SciKit Learn ima vodeću primenu u obrazovanju i istraživanju vezane za mašinsko učenje, ali i industrijsku primenu. Npr. Spotify koristi SciKitLearn za preporuke muzičkih sadržaja, a Booking.com za preporuke hotela i turističkih destinacija [7].

Neuroph kao edukativni softver primenu nalazi uglavnom u akademskoj sferi za istraživačke i studentske projekte kao što su: detekcija lica, predviđanje potrošnje električne energije, računarske igre, ali i kroz integraciju kroz druge softvere kao što je npr. softver za matematiku GeoGebra [8].

Apache Spark se koristi kada je potrebna obrada velikih količina podataka, koju je potrebno ubrzati izvršavanjem na grupi računara u klasteru. Kompanija eBay koristi Spark za analizu velikog broja transakcionih logova. NASA koristi Spark za Deep Space Network, najveći i najosetljiviji naučno telekomunikacioni sistem na svetu [9].

4 Zaključak

Otvoreni softver ima ključni značaj u istraživanju i primeni veštačke inteligencije. Taj značaj je toliko veliki da se može reći da bez otvorenog softvera ne bi ni postojao razvoj i primena savremenih tehnika veštačke inteligencije. Baš kao što bez Linux-a i Apache Web servera ne bi bila moguća masovna ekspanzija internet servisa, bez otvorenog i slobodnog softvera nema ni masovne ekspanzije veštačke inteligencije. Ova činjenica je veoma dobro prepoznata i od strane ključnih tehnoloških kompanije kao što su Google [10] i Facebook [11], i one svoje alate i projekte iz oblasti veštačke inteligencije čine dostupnim pod licencama otvorenog koda. Ovi projekti čine glavni alat za dalje istraživanje i inovaciju od strane istraživačke zajednice u akademskim, ali i industrijskim krugovima.

Međutim, veliki broj softvera u ovoj oblasti dovodi do fragmentacije u ovoj oblasti i otežava izbor odgovarajućeg softvera u konkretnim slučajevima. U tim slučajevima treba imati na umu konkretan zadatak odnosno metod/algoritam koji će se koristiti, iskustvo razvojnog tima, količinu podataka i zahteve za integraciju u produkciji. Obzirom da je problem fragmentacije prepoznat, već su se javile i inicijative za standardizaciju u određenim oblastima [11] .

Zahvaljujući licencama otvorenog koda softver za veštačku inteligenciju ima realni potencijal da značajno unapredi mnoge oblasti istraživanja, ali i poslovnu primenu veštačke inteligencije. Bez otvorenih licenci i istraživanja i primena bi bili značajno usporeni i ograničeni.

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OTVORENI GENERATOR IZVEŠTAJA I SKRIPTI ZASNOVAN NA PARSERU WELL-FORMED XML DOKUMENATA

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REZIME

Cilj ovog rada je da prikaže mogućnosti otvorenog generator izveštaja i skripti. Alat koji implementira generator nazvan je *WEXA* (skr. *Well-formed XML* parser). Softversko rešenje je nastalo kao rezultat neprekidne potrebe da se isti podaci iznova obrađuju. Kao krajnji proizvod alata, dobijaju se izveštaji različitih formata. Podaci koji su unapred pripremljeni i koji ispunjavaju uslov sintaksne ispravnosti odnosno imaju osobinu da su *well-formed*, mogu se parsirati ovim alatom. Uočena je mogućnost da se isti mehanizam može proširiti kako bi se podaci iskoristili za generisanje računarskih skripti, prevashodno napisanih u formatu *bash* skripti. Pored otvorenosti koda, a kao posledica odabranih tehnologija, omogućeno je transparentno praćenje izvršavanja svake komande ovog alata. Glavna odlika ovog alata ogleda se u jednostavnosti primene i lakoći proširivanja ili prilagođavanja generatora specifičnostima podataka ili korisnika.

Ključne reči: otvoreni generator izveštaja, javascript, otvoreni generator skripti, *well-formed XML*, parser *XML* dokumenta, transparentno izvršavanje, prilagođavanje alata.

