Zbornik 20. mednarodne multikonference

INFORMACIJSKA DRUŽBA - IS 2017

Zvezek I

Proceedings of the 20th International Multiconference

INFORMATION SOCIETY - IS 2017

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Delavnica za elektronsko in mobilno zdravje ter pametna mesta
Workshop Electronic and Mobile Healt and Smart Cities

Uredila / Edited by
Matjaž Gams, Aleš Tavčar

http://is.ijs.si

9.–13. oktober 2017 / 9–13 October 2017
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Ljubljana, oktober 2017

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PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2017

Multikonferenca Informacijska družba (http://is.ijs.si) je z **dvajseto** zaporedno prireditvijo osrednji srednjeevropski dogodek na področju informacijske družbe, računalništva in informatike. Letošnja prireditev je ponovno na več lokacijah, osrednji dogodki pa so na Institutu »Jožef Stefan«.

Informacijska družba, znanje in umetna inteligenca so spet na razpotju tako same zase kot glede vpliva na človeški razvoj. Se bo eksponentna rast elektronike po Moorovem zakonu nadaljevala ali stagnirala? Bo umetna inteligenca nadaljevala svoj neverjetni razvoj in premagovala ljudi na čedalje več področjih in s tem omogočila razcvet civilizacije, ali pa bo eksponentna rast prebivalstva zlasti v Afriki povzročila zadušitev rasti? Čedalje več pokazateljev kaže v oba ekstrema – da prehajamo v naslednje civilizacijsko obdobje, hkrati pa so planetarni konflikti sodobne družbe čedalje težje obvladljivi.

Letos smo v multikonferenco povezali dvanajst odličnih neodvisnih konferenc. Predstavljenih bo okoli 200 predstavitev, povzetkov in referatov v okviru samostojnih konferenc in delavnic. Prireditev bodo spremljale okrogle mize in razprave ter posebni dogodki, kot je svečana podelitev nagrad. Izbrani prispevki bodo izšli tudi v posebni številki revije Informatica, ki se ponaša s **40-letno** tradicijo odlične znanstvene revije. Odlične obletnice!

Multikonferenco Informacijska družba 2017 sestavljajo naslednje samostojne konference:

- Slovenska konferenca o umetni inteligenci
- Soočanje z demografskimi izzivi
- Kognitivna znanost
- Sodelovanje, programska oprema in storitve v informacijski družbi
- Izkopavanje znanja in podatkovna skladišča
- Vzgoja in izobraževanje v informacijski družbi
- Četrta študentska računalniška konferenca
- Delavnica »EM-zdravje«
- Peta mednarodna konferenca kognitonike
- Mednarodna konferenca za prenos tehnologij - ITTC
- Delavnica »AS-IT-IC«
- Robotika

Soorganizatorji in podporniki konference so različne raziskovalne institucije in združenja, med njimi tudi ACM Slovenija, SLAIS, DKZ in druga slovenska nacionalna akademija, Inženirska akademija Slovenije (IAS). V imenu organizatorjev konference se zahvaljujemo združenjem in inštitucijam, še posebej pa udeležencem za njihove dragocene prispevke in priložnost, da z nami delijo svoje izkušnje o informacijski družbi. Zahvaljujemo se tudi recenzentom za njihovo pomoč pri recenziranju.

V 2017 bomo petič podelili nagrado za življenjske dosežke v čast Donalda Michija in Alana Turinga. Nagrado Michie-Turing za izjemen življenjski prispevek k razvoju in promociji informacijske družbe bo prejel prof. dr. Marjan Krisper. Priznanje za dosežek leta bo pripadlo prof. dr. Andreju Brodniku. Že šestič podeljujemo nagradi »informacijska limona« in »informacijska jagoda« za najbolj (ne)uspešne poteze v zvezi z informacijsko družbo. Limono je dobilo padanje slovenskih sredstev za akademsko znanost, tako da smo sedaj tretji najslabši po tem kriteriju v Evropi, jagodo pa »e-recept«. Čestitke nagrajencem!

Bojan Orel, predsednik programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD - INFORMATION SOCIETY 2017

In its **20th year**, the Information Society Multiconference (http://is.ijs.si) remains one of the leading conferences in Central Europe devoted to information society, computer science and informatics. In 2017 it is organized at various locations, with the main events at the Jožef Stefan Institute.

The pace of progress of information society, knowledge and artificial intelligence is speeding up, and it seems we are again at a turning point. Will the progress of electronics continue according to the Moore's law or will it start stagnating? Will AI continue to outperform humans at more and more activities and in this way enable the predicted unseen human progress, or will the growth of human population in particular in Africa cause global decline? Both extremes seem more and more likely – fantastic human progress and planetary decline caused by humans destroying our environment and each other.

The Multiconference is running in parallel sessions with 200 presentations of scientific papers at twelve conferences, round tables, workshops and award ceremonies. Selected papers will be published in the Informatica journal, which has **40 years** of tradition of excellent research publication. These are remarkable achievements.

The Information Society 2017 Multiconference consists of the following conferences:

- Slovenian Conference on Artificial Intelligence
- Facing Demographic Challenges
- Cognitive Science
- Collaboration, Software and Services in Information Society
- Data Mining and Data Warehouses
- Education in Information Society
- 4th Student Computer Science Research Conference
- Workshop Electronic and Mobile Health
- 5th International Conference on Cognitonics
- International Conference of Transfer of Technologies - ITTC
- Workshop »AC-IT-IC«
- Robotics

The Multiconference is co-organized and supported by several major research institutions and societies, among them ACM Slovenia, i.e. the Slovenian chapter of the ACM, SLAIS, DKZ and the second national engineering academy, the Slovenian Engineering Academy. In the name of the conference organizers we thank all the societies and institutions, and particularly all the participants for their valuable contribution and their interest in this event, and the reviewers for their thorough reviews.

For the fifth year, the award for life-long outstanding contributions will be delivered in memory of Donald Michie and Alan Turing. The Michie-Turing award will be given to Prof. Marjan Krisper for his life-long outstanding contribution to the development and promotion of information society in our country. In addition, an award for current achievements will be given to Prof. Andrej Brodnik. The information lemon goes to national funding of the academic science, which degrades Slovenia to the third worst position in Europe. The information strawberry is awarded for the medical e-recipe project. Congratulations!

Bojan Orel, Programme Committee Chair
Matjaž Gams, Organizing Committee Chair

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Invited lecture

AN UPDATE FROM THE AI & MUSIC FRONT

Gerhard Widmer
Institute for Computational Perception
Johannes Kepler University Linz (JKU), and
Austrian Research Institute for Artificial Intelligence (OFAI), Vienna

Abstract
Much of current research in Artificial Intelligence and Music, and particularly in the field of Music Information Retrieval (MIR), focuses on algorithms that interpret musical signals and recognize musically relevant objects and patterns at various levels -- from notes to beats and rhythm, to melodic and harmonic patterns and higher-level segment structure --, with the goal of supporting novel applications in the digital music world. This presentation will give the audience a glimpse of what musically "intelligent" systems can currently do with music, and what this is good for. However, we will also find that while some of these capabilities are quite impressive, they are still far from (and do not require) a deeper "understanding" of music. An ongoing project will be presented that aims to take AI & music research a bit closer to the "essence" of music, going beyond surface features and focusing on the expressive aspects of music, and how these are communicated in music. This raises a number of new research challenges for the field of AI and Music (discussed in much more detail in [Widmer, 2016]). As a first step, we will look at recent work on computational models of expressive music performance, and will show some examples of the state of the art (including the result of a recent musical 'Turing test').

References
Widmer, G. (2016).
Getting Closer to the Essence of Music: The Con Espressione Manifesto.
ACM Transactions on Intelligent Systems and Technology 8(2), Article 19.

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10. oktober 2017 / 10th October 2017
Ljubljana, Slovenia

PREDGOVOR

V letu 2017 smo pripravili tretjo delavnico na temo »e&m-zdravstva« (elektronsko in mobilno zdravstvo, kratko EMZ), tj. predlog izvedbe infrastrukture in vpeljave uporabe informacijsko in mobilno podprte celostne zdravstvene oskrbe za izboljševanje preventivne, diagnostične in terapevtske obravnave državljanov, ki bi zmanjšala stroške, obenem pa povečala dostopnost zdravstvene oskrbe v obdobju 2016-2020.

V letu 2016 je bil sprejet Raziskovalno Razvojni in Inovacijski (RRI) program EkoSMART v domeni pametne specializacije S4 na področju pametnih mest in skupnosti, kjer EMZ predstavlja enega od šestih nosilnih stebrov programa v obliki RRP (Raziskovalno-Razvojnega Projekta). V okviru javnega razpisa »RRI v verigah in mrežah vrednosti« − sklop 1: »Spodbujanje izvajanja raziskovalno-razvojnih programov (TRL 3-6)« je predvidenih 5,9 milijona evrov nepovratnih javnih sredstev za program EkoSMART.

Projekt EMZ sestavlja 5 delovnih sklopov oziroma delovnih paketov (DP), ki jih vodijo UKCL, IJS, FERI UM in FRI UL:

- Informacijske tehnologije za podporo celostni oskrbi / bolnice / prof. Z. Pirtošek
- Podpora na domu za zdrave, starejše in za kronične bolnike / doma / prof. M. Gams
- Mobilno spremljanje vitalnih in okolijskih podatkov / mobilno / dr. R. Trobec
- Računalniška podpora, podatki, kreiranje novih znanj /algoritmi / prof. P. Kokol
- IKT platforma / prof. M. Bajec

Delavnica EMZ omogoča celoletno pregledovanje in usklajevanje sklopa EMZ znotraj programa EkoSMART. Podobno kot v letu 2016 se bodo partnerji javno predstavili vsem drugim z že precej usklajenim predlogom. Vse predstavitve bomo nato dokončno uskladili in pripravili specifikacijo dela na programu za naslednje obdobje (sep. 2017 – avg. 2018). Potrebno se je zavedati, da je prvo leto dela že za nami in da je potrebno pregledati in predvsem povezati prispevke v smiselno celoto. Povezovali jih bomo najprej znotraj delovnih sklopov (delovnih paketov), nato znotraj RRP EMZ, nato pa še znotraj celotnega programa EkoSMART. Prvi povezovalni okvir je narejen za vse slovenske občine na ui-obcine.ijs.si, kjer sta tudi repozitorija prototipov in domen. Na delavnici bomo vse prispevke poskušali povezati z omenjenim okvirjem.

Pobudo e&m-zdravstvo so vzpodbudile potrebe po horizontalnem in vertikalnem povezovanju, trendi in dileme področja. Predlagana pobuda e&m-zdravje vpeljuje v zdravstveno oskrbo nove koncepte, ki bodo s svojimi multiplikacijskimi in sinergijskimi učinki sprožili hitrejšo in učinkovitejšo prilagoditev obstoječega sistema celostne zdravstvene oskrbe na današnje izzive. Ključna strokovna komponenta je umetna inteligenca, ki bo po napovedih strokovnjakov revolucionirala zdravstvo skupaj z novimi IKT rešitvami. Javno zdravstvo po vsem svetu se otepa izrednih problemov, najboljšo rešitev pa strokovnjaki po svetu vidijo v vpeljavi storitev IKT in umetne inteligence.

E&m-zdravstvo (EMZ) vidimo kot eno najbolj perspektivnih smeri v več pobudah od zdravstva do pametnih mest. E&m-storitve nudijo izboljšano kvaliteto življenja državljanom ob zmanjšanih stroških, hkrati pa omogočajo preboj Slovenije v svet na e&m-področju. E&m-zdravstvo se bo predvidoma vsebinsko oblikovalo delno kot samostojna pobuda s svojo platformo, organizacijo in projekti, ki bo povezana tako s pametnimi mesti kot z zdravjem. Ključne komponente za uspešno izvedbo EMZ so inovativni človeški viri, njihovo usklajeno delovanje in vpeljava EMZ v Sloveniji.

Amerika generira dvakrat več pomembnih inovacij v zdravstvu kot EU ter vlaga štirikrat več sredstev v nova, z medicino povezana podjetja. Kitajska namenja največ sredstev za znanost, medtem ko je Slovenija tretja najslabša po državnem financiranju znanosti v Evropi. Leta 2025 bo več kot milijarda, ali skoraj osmina svetovnega prebivalstva, starejša od 60 let. Stroški za zdravstveno oskrbo starejše populacije predstavljajo v EU skoraj polovico vseh stroškov za zdravstvo, kar pomeni, da grozi zdravstvenemu in gospodarskemu sistemu in kvaliteti življenja zlom, če ne bomo vpeljali storitev e&m-zdravja.

Druga pomembna komponenta je povezovanje in ustvarjanje kritične mase komplementarnih partnerjev, ki edino omogoča uspešen prodor na svetovna tržišča. Slovenija potrebuje sodelovanje in koordiniranje že zaradi svoje relativne majhnosti, kar dokazuje relativno slaba izkušnja z velikim številom malih in razdrobljenih projektov, ki nimajo dovolj podpore za vpeljavo novih rešitev.

Tretja ključna komponenta je vpeljava EMZ v slovensko zdravstvo, ki bo na ta način dobilo novo priložnost, da vzpostavi nacionalno platformo in mednarodne standarde, preseže ujetost v nedopustno dolge čakalne dobe za pregled pri specialistih, poveže razdrobljene in nekompatibilne sisteme in že samo s tem opraviči vložena sredstva. Po zadnjem povečanju sredstev za področje zdravstva so se čakalne vrste povečale, kar kaže, da sedanji tradicionalni pristop ne zmore prinesti realnih izboljšav.

Matjaž Gams, Aleš Tavčar

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Zvezdan Pirtošek (co-chair)

Roland Petek

Jure Bon

Peter Kokol

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Marko Hren

Aleš Tavčar

Stanislav Erzar

Janez Uplaznik

Integracija v EMZ EkoSMART

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POVZETEK

V prispevku je na kratko predstavljen modul Elektronsko in mobilno zdravje (EMZ) znotraj programa EkoSMART. Sledijo navodila za sestavljanje prispevkov in partnerjev v integriran projekt.

Ključne besede

Elektronsko in mobilno zdravstvo, pametna mesta, pametna specializacija

1. UVOD

V letu 2016 je bil sprejet Raziskovalno Razvojni in Inovacijski (RRI) program EkoSMART [3] v domeni pametne specializacije S4 na področju pametnih mest in skupnosti, kjer EMZ predstavlja enega od šestih nosilnih stebrov programa v obliki RRP (Raziskovalno-Razvojnega Projekta). V okviru javnega razpisa »RRI v verigah in mrežah vrednosti« − sklop 1: »Spodbujanje izvajanja raziskovalno-razvojnih programov (TRL 3-6)« je predvidenih 5,9 milijona evrov nepovratnih javnih sredstev za program EkoSMART.

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1. Informacijske tehnologije za podporo celostni oskrbi / bolnice / prof. dr. Z. Pirtošek
   Podpora aktivnostim v bolnici.
2. Podpora na domu za zdrave, starejše in za kronične bolnike / doma / prof. dr. M. Gams
   Podpora predvsem starejšim doma.
3. Mobilno spremljanje vitalnih in okolijskih podatkov / mobilno / prof. dr. R. Trobec
   Senzorji.
4. Računalniška podpora, podatki, kreiranje novih znanj /algoritmi / prof. dr. P. Kokol
   Navezava na dentalno zdravstvo.
5. IKT platforma / prof. dr. M. Bajec
   Platforma in povezovanje z EkoSMART.

V letu 2016 smo zastavili povezovanje preko bele knjige EMZ [1], v letu 2017 gremo na delavnici EMZ korak dlje.

2. EMZ IN OBČINE

Razvili smo ogrodje in nekaj sistemov [2] (ui-obcine.ijs.si) občin kot korak dlje od pametnih mest in oboje sistematično skušamo vpeljati v občine, društva upokojencev in druga društva ter v civilno družbo z namenom, da Slovenija ponudi boljšo izkušnjo za vse občane - da imajo več informacij, storitev in podpore. Umetna inteligenca in IKT napredujeta neverjetno hitro, raziskovalni oddelki razvijajo fantastične nove sisteme, spotoma pa nastajajo tudi sistemi, ki jih lahko namestijo in vzdržujejo inštitucije lokalne samouprave in civilne družbe.

Sistem sestavljajo naslednji bloki:

- Občinska televizija – vsakdo lahko razvije svojo občinsko televizijo s sledenjem navodilom. Potreben je prenosnik in kamera in nekaj znanja računalništva. Običajno občinska TV prenaša ali sprotno dogajanje v živo, ali pa se veti predpripravljena datoteka s tekočimi informacijami za tekoči teden.
- 3D virtualni asistent – ponovno je z nekaj znanja računalništva po navodilih možno izdelati sistem 3D virtualnega asistenta, ki vodi po stavbah, recimo upravni stavbi občine.
- Turizem – sistem omogoča informiranj o turističnih znamenitostih v naravnem jeziku in načrtovanje turističnih obiskov. Sistem vsebuje preko 3000 znamenitosti in je neposredno uporaben.
- Asistenti – za vsako slovensko občino je narejen svoj občinski asistent, ki odgovarja na vprašanja v naravnem jeziku. Obstaja tudi pokrajinski asistent in slovenski asistent – slednja sta sestavljena iz pripadajočih občinskih asistentov. Obstaja pa tudi asistent za starejše občane (zdusko) in za EkoSMART. Narejeni sta dve interaktivni mapi Slovenije, prva z občinami in druga z društvi upokojencev. Ko kliknete na mapo, se vzpostavi povezava z občino oz. društvom.

Partnerji EkoSMART so povabljeni, da se vključujejo v obstoječe bloke oz. dodajajo nove.

Za EMZ pa je najpomembnejši blok Zdravje.

3. EMZ IN ZDRAVJE

Blok »zdravje« v okviru občin (ui-obcine-ijs.si) nudi informacije o prvi pomoči, zdravstvene nasvete doma in iz tujine, informacije iz NIJZ, iz programa pametne specializacije EkoSMART ter podprojekta Elektronsko in mobilno zdravje, repozitorijev domen in prototipov, sistemov za nadziranje stresa in skrb za starejše. Storitev je dostopna v asistentih – kliknete na svojo občino, levo zgoraj, izberete aplikacijo »Zdravje«.

V nadaljevanju so našteti podsistemi in kako se vključevati v njih:

Prva pomoč: Tu dobite nasvete v primeru nujne pomoči (Mobilno Android IOS). Sistem zna do neke mere tudi sam odgovarjati na enostavna vprašanja tipa »zlomil sem si nogo«.

Integracija: dodati nove storitve prve pomoči.

Zdravstveni nasveti slovensko: Če imate zdravstvene težave, je pametno obiskati zdravnika, neodvisno od tega pa lahko pogledate, kaj pravijo strokovnjaki na spletu.

Integracija: dodati nove storitve slovenskih zdravstvenih nasvetov.

Tuji zdravstveni sistemi za pomoč, svetovanje in drugo mnenje:

Uptodate

health.com

webmd.com

10 najboljših aplikacij zdravstvenih svetovalnic

NIJZ: Tu je zbrana vrsta koristnih storitev za zdravje.

Integracija: povezovati storitve EMZ in NIJZ.

PROJEKTI

IN LIFE: s projektom IN LIFE želimo omogočiti starejšim z opešanimi kognitivnimi sposobnostmi bolj samostojno življenje. Če vas zanima testiranje sistema, pišite na jani.bizjak (at) ijs.si

E-gibalec: aplikacija za mobilne telefone, ki je bila razvita z namenom približati osnovnošolcem športne aktivnosti in jih spodbuditi k več gibanja.

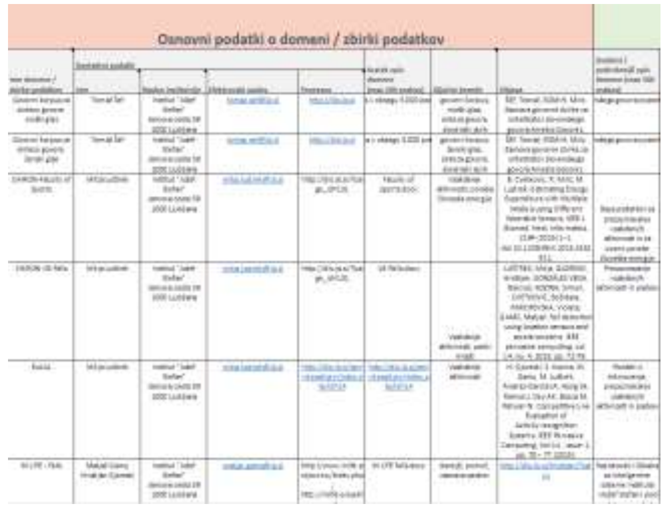
ASPO: spletna aplikacija za prepoznavanje in informiranje o spolno prenosljivih okužbah.

Zaznavanje stresa: cilj študentskega projekta OSVET je spletni pogovorni svetovalec (chatbot) za zaznavanje stresa pri uporabnikih in nudenje psihosocialne pomoči preko spleta. Uporabnik lahko izpolni tudi anketo, ki izračuna stopnjo stresa. Aplikacija je še v razvoju.

EkoSmart, EMZ: namen programa EkoSmart je razviti ekosistem pametnega mesta. V okviru EMZ (Elektronsko in Mobilno Zdravje) zbiramo repozitorije domen in prototipov, tako lahko vidite, kdo v Sloveniji hrani katere podatke in katere prototipe. Tu razvijamo asistenta za EMZ.