1 Uvod

U eri primene računara i računarskih tehnologija, u gotovo svim sferama društva, neophodno je voditi računa kako se podaci čuvaju, ažuriraju i koriste. U najvećem broju slučajeva podaci imaju višestruku primenu i to omogućava korisnicima da ih upotrebljavaju na različite načine. Takođe, treba napomenuti da računari imaju važnu ulogu u tom sistemu. Računari nisu samo sredstvo za obradu podataka, već predstavljaju krajnje korisnike. Zbog postojanja interakcije čovek-računar, u ovom radu su pri implementaciji *WEXA* alata razmatrani različiti oblici mašinski čitljivih podataka.

Mašinski čitljivi podaci su važan deo *WEXA* alata. Za podatke koji ispunjavaju uslov da su mašinski čitljivi, postoji garancija da se kao takvi mogu deliti među mašinama [1][2]. Ako se još obezbedi da su mašinski čitljivi podaci i ljudski čitljivi, onda je interakcija čovek-računar u potpunosti podržana zahvaljujući njihovoj strukturi. Ovo je glavni razlog koji je uticao pri odabiru formata i strukture podataka čije će parsiranje biti predstavljeno.

WEXA je nastao usled svakodnevne potrebe da se podaci obrađuju od strane više korisnika zarad dobijanja različitih izveštaja. Kako su u celom procesu rada uključeni mnogi korisnici, koji se međusobno razlikuju prema stepenu računarskih veština kao i radnih pozicija, bilo je neophodno realizovati alat koji je dovoljno intuitivan za svakoga od njih. Zbog same različitosti korisnika, različite su i potrebe za generisanjem izveštaja i skripti.

Alat je razvijen tako da svaki korisnik može preuzeti *WEXA* instancu i pokrenuti je lokalno na svom računaru, a jedino što je potrebno je postojanje internet pretraživača kod korisnika. Tehnologije koje su korišćene za realizaciju ovog alat su *JavaScript, HTML* i *CSS*. Korišćene tehnologije su osnovne komponente većine današnjih alata.

2 Mašinski čitljivi podaci

Različite su kategorije i podkategorije podataka koje se mogu smatrati mašinski čitljivim. Po pravilu, podaci koji su mašinski čitljivi su zasigurno i struktuirani podaci [3]. Glavna podela koja postoji među mašinskim čitljivim podacima jeste da li imaju osobinu i da su ljudski čitljivi. Podaci koji su zapisani u formatu kao što su *.csv, .xml, .json* pripadaju samo klasi data fajlova i ne smatraju se ljudski čitljivim. Postoje različiti interpretatori navedenih formata, koji mogu da povećaju stepen ljudske čitljivosti, ali po pravilu ti formati i dalje nisu ljudski čitljivi.

Sa druge strane postoje fajlovi koji mogu biti *.html* ili *.xslt* koji se smatraju ljudski čitljivim podacima. U osnovi ako se posmatra sintaksna struktura *.xml* i *.html* koda, onda ne postoji razlika između ova dva formata. Ipak, zbog semantičke logike koja postoji u *.html* zapisima i preciznije definisanih pravila pisanja *.html* fajlova, smatra se da su *.html* zapisi mašinski i ljudski čitljivi [4].

Navedena osobina koja proističe iz sličnosti *.html* i *.xml* fajlova je prvi razlog zbog kog je *.xml* format uzet u razmatranje za primenu. Razmatrano je korišćenje *.json* formata iz razloga što je taj format jednostavnije koristiti sa strane alata, imajući u vidu da je alat prevashodno napisan na *JavaScript* programskom jeziku. Ipak, *.json* ne podržava koncept metapodataka, pa zbog toga nije dalje razmatran [5].

Fajlovi koji su u *.xml* formatu se smatraju *well-formed* ako ispunjavaju uslov da su sintaksno ispravni [6]. Sintaksna ispravnost je lako proverljiva pomoću internet pretraživača. Ako nešto nije uredu sa fajlom, pretraživač će ukazati precizno na grešku. Pravila koja moraju da se ispoštuju kako bi se *.xml* fajl smatrao da je *well-formed* jesu da je sadržaj razdvojen tagom za početak i kraj, da je definisan sadržaj i da je sadržaj hijerarhijski struktuiran. Navedena pravila su samo najosnovnija pravila koja se moraju ispoštovati. Sa druge strane postoje pravila koja se definišu na nivou entiteta. Neka od tih pravila definišu tagove kao *case-sensitive* elemente, kao i da se vrednosti atributa moraju naći pod znacima navoda i da nema preklapanja tagova [7][8].

Postoji još pravila kao i smernica kako treba pisati mašinski čitljive dokumente kao *.xml* fajlove. Skup pravila, kao i osobine *.xml*, mogu se proširiti zahvaljujućim šemama koje preciznije definišu semantičku i sintaksnu ispravnost *.xml* fajlova. Šeme definišu pravila na osnovu različitih segmenata primene *.xml* fajlova. Za korišćenje *WEXA* alata dovoljno je da je *.xml* fajl *well-formed*, odnosno da prolazi sintaksnu proveru od strane internet pretraživača.

3 Korišćene tehnologije i implementacija

WEXA alat je razvijen kao internet aplikacija pomoću JavaScript, *HTML* i *CSS* tehnologija. Glavni razlog za primenu odabranih tehnologija jeste njihova praktičnost i jednostavnost prilikom razvoja. Korišćene tehnologije su podržane, barem osnovne komponente, kod većine internet pretraživača

[9]. Zbog toga su promene uočljive u realnom vremenu. Sa druge strane nije potrebno posebno razvojno okruženje kako bi se napisala aplikacija koja koristi predložene tehnologije. Dovoljan je jednostavan tekstualni editor, kao što je *Notepad* ili *Pluma*.

Zbog jednostavnog koncepta održavanja, nije neophodno napredno poznavanje internet tehnologija i složenih programerskih paradigmi. Ova osobina ujedno omogućava da se alat može specijalizovati za potrebe obavljanja jednog konkretnog posla. Primer je dodavanje posebnih filtera ili čitanje specifičnijih *.xml* fajlova.

Internet pretraživači predstavljaju okruženje za pokretanje *WEXA* alata. To omogućava da proces izvršavanja bude u potpunosti transparentan te krajnji korisnik ima potpunu kontrolu nad programskim kodom. Takođe, zbog prirode korišćenih tehnologije kao i internet pretraživača kao okruženja za izvršavanje, omogućeno je da korisnici mogu *WEXA* alat preuzimati sa interneta, prilagoditi svojim potrebama i izvršavati lokalno na svom internet pretraživaču.

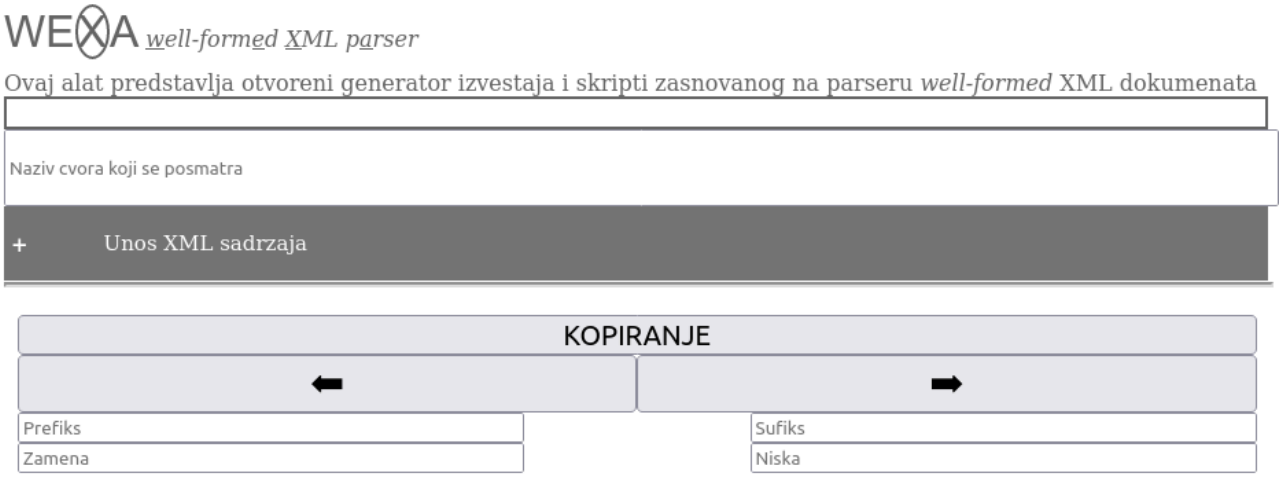
3.1 Pregled funkcionalnosti *WEXA* alata