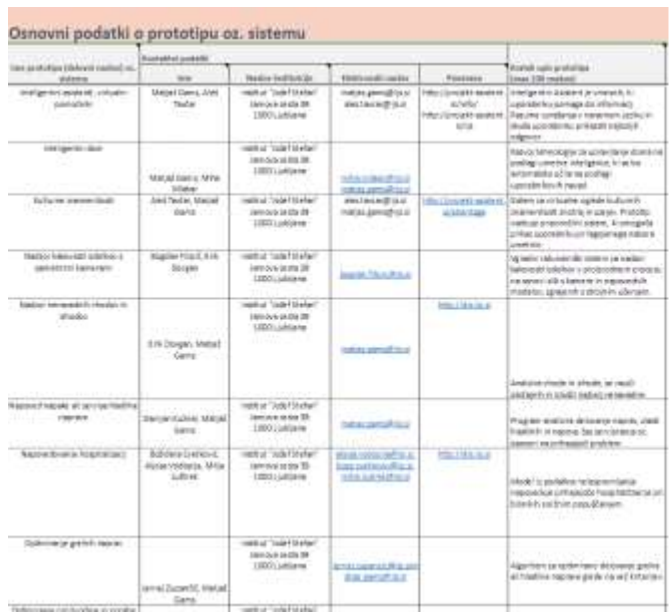
Integracija: dodajati projekte partnerjev EMZ.

Obstajata **repozitorija domen in prototipov** v obliki spletnih aplikacij.



Osnovni podatki o domeni / zbirki podatkov

Slika 1: Del izpisa vsebine repozitorija domen.



Osnovni podatki o prototipu oz. sistemu

Slika 2: Del izpisa vsebine repozitorija prototipov.

Integracija: dodajati nove prototipe in domene v repozitorija.

4. ZAKLJUČEK

Narejen je okvir in znotraj tega vrsta storitev, kamor bodo partnerji EMZ in EkoSMART dodajali svoje storitve, sisteme in dosežke. Če ni jasno, kako se doda oz. integrira, potem je najbolje poslati elektronsko pošto avtorjema tega prispevka.

5. ZAHVALA

Raziskave/delo je delno sofinancirano s strani Ministrstva za izobraževanje, znanost in šport in Evropske unije iz Evropskega sklada za regionalni razvoj (ESRR).

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POVZETEK

Slovenija in celotna Evropa se srečujeta z demografskimi spremembami z izrazitim staranjem prebivalstva in nizko rodnostjo. Skladno s povečevanjem števila in deleža starejših se povečuje število bolnikov z nenalezljivimi kroničnimi boleznimi (NKB), ki predstavljajo največji delež sredstev zdravstvenega sistema. Učinkovito obvladovanje NKB bo v prihodnje ključno za vzdržnost zdravstvenih sistemov. Večja vključenost pacientov v proces zdravljenja skupaj z uporabo sodobnih tehnologij predstavlja osrednjo izhodišče za dosego finančno učinkovitejšega sistema.

V projektu EkoSmart bomo na raziskovalni platformi eOskrba razvili in klinično validirali nove intervencije, ki bodo namenjene tako osebju in bolnikom v klinični praksi oz. posameznim raziskovalnim skupinam za potrebe znanstveno-raziskovalnega dela. Tako bomo v sodelovanju Univerzitetnega kliničnega centra Ljubljana (UKC), Medicinske fakultete (MF) in Fakultete za računalništvo in informatiko Univerze v Ljubljani (FRI) razvili pilotni sistem za spremljanje EKG in ostalih parametrov pri kardiovaskularnih bolnikih v postoperativni fazi. Sistem bo omogočal tudi medsebojno primerjavo različnih senzorjev in s tem njihovo klinično validacijo.

Ključne besede

EkoSmart, e-zdravje, interoperabilnost, Parkinsonova bolezen, srčno-žilne bolezni, diabetes, astma, debelost.

1. IZHODIŠČA

Staranje prebivalstva je v t.i. zahodnem svetu prisotno in neizogibno, poglavitna razloga pa sta nizka rodnost in daljša življenjska doba. Tako naj bi se po napovedih Eurostata delež starejših od 65 let povečal do leta 2040 s sedanjih 19% na 27% celotnega prebivalstva [1]. Ob povečevanju števila (in še bolj izrazito deleža) starejših prebivalcev se sočasno povečuje tudi število bolnikov z NKB, ki že danes predstavljajo kar 70% vseh vzrokov smrtnosti [2].

Obvladovanje stroškov naraščujočih kroničnih bolezni kot so astma, diabetes, bolezni srca in ožilja in nevrodegenerativne bolezni, je bistveno za dolgoročno vzdržnost zdravstvenega sistema, k čemur lahko pomembno prispeva dobro načrtovana vpeljava novih informacijskih in komunikacijskih tehnologij (IKT).

Pri vpeljavi IKT v zdravstveno okolje je med drugim ključno:

- Uporaba že obstoječih tehnologij oz. razvoj novih, ko je to potrebno/smiselno.
- Zagotavljanje semantične interoperabilnosti podatkov med posameznimi deležniki v zdravstvu.
- Aktivno vključevanje medicinske stroke in pacientov že v fazah izdelave z IKT podprtih procesov zdravstvene oskrbe.
- Zagotavljanje finančne učinkovitosti vpeljevanja novih / prilagojenih storitev, tudi s podporo odprtokodnih rešitev.

V različnih zdravstvenih sistemih v različnih državah, tudi v Sloveniji, so v preteklih letih pilotno vpeljali in klinično validirali že večje število IKT podprtih kliničnih poti (intervencij). Tako je bila v Sloveniji med prvimi dokazovana tako klinična [3] kot finančna [4] učinkovitost z IKT podprte intervencije za bolnike z depresijo.

Korak naprej v razvoju tehnološko naprednih rešitev za implementacijo zdravstvenih intervencij predstavlja odprtokodna rešitev eOskrba, kjer so bile na enotni platformi razvite in pilotno preizkušane različne intervencije (eAstma, eDiabetes, eHujšanje) na različnih nivojih zdravstvene oskrbe (primarna, sekundarna, terciarna); učinkovitost intervencij pa je bila tudi klinično validirana [5].

V okviru projekta EkoSmart se na osnovi platforme eOskrba razvijajo nove intervencije, tudi z vpeljavo zbiranja in analize večjega števila podatkov iz različnih senzorjev. Zelo pomembno mesto pri razvoju novih intervencij bomo namenili (z)možnosti sistema za avtomatizirano pošiljanje podatkov v nacionalno informacijsko hrbtenico in posledično dostopnost (anonimiziranih) podatkov vsem (tudi raziskovalno usmerjenim) zainteresiranim uporabnikom.

1.1 Tehnologija

Ročno merjenje in beleženje posameznih zdravstvenih podatkov, ne glede na mesto njihovega nastanka (pacient doma ali zdravstveni delavec v ustanovi) je še vedno zelo prisotno. Avtomatizirano odčitavanje in (brezžično) elektronsko beleženje podatkov je postalo mnogo učinkovitejše (hitrejše, cenejše) od prej omenjenega načina. Tako lahko z relativno majhnimi sredstvi uporabimo tehnologije, ki so že na voljo, npr. mobilni telefon, ki lahko v procesu zdravstvene oskrbe deluje kot:

- zaslon za spremljanje (zdravstvenih) podatkov, meritev, video posnetkov;
- vmesnik za brezžični zajem podatkov iz specializiranih medicinskih naprav;
- lokalno skladišče podatkov;
- komunikacijska naprava s spletom;
- zajem podatkov kot so: lokacija, smer in hitrost gibanja (GPS); pospeški in pojemki (pospeškometer), slika in video (kamera), zvok (mikrofon).

Posebno prednost predstavljajo operacijski sistemi (iOS, Android), ki omogočajo praktično neomejen razvoj in uporabo mobilnih aplikacij.

1.2 Izmenljivost informacij

Uporaba IKT orodij omogoča hitro in zanesljivo pridobivanje kliničnih in ostalih podatkov oz. informacij, pogosto ključnih za obravnavo pacientov. Hiter razvoj naprednih senzorjev z brezžičnim in avtomatiziranim prenosom podatkov na mobilne naprave nudi številne možnosti razvoja naprednih rešitev za uporabnike: zdravstveno osebje, paciente in ostale deležnike v procesu zdravljenja.

Čeprav so posamezne informacije o pacientu s pomočjo omenjene tehnologije za diagnostiko (in spremljanje terapije) že zelo uporabne, pa še vedno obstaja izrazito ozko grlo zaradi lokalne (proizvajalec naprave) hrambe posameznih podatkov. Prav tako tehnološka podjetja praviloma t.i. »surove podatke« obdelujejo in končnemu uporabniku ponujajo le t.i. »obdelane podatke«. Neusklajenost med posameznimi ponudniki in različnimi informacijskimi sistemi se rešuje z vpeljavo standardov, ki omogočajo semantično interoperabilnost - bistveno za enoznačno interpretacijo podatka/informacije v različnih informacijskih sistemih [6].

V projektu EkoSmart bomo uporabili standard OpenEHR, posamezne podatke pa se bo pošiljalo v nacionalno bazo pri NIJZ; s čimer bodo podatki na voljo ostalim zaintereiranim uporabnikom, anonimizirani podatki pa bodo na voljo tudi za raziskovalne namene.

1.3 Vključevanje uporabnikov

Nove storitve so namenjene uporabnikom, ki so v zdravstvenem sistemu praviloma medicinsko osebje, pacienti in (v nekaterih primerih) njihovi svojci. Uspešnost vpeljave novih storitev je v mnogočem odvisna od dejstva, kako bodo nove storitve zadovoljevale pričakovanja in zahteve zdravnikov, medicinskih sester, bolnikov, svojcev itd. Za učinkovit razvoj in uporabo z IKT podprtih zdravstvenih storitev je tako ključno sodelovanje zgoraj omenjenih skupin uporabnikov od prvih faz (t.j. načrtovanje storitev) do končne validacije.

1.4 Finančni vidik

Inovativna dejavnost na področju zdravstvene oskrbe s pomočjo vpeljave IKT rešitev je lahko finančno učinkovita, vendar pa to ni samoumevno. Pravilno načrtovanje razvoja, vpeljave in validacije posameznih novosti je bistveno za izboljšanje zdravstvenega stanja (kroničnih) bolnikov, ki ima hkrati tudi finančno ugodne posledice (cenejše zdravljenje).

Spremljanje finančnega učinka bomo uvedli tudi pri razvoju novih intervencij.

2. EKOSMART IN RAZVOJ NOVIH INTERVENCIJ

V okviru projekta EkoSmart razvijamo dve intervenciji, ki bosta namenjeni kardiovaskularnim bolnikom v postoperativni bolnišnični obravnavi in bolnikom s parkinsonovo boleznijo, oz. zdravstvenim delavcem pri vodenju zdravstvene oskrbe omenjenih skupin bolnikov.

2.1 eOskrba – (tudi) raziskovalna platforma

V preteklih letih se je v slovenskem prostoru že validirala vpeljava novih intervencij z uporabo IKT storitev na področju oskrbe bolnikov s NKB. Tako je bila med drugim razvita odprtokodna platforma eOskrba, na kateri bomo v okviru projekta EkoSmart razvili dve novi intervenciji. Poleg tega se bo razvil vmesnik za pošiljanje podatkov v nacionalno bazo podatkov o pacientu. Razviti intervenciji bosta vključevali tudi uporabo sodobnih, brezžičnih senzorjev.

2.2 Postoperativno vodenje kardiovaskularnih bolnikov

Spremljanje kardiovaskularnih bolnikov v postoperativni fazi je izrazito pomembno zaradi pojava morebitnih zapletov, med drugim tudi atrijske fibrilacije. Z uporabo EKG naprav, ki so lahko bodisi prenosne bodisi stacionarne, se lahko doseže relativno dober nadzor nad bolniki. Težavo predstavljata visoka cena prenosnih EKG merilcev (t.i. holter aprati) in neažurnost podatkov – prenosne EKG naprave praviloma ne pošiljajo podatkov v realnem času na strežnik, ampak se podatki hranijo lokalno v napravi in jih zdravniki odčitajo ob ponovnem prihodu v bolnišnico.

Predvidevamo, da bi uporaba cenejše naprave, ki omogoča prenos podatkov »skoraj v realnem času« lahko pomembno hitreje zaznala morebitne zaplete in na ta način preprečila marsikateri postoperativni zaplet.

V okviru projekta razvijamo celovito storitev, ki med drugim omogoča sočasno spremljanje/beleženje podatkov iz obstoječih standardnih EKG naprav in mobilnega EKG senzorja Savvy, z namenom primerjave pridobljenih podatkov in izboljšave klinične oskrbe.

2.3 Vodenje bolnikov s Parkinsonovo boleznijo

Parkinsonova bolezen je ena izmed najpogostejših oblik nevroloških bolezni, zaradi staranja prebivalstva pa se število bolnikov hitro povečuje. Tako naj bi se število bolnikov od leta 2010 do 2040 podvojilo, sami stroški zdravljenja in izgube zaradi bolezni so (za ZDA) ocenjeni na 22.800 USD na pacienta [7].

V okviru projekta razvijamo spletno-mobilno aplikacijo za spremljanje bolnikov s parkinsonovo boleznijo, predvsem z namenom aktivne uporabe (tudi v raziskovalne namene) beleženih podatkov. Kasneje predvidevamo integracijo s specifičnimi senzorji, ki se uporabljajo za spremljanje zdravstvenega stanja bolnikov in v prihodnosti razvoj celovite storitve, tako za bolnišnično oskrbo, kot tudi spremljanje pacientov na domu.

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Visual Working Memory and its impairments in Parkinson's disease

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ABSTRACT
Visual Working Memory (vWM) is a set of processes enabling short-term visual information maintenance and manipulation. Methodological developments in the past twenty years have encouraged more standardized and reliable ways to quantify vWM capacity and probe its sub-processes. Visual WM is recognized as a bottleneck in information processing system due to its highly limited capacity, yet, its central role in human cognition makes it a key research topic in understanding cognitive deficits and impairments in clinical populations. Parkinson's disease (PD) is one of the neurodegenerative disorders marked by vWM impairments. Considering that vWM impairments start at the early stages of PD, behavioral and electrophysiological vWM capacity measurements could act as important early disease biomarkers. This work was carried out for the purposes of developing the peripheral sensing techniques for EkoSMART project.

General Terms
Experimentation, Human Factors, Theory

Keywords
Visual Working memory, Parkinson's disease

1. INTRODUCTION

1.1.1. Visual working memory definition

Visual Working memory (vWM) is a capacity-limited system responsible for the short-term maintenance and manipulation of visual information [4]. It is an integrative part of the visual information processing system, responsible for such functions as integration of pre-saccadic and post-saccadic retinal images and binocular integration [10]. Furthermore, the functional role of visual WM expands beyond perceptual and processing roles. It has been repeatedly and reliably shown that vWM underlies a range of higher cognitive functions, such as fluid intelligence, reasoning, language comprehension and math abilities [11], acting as an online workspace for keeping information "in mind" [7]. Growing recognition of the vWM role in healthy and impaired cognition has resulted in a substantial increase in studies and publications related to the topic: In 2014 there were 18.224 citations in PubMed and 1.580.000 search results in Google Scholar related to working memory, whereas in 2017 the number grew to 42.474 PubMed citations and 4.750.000 Google Scholar search results [3].

1.1.2. Behavioral vWM capacity quantification

One of the most prominent and researched properties of vWM is its highly limited capacity. Different theoretical models and frameworks have always recognized that short-term storage and control mechanisms are the bottleneck in the human information processing system. However, despite the long history of research, the precise quantification of vWM capacity had varied greatly from one study to another due to the general lack of standardized measurement procedures. The turn point in the field was marked by a seminal paper of S. Luck and E. Vogel in 1997 [9]. Through a set of influential experiments, the authors introduced a game-changing discrete-slot framework of vWM capacity, as well as popularized a change-detection paradigm and a behavioral vWM capacity index K.

According to their discrete-slot model, vWM capacity is limited to, on average, 3-4 memory representations. As a result, in case of a supra-threshold memory set, only a fraction of information (3-4 representations) can be retained in vWM [5, 9]. Moreover, the individual differences in memory capacity, ranging from 1.5 to 6 items, are stable both across different stimulus modalities and time.

In addition, S. Luck and E. Vogel popularized a change-detection paradigm for quantification of vWM capacity which remains one of the dominant experimental paradigms in the field. Essentially, in a change detection paradigm the observer is presented with a memory set for a brief period of time (typically 100-200 ms) and after a short period of retention (typically around 900 ms) he is shown a probe and has to indicate whether a change has occurred [9]. There are two variants of the change-detection task: A single-probe version requires the subject to make a judgment about one item, while a whole-display version requires to make a decision regarding any element in the whole memory set. The change detection paradigm has been used and established for a variety of visual features, such as color, shape, size or orientation [9], as well as complex visual stimuli [6]. Although the change-detection task is very simple and straightforward, it has been shown to correlate well with a range of more complex tasks for fluid intelligence and high level aptitude tests [11].

Finally, S. Luck and Vogel have popularized a behavioral capacity index K for standardized vWM capacity measurement. The capacity index K is derived from accuracy parameters, such as false alarm rate and hit rate, and adjusted to the memory set size and the version of change detection task (single-probe or whole-display) [12]. The index K has enabled reliable quantification of vWM capacity across different stimuli and task modifications.

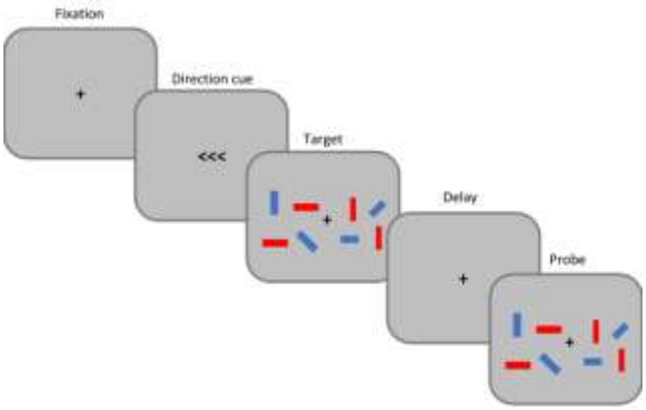

Figure 1. Example of simplified bilateral change-detection task design

1.1.3. Electrophysiological vWM capacity marker

It has been long observed that visual WM tasks are accompanied by a slow negative wave at temporal and occipital scalp sites [4]. However, the productive use of this observation was impeded by difficulties in separating visual working memory processes from those of visual perception, general effort or task difficulty. The ground-breaking change in the electrophysiological study of vWM came from E. Vogel and M. G. Machizawa [13] with the introduction of a modified bilateral variant of the change-detection paradigm (Figure 1). The modified task differed from the original one in a directional cue preceding the memory set, resulting in vWM processing being focused on one visual hemifield. This method, known as contralateral control method, can be applied to any lateralized brain system, such as visual or motor, in order to isolate specific processes.

Consequently, E. Vogel and M. G. Machizawa observed a slow negative wave larger at the contralateral (to the stimuli) temporal and posterior electrode sites. They used a subtraction method to construct a difference wave and termed it the Contralateral Delay Activity (CDA). They immediately noticed that the CDA has a great load sensitivity, which is reflected by its amplitude changes (Figure 2). Moreover, the CDA has been shown to mirror the same interpersonal vWM capacity differences as those reflected by the behavioral index K [13, 14]. Importantly, while the index K is a summary measurement of the overall performance (accuracy), the CDA allows online probing into different vWM sub-processes, such as encoding, maintenance and retrieval.

As a result, it has been shown that individual differences in vWM capacity in healthy adults can be explained by the differences in the resistance to distractors rather than the capacity itself. E. Vogel and colleagues [14] termed this vWM property Filtering Efficiency (FE). Essentially, FE indicates how well a person can resist encoding task-irrelevant distractors and use his highly limited vWM capacity efficiently. It has been since shown that FE deficits are present in many neurodegenerative and psychiatric disorders characterized by some kind of vWM impairments.

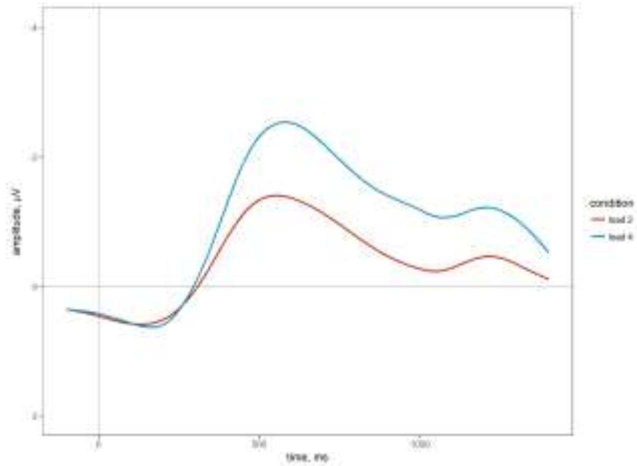

Figure 2. Example of a CDA waveform at memory load of 2 (red line) and 4 (blue line), based on real experimental data from healthy participants

1.1.4. Visual WM deficits in Parkinson's disease

One of the clinical populations marked by vWM deficits comprise Parkinson's disease (PD) patients. PD is a neurodegenerative disorder characterized by a range of motor symptoms, such as resting tremor, rigidity, and bradykinesia [2]. The motor symptoms, however, are accompanied by cognitive deficits in executive functions and goal-directed behavior [2, 8]. It is known that both the motor and cognitive symptoms are caused by dopaminergic deficit in basal ganglia, as L-dopa administration has been shown to ameliorate performance deficits in cognitive tasks, both in terms of accuracy and reaction times [2].