WEXA alat je podeljen na tri komponente. Svaka komponenta predstavlja zasebnu logičku celinu pri čemu postoji veza između svake komponente. Komponente alata su:

1. Panel za upis *XML* zapisa;
2. Panel sa ekstrahovanim entitetima;
3. Radni okvir za generisanje izveštaja i skripti.

Panel za upis *XML* ne proverava da li je zapis *well-formed*. Od korisnika se očekuje da će uneti zapis koji je valjan. Ako postoji greška, neće doći do ekstrahovanja tagova i neće se nastaviti procedura generisanja izveštaja i skripti. U okviru panela za upis *XML* zapisa postoji polje za unos naziva čvorova koje treba ekstrahovati. Za uspešno parsiranje neophodno je da svaki čvor ima sve tagove koji se ekstrahuju, čak i kada je ono prazno. Svi tagovi koji se ekstrahuju moraju imati atribut pod nazivom *type*, jer on reprezentuje naziv posmatrane vrednosti.

Nakon uspešnog unosa, u okviru panela sa ekstrahovanim entitetima formiraće se tabela. Svako polje tabele sadrži dugme koje reprezentuje sve vrednosti nekog entiteta. Pritiskom na dugme vrednosti se ispisuju u radnom okviru. Vrednosti jednog pojedinačnog taga se ispisuju u zasebnim redovima. Redovi su sortirani na osnovu taga koji je prvi ispisan, odnosno na osnovu vrednosti prvog dugmeta koje je pritisnuto. Sortiranje se vrši u alfabetskom poretku. Izgled početnog ekrana dat je na Slici 1.



Slika1 Izgled početnog ekrana *WEXA* alata.

Radni okvir se koristi za rad sa podacima. Postoji nekoliko funkcionalnosti koje se mogu primeniti kako bi se generisao željeni rezultat, i to:

1. Kopiranje trenutnog stanja;
2. Vraćanja prethodnog stanja i ponovno izvršavanje stanja. Operacije poznate kao *Undo* i *Redo*;
3. Dodavanje prefiksa;
4. Dodavanje sufiksa;
5. Pronalaženje niske i njena zamena novom vrednošću. Operacija poznata kao *Find & Replace*.

Svaka promena uneta kroz bilo koju funkcionalnost je vidljiva u realnom vremenu. Da bi promene bile sačuvane neophodno je dvaput kliknuti na primenjenu funkcionalnost i promena će se izvršiti i sačuvati. Sačuvane promene predstavljaju osnovni tekst. Kako bi se obezbedila logička podela između prefiksa, osnovnog teksta i sufiksa uvedene su zelena, plava i crvena boja teksta, respektivno. Omogućeno je da se prefiks, a što je još važnije, i sufiks sačuvaju kao deo osnovnog teksta. To omogućava da se kombinuje unos kao što je prefiks-tag-sufiks-tag-sufiks.

Slika2 Primer komande za kopiranje koja kombinuje dodavanje taga i sufika.

Alat može generisati različite formate izveštaja. Unosom separatora u polje za sufiks definiše se tip izlaznog fajla. Ako je potrebno generisati *.csv* fajl, onda će se u sufiks uneti znak zareza kao separator.