Visual WM deficits in PD were first defined with regard to its reduced capacity, however, development of the CDA allowed more accurate dissection of the vWM pathology in PD. E. Y. Lee and colleagues [8] used a bilateral whole-display change-detection task to quantify vWM performance in 21 idiopathic PD patient and 28 healthy controls. The behavioral capacity index K and CDA provided convincing evidence that Parkinson's disease patients have both reduced vWM capacity and impaired filtering efficiency. The authors hypothesized that the loss of dopaminergic input to the basal ganglia could lead to reduced function of globus pallidus in regulating task-relevant information storage in vWM. They also suggested that bradyphrenia could cause the observed reduced capacity and filtering efficiency, as patients could not deal efficiently with the rapid pace of the task.

Visual WM studies in PD patients are important not just for obtaining a better insight into the underlying pathology. P. S. Boggio with colleagues [1] have reported a significant improvement in WM task accuracy after active anodal tDCS stimulation over lDLPFC with 2mA, opening a discussion about possible therapeutic cognitive rehabilitation in PD.

2. CONCLUSIONS

Improved methodology in behavioral and electrophysiological quantification of visual working memory allows more accurate understanding of vWM impairments in PD patients. Considering that vWM impairments start at the early stages of PD, behavioral and electrophysiological vWM capacity measurements could act as important early disease biomarkers.

3. ACKNOWLEDGEMENTS

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Open Source C++ Libraries for Electrophysiological Data Preprocessing and Analysis

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ABSTRACT
In this paper, we describe two open source C++ libraries developed to facilitate and automate preprocessing and analysis of electromyography (EMG) and electroencephalography (EEG) data (palMEP and palEEG, respectively). Additionally, we introduce a graphical user interface (GUI) software for EMG data analysis. These tools fill existing gaps in open source data preprocessing and analysis solutions in the field of electrophysiology and neuro-stimulation. They are aimed at enabling research and its reproducibility and, at the same time, facilitate the transition of experimental clinical therapeutic methods from an open loop brain stimulation paradigm towards an adaptive more personalized closed loop paradigm. This work was carried out for the purposes of developing the peripheral sensing techniques for EkoSMART project. First, the purpose of developed tools will be introduced in the context of neuroscientific research in general and non-invasive neuro-stimulation in particular. Secondly, the inner workings of the libraries will be thoroughly described. Finally, current work in progress and future directions in development will be discussed.

Keywords
EMG, EEG, Neurostimulation, FFT, open source.

1. INTRODUCTION
Open source solutions for preprocessing and analysis of electrophysiological and neuroimaging data are now mainstream in neuroscientific research. Publically available toolboxes, such as EEGLAB[1], FieldTrip [2], or SPM[3], have gained major adhesion from the international research community. The rapid pace at which new preprocessing and analysis methods appear as well as the dynamic nature of their implementation made it somewhat necessary that toolboxes be created within the open source community so that the software would be up to date with the ongoing progress in research methodologies. Moreover, the open source model enables and promotes the interaction and exchange of information among scientist in the neuroscientific community. This, in turn, allows the seamless implementation of cutting edge methods on common universally available platforms, which is then reflected in evermore standardized data preprocessing and analysis pipelines and, hence, higher transparency and replicability of research methods and results.

While there is an abundance of well-established open source EEG and neuroimaging data preprocessing and analysis tools, there is a lack of specific solutions for the analysis of EMG data obtained in the context of non-invasive electric and magnetic transcranial stimulation, which is a well stablished neuroscientific research method for studying and altering brain function non-invasively [4]. Additionally, well-established software solutions for the analysis of EEG and MEG data, such as EEGLAB or FieldTrip, are mostly developed and implemented within the Matlab (MathWorks, Inc. Chicago) programing environment, which is a leading commercial software in scientific computing. While Matlab is commonly available in research institutions throughout the world, many research groups and individuals are often unable to afford the licence fees associated with commercial software packages, and are, therefore, forced to operate outside the mainstream of preprocessing and analysis methods.

The aim of the work in progress that the libraries here presented constitute, is to fill the two aforementioned gaps. On the one hand, we have developed an open source solution, named palMEP, to perform preprocessing and analysis of EMG data in general, and of data that has been gathered while using electric or magnetic stimulation, in particular. The methods and functionality of palMEP have been developed according to standard practices in the research community and reflect the idiosyncrasies and challenges that researchers in the field of neuro-stimulation typically face when dealing with EMG data gathered concurrently with methods such as Transcranial Magnetic Stimulation (TMS) or peripheral electric stimulation. On the other hand, we are currently developing a homologue of the EEGLAB and FieldTrip toolboxes, named palEEG, which will not be dependent on a commercial software development framework. At the moment, palEEG includes an interface to import Matlab based files containing workspace variables in general and EEGLAB and ERPLAB data structures in particular. palEEG also currently implements an experimental implementation of time-frequency decomposition using Morlet wavelets.

2. palMEP
In this section we describe the philosophy and implementation of an open source GUI based software for the preprocessing and analysis of EMG data.

2.1. *Intended usage and Scope*
This software is aimed at students, researchers and clinicians in electrophysiology and neuroscience, who have little or no experience in programming and/or in signal processing and analysis. This program is also intended for users who do have this

knowledge, but would benefit from an easy to use tool for manipulation, visualization and automation of motor evoked potentials (MEPs) analysis and preprocessing tasks.

To this end, the user interface is designed to be intuitive and simple, stripped down to the most necessary elements to reach the most commonly sought after goal: to get reliably preprocessed MEP measures in a format that is friendly to mainstream statistical analysis softwares, such as SPSS© or R[5].

The measures of choice included in this program, peak to peak, log and root mean square amplitude, are the most widely used to describe MEPs elicited by transcranial magnetic and electric stimulation. When using these stimulation methods, a large inter-trial variability is to be expected [6], hence, visual inspection of single trials might be necessary in order to reject MEPs which might have been influenced by unwanted background muscle contraction [7], or which are far too large or small. This software provides a clear and intuitive signal viewer for trial by trial visual exploration. Additionally, mean and standard deviation are also calculated, in order to allow further analysis outside this software.

This software supports the commonly used CED (Cambridge Electronic Design Limited, Cambridge, UK) Signal and Spike2 software files, as well as comma, space or tab delimited text files, which further extends the compatibility of this program to any other software which supports custom text file export.

This software is distributed, together with the source code, under the GNU GPLv3 licence. The source code is fully documented according to the Doxygen standard. The software also includes a detailed user manual in pdf format.

2.2. Implementation and Functionality

palMEP is implemented in C++ using the QT (The Qt Company Ltd) programing environment. This software depends on the CED CFS library and the CEDS64ML interface libraries, for reading Signal and Spike files, respectively. Additionally, it depends on the QCustomPlot library by Emanuel Eichhammer for signal plotting and visualization. All these dependencies are publically available and routinely maintained.

palMEP has two main modes of operation: single-trial based processing, and automatic processing of single or multiple files.

In single-trial mode, the user can easily highlight the area of interest where measures will be performed in for each trial using two interactive vertical cursor bars (see Figure 1).

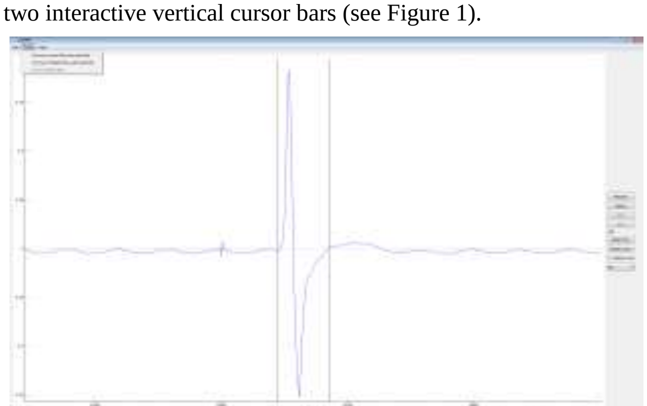

Figure 1. palMEP GUI layout.

palMEP computes the following measures and metadata of interest, and stores them in a tab delimited text file of the users choosing (see Figure 2 for a sample of the output):

1) The peak to peak amplitude: $|V_{max}| + |V_{min}|$
2) The natural logarithm of the peak to peak amplitude: $\ln(|V_{max}| + |V_{min}|)$.
3) The root mean square amplitude [9]: $RMS = \sqrt{\frac{1}{T}\sum_{t=1}^{T} EMG^2(t_i)}$. Where $EMG^2(t_i)$ is the squared value of each datum of EMG within the data window [10].
4) The latency in milliseconds: $\frac{indx_2 - indx_1}{sampling\ rate(Hz)}$. Where $indx_i$ is the index of a data point in a time series. For unknown sampling rates (delimited text files), the latency is expressed in number of data points: $indx_2 - indx_1$.
5) The sampling state, as defined in the original Signal file, or as computed from a marker channel in a Spike file. For delimited text files, state is always 0.
6) The name of the data channel as described in the original Signal or Sipke file. For delimited text files *'Channel_ID'* is always *'unknown'*.
7) The full path of the processed file.

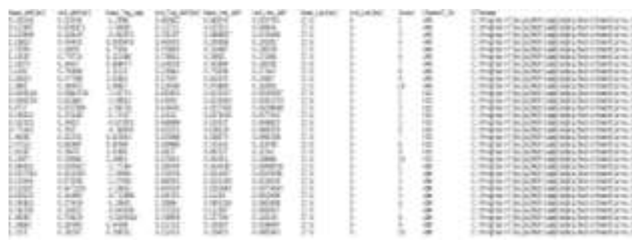

Figure 2. palMEP results output sample.

An innovative feature of this software is an algorithm designed to detect the MEP automatically, without any user input. This allows automatic processing of an unlimited number of files without previous visual inspection. The algorithm implements two methods, and if they do not coincide, it picks the solution of the one which provided the smaller result (discrepancy is usually due to one method detecting the artifact and the other detecting the MEP). The first method finds the maximum difference between each pair of consecutive data points in the sweep. The second method estimates the rate of change by iteratively calculating the first derivative in 5 data point segments, then the segment with the maximum rate of change is taken.

```
int detect_pulse(QVector<double> &data, double srate)
{
    std::vector<double> diffsa, diffsb, a(5);
    //Maximum difference method
    for (int i=0; i<data.size()-1; i++ )
        diffsa.push_back(abs((data[i])-(data[i+1])));
    int posa = std::distance(diffsa.begin(), std::max_element(diffsa.begin(), diffsa.end()));
    //Rate of change detection via first derivative method.
    for (int i=2; i<data.size()-2; i++ ){
        a[0] = data[i-2]; a[1] = data[i-1]; a[2] = data[i]; a[3] = data[i+1]; a[4] = data[i+2];
        diffsb.push_back(first_Derivative(a,srate));
    }
    int posb = std::distance(diffsb.begin(), std::max_element(diffsb.begin(), diffsb.end()));
    if (posa<posb || posb==0)
        return posa;
    else
        return posb;
}

/*| ...*/
double first_Derivative(std::vector<double>a, double srate)
{
    double t = 1/(srate*1000);
    double firstDer = (   4.0 / 3.0 * (a[3] - a[1]) / (2.0 * t)
                       - 1.0 / 3.0 * (a[4] - a[0]) / (4.0 * t) );
    return firstDer;
}
```

3. palEEG

In this section we describe the philosophy and implementation of an open source library for importing Matlab based variables, as well as EEGLAB and ERPLAB [8] data structures, and performing time-frecuency decomposition using Morlet wavelets.

3.1. Intended usage and Scope

This library is work in progress, and is intended to become a homologue alternative to the Matlab based EEGLAB, ERPLAB and FieldTrip toolboxes. At the moment, the library includes a set of useful functions and, in the near future, will include a GUI similar to palMEP to enable easy access to EEG preprocessing and analysis methods and data visualization.

This software is distributed, together with the source code, under the GNU GPLv3 licence.

3.2. Implementation and Functionality

palEEG is implemented in C++ using the QT programing environment. This software depends on the Armadillo linear algebra library [9] for matrix operations and manipulations. We have chosen Armadillo (namespace: *'arma'*), because it is well-established and maintained, it has good performance and provides a syntax and functionality similar to Matlab. For reading Matlab files, palEEG depends on the MAT File I/O Library by Christopher C. Hulbert. We have chosen this library because it constitutes a decent open source alternative to the proprietary library provided by Matlab. For computing discrete Fourier transforms (DFT) palEEG depends on the Fastest Fourier Transform in the West (FFTW) library [10]. This library has been chosen because it is possibly the fastest implementation of the fast Fourier transform (FFT) algorithm, and is also the library used by Matlab to compute FFT.

FFTW uses the following formulas for the FFT and its inverse:

$$Y_k = \sum_{j=0}^{n-1} X_j e^{-2\pi jk\sqrt{-1}/n}$$

$$Y_k = \sum_{j=0}^{n-1} X_j e^{2\pi jk\sqrt{-1}/n}$$

palEEG currently includes 4 functions for loading Matlab files, these functions are declared and implemented in *'readmat.h'* and *'readmat.c'*, respectively:

1) *'read_2dmat'*, allows reading a single vector or 2d matrix (row_n x col_n) from a .mat Matlab file.

```
int read_2Dmat(const char* filename, arma::mat &matout);
```

2) *'read_3dmat'*, allows reading a 3d matrix (row_n x col_n x $slice_n$) from a .mat Matlab file.

```
int read_3Dmat(const char* filename, arma::cube &matout);
```

3) *'read_EEG'*, allows reading an EEGLAB EEG data structure contained in either a .set or .mat data file.

```
int read_EEG(const char* filename, eegData &EEG);
```

4) *'read_EEG'*, allows reading an ERPLAB ERP data structure contained in either a .erp or .mat data file.

```
int read_ERP(const char* filename, erpData &ERP);
```

All 4 reading functions are numeric type sensitive (integer, single or double precision floating point numbers), and will convert the values to double precision, when appropriate. The functions carry out sufficient error checking to avoid crashes and will return success or failure accordingly.

Funcitons 3 and 4 store the read data into an eegData or erpData structure, respectively. These data structures are designed to keep the structure of the data as close as possible to the original EEG or ERP structure in Matlab, while only retaining the essential information for further processing in palEEG. A simplified declaration of the 2 data structures would be as follows:

```
struct eegData: public QObject{            struct erpData: public QObject{
    Q_OBJECT                                   Q_OBJECT
public:                                    public:
    double              srate;                 double              srate;
    QVector<int>        dims;                  QVector<int>        dims;
    arma::Cube<double>  data;                  arma::Cube<double>  data;
    QVector<double>     times;                 QVector<double>     times;
    QVector<QString>    channels;              QVector<QString>    channels;
    eventStruc          event;                 QVector<QString>    bindescr;
    int                 isloaded = 0;          int                 isloaded = 0;
public slots:                              public slots:
signals:                                   signals:
};                                         };
```

The *'eventStruc'* stores all the relevant marker and event information from the original Matlab event structure, retaining the subfield names for easier portability.

```
struct eventStruc: public QObject{
    Q_OBJECT
public:
    QVector<QString> type;
    QVector<double>  epoch;
    QVector<QString> estat;
public slots:
signals:

};
```

The time-frequency decomposition functions are declared and implemented in *'dotf.h'* and *'dotf.c'*, respectively.

The main function is declared as follows:

```
int do_TFeeg(eegData &EEG, std::vector<int> &freqs, std::vector<int> &cycles,
             std::vector<int> &baseline, std::vector<int> &timeLims,
             std::string &channel2use, std::string &bin2use, tfData &tf, int &type);
```

It takes the imported data and first computes the event-related potential (ERP) for any chosen experimental condition and EEG channel. It then performs the FFT of the vectorized original data. Next, it creates the Morlet Wavelet [11], according to the *'cycles'* parameter defined by the user, and computes its FFT. The FFT of the data is then element-wise multiplied by the FFT of the wavelet. Finally, the inverse FFT of the resulting multiplication is computed. This results in a vector of complex elements containing power and phase information for all the chosen time points in each of the specified frequencies. The resulting vector is then reshaped into 3 different 3d matrices (channel x Frequency x

Time), containing the raw complex-number result of the decomposition, the power and the ITPC results, respectively, and stored into a *'tfData'* structure, which is defined as follows:

```
struct tfData: public QObject{
    Q_OBJECT
public:
    arma::cx_mat          tfmat;
    arma::mat             tf_pow;
    arma::mat             tf_itpc;
    arma::mat             erp;
    std::vector<double> freqs     [3];
    std::vector<double> baseline [2];
    std::vector<double> timelims [2];
    std::string           channel2use;
    std::string           bin2use;
public slots:
signals:
};
```

The '*do_TFeeg'* function supports three different modes of operation, that can be specified via the *'type'* parameter:

1) 'Absolute Power', computes the total power (phase-locked + non-phase-locked power) and the inter-trial phase coherence.
2) 'Phase locked' Power, computes the power of the ERP only.
3) 'Non-phase-locked Power', subtracts the ERP from each individual trial in the original data before running time-frequency decomposition.

The different time-frequency measures follow the definitions by Brian J. Roach and Daniel H. Mathalon [12], while the algorithms used to compute time-frequency decomposition closely follow Mike X. Cohen [13].

Subsequent iterations of palEEG will include a GUI, additional data preprocessing tools, such as filtering and ICA based artifact rejection, new data and result visualization methods, as well as time-frequency based connectivity measures.

4. CONCLUDING REMARKS

The libraries here described constitute work in progress meant to fill existing gaps in open source data preprocessing and analysis solutions in the field of electrophysiology and neuro-stimulation. These tools are aimed at enabling research and its reproducibility and, at the same time, facilitate the transition of experimental clinical methods from an open loop paradigm towards an adaptive more personalized closed loop paradigm, which we hope to achieve by developing fully open source optimized solutions for data preprocessing and analysis.

If you would be interested in either getting a copy or collaborating in the development of these libraries, contact the author of this paper.

5. ACKNOWLEDGEMENTS

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Using brain state-dependent transcranial magnetic stimulation for investigating causal role of cortical oscillations in functional states

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ABSTRACT

Non-invasive brain stimulation is being used for manipulation of cortical oscillations in research and clinical context for development of possible therapeutic applications in brain disorders. Effects of brain stimulation show strong inter- and intra-individual variation. In general there are several sources of this variability, e.g. neuroanatomical and neurochemical factors. This article describes our work in the scope of EkoSMART consortium on development of peripheral sensing techniques. Here we focus on the rapidly varying neurophysiological factors – cortical oscillations. Current state of cortical oscillations can be continually recorded with peripheral sensors like EEG scalp electrodes and used online for continuous monitoring and adjustments of brain stimulation parameters. By adjusting the timing, intensity and frequency of transcranial stimulation to specific brain states it is possible to reduce variation in the treatment effects. However, since brain state-dependent stimulation (BSDS) requires online monitoring and analysis of neurophysiological data, it is technically demanding. BSDS has been made possible by recent technological advances and advances in analytical procedures. While EEG data has been traditionally analyzed in time- or frequency-domain only, time-frequency analysis is being increasingly used and it offers better insight into neurophysiology of oscillations. BSDS is useful in the field of clinical neuroscience, where it can be used to personalize stimulation parameters, e.g. adjust deep brain stimulation depending on the severity in symptoms in Parkinson's disease. Because it enables manipulation of cortical oscillations when a specific brain state is detected, it allows stronger causal inferences about their role in behavior and brain states. Therefore, BSDS can be also used as a tool for verification or falsification of hypotheses in cognitive neuroscience.

Keywords

Brain state-dependent stimulation, transcranial magnetic stimulation, time-frequency analysis, electroencephalography, cortical oscillations.

1. INTRODUCTION

Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation method during which magnetic field in a coil induces an electric current in nearby conductive tissue – the brain – thereby inducing action potentials in neurons. It is a common technique for manipulating neuronal oscillations and is used for research and clinical purposes. Transcranial alternate or direct current stimulation (TACS / TDCS) is a similar, although much weaker technique for modulating neural activity.

Effects of the TMS treatment show strong inter- and intra-individual variability and are influenced by neuroanatomical, neurochemical and neurophysiological factors [10]. These factors can be trait-related and can be stable (e.g. cortical thickness, individual alpha rhythm frequency) or can vary intra-individually (e.g. circadian fluctuations). On the other hand, state-related determinants can vary strongly and rapidly within and between treatment sessions. For example, it has been shown that phase and amplitude of cortical oscillations influence corticospinal excitability as measured with motor evoked responses [1, 15]. In the case of trait-related factors, variability of TMS intervention can be reduced by pre-selection of individuals based on a certain trait or by homogenizing the influencing variable, e.g. applying the treatment at the same time of the day. However, cortical oscillations can also vary on a millisecond scale and to reduce the effects of these factors, brain-state dependent stimulation is needed.

2. FEASIBILITY OF BRAIN-STATE DEPENDENT STIMULATION

Brain-state dependent stimulation (BSDS) requires online monitoring and analysis of neurophysiological data (see Figure 1). Karabanov et al. [10] distinguish between (1) state-informed noninvasive transcranial stimulation (NTBS) and (2) adaptive, closed-loop[1] NTBS. In the former, the timing, frequency or the intensity of stimulation is adjusted according to the predefined state (e.g. phase or power of cortical oscillations), whereas in the latter, stimulation is dynamically adjusted depending on the stimulation-induced state changes.