Kad je reč o skriptima, *WEXA* je veoma koristan u slučaju da je potrebno ažuriranje većeg broja mašina ili alata. Kao dobar primer može poslužiti slučaj kada je potrebno novu verziju nekog računarskog fajla postaviti na nekoliko različitih mašina. Ovakva vrsta skripte može se dobiti u svega nekoliko koraka, a najvažniji su:

1. Dodavanjem prefiksa kojim se definiše komanda i putanja do računarskog fajla;

2. Unos vrednosti taga koji reprezentuje putanju do mašina;

3. Dodavanjem sufiksa kojim se definiše odredišna putanja u okviru ciljane mašine.

Nakon generisanja skripte potrebno je sadržaj sačuvati u okviru lokalnog fajla, dodeliti mu dozvolu za izvršavanje i pokrenuti.

4 Zaključak

Implementirani alat je praktično rešenje realizovano kako bi pojednostavilo rešavanje čestih zadataka koji zahtevaju generisanje različitih izveštaja ili skripti. Najčešće su to slučajevi kada se jedan fajl propagira na različite mašine, kada se sa mašina preuzimaju podaci ili kada se upoređuju različite karakterstike aplikacija. Alat je proširen i prilagođen za korišćenje od strane softverskih inženjera koji neretko imaju potrebu da pokreću najrazličitije skripte za potrebe tehničkog održavanja i unapređenja računarske infrastrukture.

Zbog odabira široko primenjivih tehnologija, alat je lako proširiv. Omogućena je laka prenosivost i instanciranje alata ako se ukaže potreba za dodatnim proširenjima ili prilagođavanjima radi obavljanja specifičnih zadataka. Intuitivan dizajn omogućava praktično korišćenje alata bez obzira na računarske veštine korisnika. Takođe, odabrane tehnologije podržavaju koncept otvorenosti i transparentnosti računarskog koda kao i njegovog izvršavanja.

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OTVORENI NASTAVNI MATERIJALI /
OPEN EDUCATIONAL RESOURCES

Milan Bjelica, „Telekomunikacione i računarske mreže: uvodni tečaj“

Udžbenik "Telekomunikacione i računarske mreže: uvodni tečaj" pisan je ciljano kao elektronska publikacija optimizovana za prikaz na mobilnim uređajima. Knjiga odstupa od prakse opširnosti naše udžbeničke literature, te je fokusirana na jedan cilj, a to je spremanje ispita iz predmeta koji pokriva. Za sve dodatne informacije, zainteresovane čitateljke i čitaoci upućuju se na spoljašnje hiperlinkove.

Uz udžbenik postoji i prateća zbirka zadataka, koja u drugom izdanju izlazi kao elektronska publikacija.

Obe knjige dostupne su na sajtu izdavača: https://www.mensa.rs/sr/publikacije/udzbenici/.

Kosta Jovanović, Nikola Knežević, „Robotika – zbirka rešenih zadataka“

https://akademska-misao.rs/product/robotika-zbirka-resenih-zadataka/

„Robotika – zbirka rešenih zadataka“ je nastavna literatura koja obrađuje osnovne teme iz oblasti robotike kroz prikaz rešenih zadataka. Po svojoj strukturi i sadržaju, zbirka prati osnovni univerzitetski kurs u oblasti robotike. Konkretno, na Univerzitetu u Beogradu – Elektrotehničkom fakultetu, zbirka je namenjena predmetu Robotika i automatizacija čiju sadržinu prati. Opšte, zbirka se može koristiti i kao pomoćna literatura za studente drugih srodnih fakulteta tehničkog usmerenja i visokih tehničkih škola. Takođe, zbirka se može koristiti od strane inženjera u početnim fazama karijere u cilju uvida u osnovne principe rada robota i rešenje tipičnih problema i zadataka koji se javljaju u industrijskoj robotici.

Sadržaj Zbirke je podeljen u sledećih devet poglavlja: Osnovni pojmovi, konfiguracije i primene, Direktna kinematika – homogene transformacije, Direktna kinematika – DH notacija i kinematika industrijskih robota, Inverzna kinematika, Diferencijalna kinematika – Jakobijan, Dinamika, Planiranje trajektorije, Pogonski i senzorski sistemi robota, Upravljanje. Sadržaj zbirke prati tipične tematske celine koje se javljaju u udžbenicima za predmete robotike na relevantnim svetskim univerzitetima.

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