[1] In the literature, the term closed-loop stimulation is sometimes being used for both types of stimulation. However, Karabanov et al. [10] emphasize, that state-informed stimulation is not the same as "closed-loop" stimulation and that the latter term should only be used for a stimulation which adapts depending on stimulation effects in real-time.

In recent years several studies have shown feasibility of both types of stimulation. An example of state-informed NTBS is a study by Bergmann et al. [2]. To answer the question how the phases of cortical oscillations affect cortical excitability, Bergmann et al. applied TMS during sleep while concurrently measuring electroencephalographic (EEG) signal. Single-pulse TMS was triggered by automatic detection of up- and down-states in slow-oscillations during non-rapid eye movement sleep. It was shown that motor-evoked potentials (MEPs) and TMS-evoked potentials (TEPs) were larger during slow-oscillations up-states than during down-states. Similarly, Gharabaghi et al. [6] and Kraus et al. [11] showed that single-pulse TMS controlled by beta-band event-related desynchronization (ERD) during motor imagery resulted in an increase of corticospinal excitability whereas in the non-BSDS condition this effect was absent.

An example of an adaptive closed-loop stimulation is a study by Brittain et al. [4] who applied transcranial alternating current stimulation (TACS) over the motor cortex of patients with Parkinson's disease. Stimulation was delivered at tremor-frequency and adjusted in a way to produce phase-cancellation and thus achieving tremor-suppression up to 50%. Similarly, in a study by Little et al. [12] it was shown that deep brain stimulation in Parkinson's disease can be adjusted by providing feedback from local field potentials from the electrodes. This type of adaptive deep brain stimulation was more effective and efficacious than conventional continuous stimulation. While these studies provide proof-of-principle, it remains to be shown that EEG combined with non-invasive transcranial stimulation can also be used in a closed-loop, adaptive fashion [2].

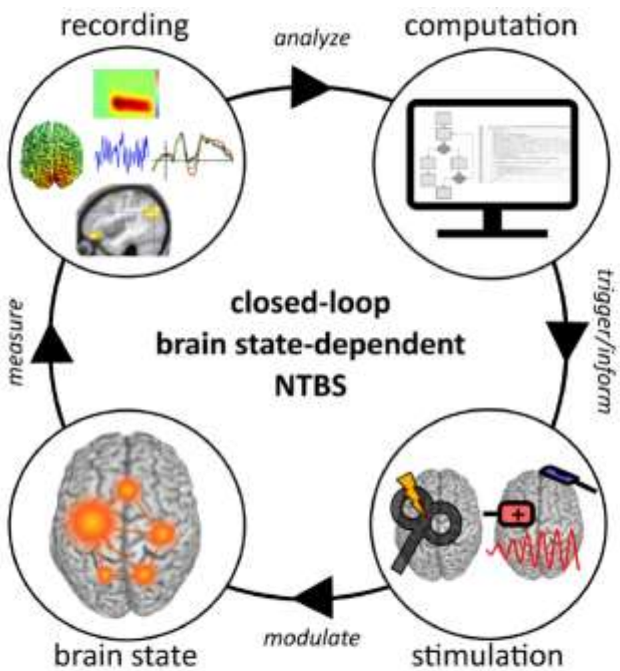

Figure 1. Closed-loop brain state-dependent non-invasive transcranial brain stimulation. Source: Bergmann et al., 2016 [3]. Originally published under CC BY license (https://creativecommons.org/licenses/by/4.0/).

Both neuroimaging (e.g. functional magnetic resonance) and electrophysiological methods (e.g. EEG) can be coupled with TMS for BSDS. TMS can be combined with fMRI for brain-states with slow fluctuations (e.g. resting state connectivity) and when spatial resolution and sensitivity to subcortical structures is important, whereas EEG is more appropriate when timing precision on sub-second level is more relevant.

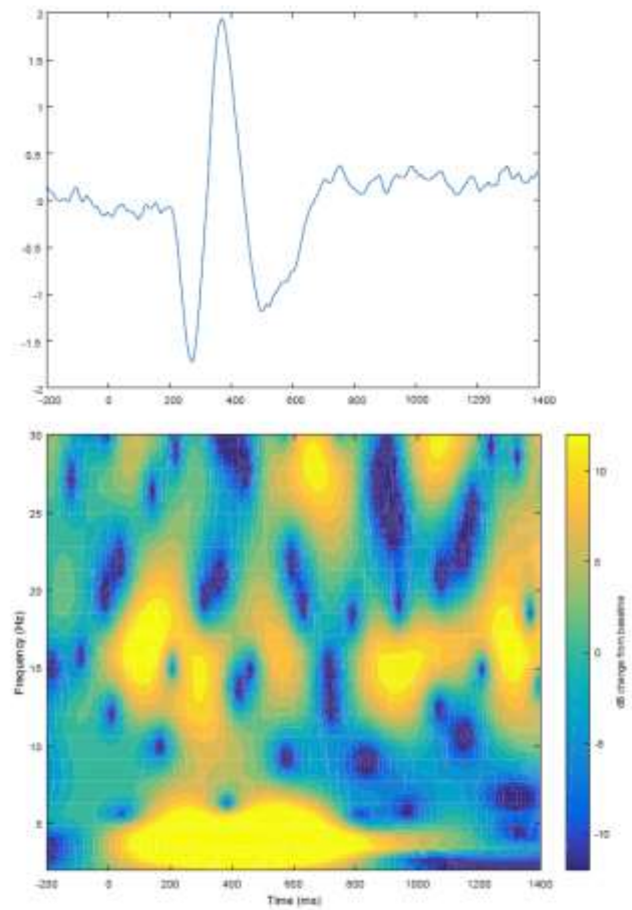

Figure 2. Same data analysed in time-domain (event-related potential, top) and with time-frequency analysis (bottom).

2.1 Challenges in online real-time analysis of brain-states

Traditionally, EEG data has been analyzed in time- or frequency-domain. In time domain analyses (see Figure 2, top), data are typically averaged across epochs based on markers, which represent events (e.g. stimulus presentation or participants' response) by which event-related potentials (ERPs) are observed. This procedure is based on an assumption that signal is constant across trials, whereas all trial-to-trial variability is considered to be noise. One major disadvantage of ERP technique which originates from this assumption is that it requires a lot of trials to achieve acceptable signal-to-noise ratio. While this procedure is still being used, it is now known that this assumption is false since even temporally fluctuating potentials (so-called non-phase-locked or induced activity) are averaged out from the signal and therefore cannot be reliably detected with ERP technique.

In frequency-domain analyses, EEG data is decomposed from time-domain into frequency-domain using Fourier transform. With this procedure it can easily be estimated which frequencies constitute EEG signal, e.g. whether there is more activity in theta-band (4–7 Hz), beta-band (16–30 Hz), etc. This type of analysis is relatively simple and therefore widely used, e.g. for research on resting state EEG. However, the fact that brain is highly non-stationary renders results of frequency-domain analyses hard to interpret, especially when we are interested in how oscillations change in response to events. The third way to analyze EEG data is by means of time-frequency analysis. Time-frequency analysis offers good time and frequency resolution (although there exists a trade-off between them) [5]. Its results are closer to actual neurophysiology in comparison to the other two methods and therefore easier to interpret. Since it does not require a large number of trials to achieve acceptable signal-to-noise ratio and since it can be used to disentangle phase-locked and non-phase-locked activity, it is more appropriate for single-trial analyses. It also enables calculation of various connectivity measures based on phase, power, etc.

Although time-frequency analysis is more computationally consuming, it is more suitable for BSDS in comparison to time- or frequency-domain analyses. Besides usefulness in online monitoring of cortical oscillations in real-time, time-frequency analysis can also be used to generate hypotheses about the causal role of different types of oscillations and for evaluating the effects of transcranial stimulation.

Another important issue in BSDS with TMS are strong artefacts produced by stimulation lasting several milliseconds [16] and TEPs caused by stimulation. In state-informed open-loop stimulation a refractory period of several seconds can be used to avoid triggering of TMS by artefacts or TEPs, whereas for closed-loop stimulation methods for online artefact reduction yet need to be developed.

3. BRAIN STATE-DEPENDENT STIMULATION ENABLES STRONGER CAUSAL INFERENCES ABOUT CORTICAL OSCILLATIONS

Whereas the usefulness of BSDS in clinical context is evident as illustrated by examples described above, BSDS can also foster progress in cognitive neuroscience. Currently, dominant approach for investigating the role of cortical oscillations in cognition is to randomly present events and then observe changes in event-related potentials or event-related oscillations. In the case of investigation of effects of TMS on the brain, EEG is correlated with TEPs or MEPs. This approach is useful for generating hypotheses about relationship between brain and functional states, however, it is essentially a correlational approach. Stronger causal inferences are possible if events are triggered when a specific brain state is detected.

Besides BSDS where transcranial stimulation is adapted to the brain state, a stimulus presentation or task can also be adapted to the brain state, resulting in the so-called brain-state dependent task (BSDT) [8]. For example, Ngo et al. [13] applied auditory closed-loop stimulation in phase with slow oscillation up-states during sleep. This improved memory consolidation and enhanced declarative memory retention.

All three approaches can be used complementary: first, it can be shown that a specific oscillatory pattern is linked to behavior. For example, Osipova et al. [14] have shown that stronger gamma and theta activity during visual stimuli presentation predicted subsequent retrieval. A hypothesis that gamma and theta activity is causally linked to memory encoding could further be tested using BSDS, where oscillations in gamma and theta spectra would be manipulated using transcranial brain stimulation. Further, using BSDT, if low theta or gamma power were detected during stimuli presentation, these stimuli could then be presented multiple times and in this way learning would be more efficient.

4. CONCLUSION

Computational advances and advances in statistical methods have in recent years enabled analysis of trial-to-trial variations in the field of neurophysiology. This has led to new hypotheses about the functional role of cortical oscillations. Brain state-dependent stimulation can be used as a tool for testing these hypotheses and thus enables making strong causal inferences about cortical oscillations. BSDS is a significant step towards optimizing non-invasive transcranial brain stimulation interventions, thus enabling more efficient stimulation adapted to the individual’s brain and/or functional state. To conclude, research on brain state-dependent stimulation is still in its infancy and shows considerable promise in fostering progress in cognitive and clinical neuroscience.

5. ACKNOWLEDGEMENTS

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Diagnosticiranje parkinsonove bolezni iz glasu osebe

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POVZETEK

Zgodnje odkrivanje parkinsonove bolezni je pomembno za lajšanje simptomov pri bolnikih. Za prakso bi bile koristne nezahtevne, splošno uporabne avtomatizirane metode odkrivanja znakov bolezni. Ena možnost v tem pogledu je diagnosticiranje z avtomatsko analizo glasu osebe. V tem prispevku so opisani poskusi z učenjem diagnosticiranja parkinsonove bolezni iz zvočnih posnetkov glasu oseb v treh bazah podatkov, predvsem Sage Bionetworks. V poskusih ocenjena diagnostična točnost iz 10 sekundnega zvočnega posnetka je 80,7%.

Ključne besede

Strojno učenje, medicinske aplikacije, parkinsonova bolezen, diagnostika

1. UVOD

Parkinsonova bolezen je nevrodegenerativna bolezen, katere glavni simptomi so tremor v mirovanju, počasno začenjanje gibov, mišična rigidnost in tudi težave z govorom. Zgodnje odkrivanje parkinsonove bolezni je pomembno za lajšanje simptomov pri bolnikih. Za prakso bi bile koristne nezahtevne, splošno uporabne avtomatizirane metode odkrivanja znakov bolezni. Ena možnost v tem pogledu je avtomatska analiza glasu osebe, kot kažejo npr. raziskave M. Littla, A. Tsanasa in sodelavcev [2,3,7,8,9] . V njihovih raziskavah je šlo predvsem za daljinsko spremljanje poteka bolezni.

Nekatera izhodišča za pričujoče delo so opisana v [12]. V tem prispevku želimo z uporabo strojnega učenja razviti model za prepoznavanje znakov parkinsonove bolezni v glasu osebe, ki bi bil splošno uporaben kot mobilna aplikacija za zgodnje diagnosticiranje parkinsonove bolezni. Model je naučen iz primerov zvočnih posnetkov glasu »aaaa«, ki so jih bolniki in zdrave osebe posnele z elektronsko napravo. Te posnetke je potrebno analizirati in izračunati atribute, na osnovi katerih se učimo klasificirati posnetke. Rezultat klasifikacije govori o tem, ali kaže zvočni posnetek znake parkinsonove bolezni ali ne.

2. UPORABLJENI PODATKI

Za učenje učnega modela smo uporabili tri podatkovne zbirke. Dve podatkovni zbirki sta prosto dostopni na spletnem repozitoriju UCI Machine Learning Repository [1]. Tretjo podatkovno zbirko smo pridobili pri neprofitni organizaciji Sage Bionetworks. Baza je z ustrezno registracijo dostopna preko spletnega portala Synapse (https://synapse.org).

Podatkovne zbirke, ki smo jih uporabili, so objavili:

(1) Athanasios Tsanas in Max Little [2], ki sta s pomočjo desetih zdravstvenih ustanov in podjetjem Intel s pomočjo naprave za nadzor na daljavo (angl. telemonitoring) spremljala 42 oseb v obdobju šestih mesecev, ki so bile v zgodnji fazi PB. Vsaka oseba je posnela približno 200 zvočnih zapisov. V podatkovni zbirki so že izračunani atributi 5875 posnetkov. Vsak posnetek je predstavljen s 26 atributi. Celotna podatkovna zbirka obsega 890 KB.
(2) Max Little [3], ki je skupaj z Nacionalnim centrom za glas in govor (angl. National Centre for Voice and Speech) iz Denverja v Koloradu naredil raziskavo z 31 osebami, med katerimi jih je 23 imelo PB, drugih osem je predstavljalo kontrolno skupino. Vsaka oseba je posnela približno šest zvočnih zapisov. V podatkovni zbirki so že izračunani atributi 195 posnetkov. Vsak posnetek je predstavljen s 23 atributi. Celotna podatkovna zbirka obsega približno 40 KB.
(3) Sage Bionetworks [4], ki je sponzorirala raziskavo, pri kateri so sodelujoči naložili na svoj mobilni telefon aplikacijo mPower. S to aplikacijo so lahko opravili nekaj enostavnih testov (anketa, snemanje glasu, uporaba aplikacije med hojo, tapkanje in igra za testiranje spomina). Rezultati teh testov so se shranili na spletnem strežniku za poznejšo obdelavo in analizo. Izmed vseh teh informacj smo uporabili rezultate anket in posnetke glasu. Anketo je izpolnilo 6805 različnih oseb, od katerih je svoj glas posnelo 5826 različnih oseb. Sodelujoči so svoj glas lahko posneli večkrat, tako je v podatkovni zbirki 65022 zvočnih posnetkov, ki so dolgi 10 sekund in še nimajo izračunanih atributov. Število oseb, ki so izpolnile anketo in posnele svoj glas, je 4962. Izmed teh je 970 ljudi označilo, da imajo diagnosticirano parkinsonovo bolezen, drugih 3992 oseb pa ne. Ta podatkovna zbirka obsega 81.3 GB. Pri interpretaciji naših rezultatov je treba predpostaviti, da je tako pridobljena informacija o zdravstvenem stanju sodelujočih oseb dovolj zanesljiva.

3. POSKUSI

Poskuse smo izvajali v programskem jeziku Python. Pri implementaciji učnih algoritmov, kot so naključni gozdovi, metoda podpornih vektorjev in drugih, smo si pomagali s knjižnico Scikit-learn [5]. Za implementacijo nevronskih mrež smo uporabili knjižnici Keras [6] in CNTK (https://www.microsoft.com/en-us/cognitive-toolkit/). Pri preverjanju pravilnosti modela smo uporabili 10-kratno prečno preverjanje.

Za lažje nadaljnje delo smo vizualizirali nekatere anketne odgovore v bazi Sage Bionetworks. Tako smo dobili boljši pregled nad podatki, ki smo jih uporabili. Pri tem smo opazili, da so ljudje s parkinsonovo boleznijo večkrat posneli svoj glas kot ljudje brez. V povprečju so osebe s parkinsonovo boleznijo 40 krat posnele svoj glas, medtem ko so zdrave osebe v povprečju posnele svoj glas šest krat. Med analizo anketnih odgovorov smo ugotovili tudi, da so nekatere osebe, ki nimajo diagnosticirane parkinsonove bolezni, prav tako navedle letnico, kdaj naj bi se jim pojavili prvi simptomi ali pa katerega leta naj bi bili diagnosticirani s parkinsonovo boleznijo. Posnetkov teh oseb v nadaljnji analizi nismo uporabili, saj jih nismo mogli obravnavati kot dovolj zanesljive. Prav tako v nadaljnjem delu nismo uporabili posnetkov oseb, ki nimajo parkinsonove bolezni, vendar imajo kakšno drugo bolezen. S tem se je zmanjšalo število primernih oseb za analizo v podatkovni zbirki pridobljeni preko spletnega portala Synapse na 2909.

Da bi lahko združili podatkovne zbirke v eno, smo morali uporabiti atribute izračunane z enakimi algoritmi. Zbirki, ki sta jih objavila Athanasios Tsanas in Max Little, sta že imeli izračunane atribute, vendar je bilo med temi atributi samo deset takšnih, ki so bili izračunani z enakimi algoritmi in katere lahko tudi sami izračunamo. Te atribute lahko izračunamo s pomočjo knjižnice Voice Analysis Toolbox, ki jo je izdal Athanasios Tsanas (https://people.maths.ox.ac.uk/tsanas/software.html), [7] [8] [9]. To knjižnico smo v prvem delu analize uporabili za izračun atributov zvočnih posnetkov, ki smo jih pridobili preko spletnega portala Synapse. Za izračun atributov smo uporabili samo prvi veljavni posnetek posamezne osebe. Za tako izbiro smo se odločili, da bi se izognili morebitnemu vplivu privajanja pri kasnejših posnetkih.

4. REZULTATI

Klasifikacijski model, induciran iz podatkov iz prvih dveh baz z originalno izračunaninimi atributi (Tsanas in Little), je imel klasifikacijsko točnost 99.5% [11]. Zaradi suma, da tak rezultat ne more biti realen, smo iskali razlago, kako bi lahko prišlo do tako visoke točnosti. Ena možnost je, da podatkovna množica ni bila dovolj uravnotežena glede na zastopanost obeh razredov v učni množici (posnetkov zdravih oseb je bilo manj kot 1%). Druga možnost je pristranskost, saj bi lahko učni model našel povezave med posnetki istih oseb, ki so bili v podatkovnih zbirkah, ki sta jih objavila Athanasios Tsanas in Max Little. Tako bi lahko klasifikator določal razred glede na to, ali gre za isto osebo, ne pa, ali gre za znake bolezni. Verjetna razlaga bi lahko bila tudi, da so bili podatki v teh dveh zbirkah drugače obdelani. Zaradi tega smo opustili ti dve podatkovni zbirki in se osredotočili samo na podatke iz portala Synapse. Z uporabo samo enega posnetka osebe in uravnoteženo množico je imel najboljši učni model klasifikacijsko točnost 67.8%. Ta klasifikator je bil naučen z metodo podpornih vektorjev. Ta rezultat je zanimiv tudi zato, ker kaže, kako zavajajoči so lahko rezultati učenja iz izrazito neuravnoteženih podatkovnih množic. V našem prvem poskusu [11] je bila točnost preko 99%, čeprav smo pri tem uporabili metode za avtomatsko uravnotežanje podatkov.

Klasifikacijske modele, naučene z atributi izračunanimi z uporabo knjižnice Voice Analysis Toolbox, smo želeli primerjati z drugimi modeli, ki bi se učili na večjem številu izračunanih atributov. V ta namen smo uporabili tudi knjižnico OpenSmile [10], s katero smo izračunali za vsak posnetek 6375 atributov. S to knjižnico smo lahko analizirali samo podatke pridobljene preko spletnega portala Synapse, saj smo le pri teh podatkih imeli na razpolago dejanske zvočne posnetke. Prav tako smo s to knjižnico analizirali le prve veljavne posnetke posamezne osebe.

Z uporabo istih zvočnih posnetkov, le da z atributi izračunanimi s knjižnico OpenSmile, je imel klasifikator, naučen z uporabo metode podpornih vektorjev klasifikacijsko točnost 77.9%. Na teh podatkih se je med vsemi najbolje odrezal klasifikator z uporabo ansambelske metode GradientBoostingClassifier, ki je dosegel klasifikacijsko točnost 80,7%. Ta rezultat je treba interpretirati z določeno mero previdnosti glede na to, da podatki v bazi Sage Bionetworks niso uravnoteženi glede na starost ob prisotnosti oz. neprisotnosti bolezni. V podatkovni bazi je namreč povprečna starost oseb z boleznijo bistveno višja kot pri zdravih osebah.

5. ZAKLJUČKI

Naša doslej dosežena točnost diagnosticiranja parkinsonove bolezni iz glasu (parkinsonova bolezen da/ne) je 80.7%. V nadaljevanju projekta nameravamo ta rezultat, dobljen s podatki iz Sage Bionetworks, preveriti glede na možen vpliv porazdelitve oseb po starosti odvisno od prisotnosti bolezni. Izvedli bomo tudi poskuse z neposrednim učenjem z globokimi nevronskimi mrežami iz zvočnega posnetka, brez računanja izpeljanih atributov iz posnetka.

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Arhitektura sistema za oddaljeno spremljanje pacientov

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POVZETEK

V prispevku predstavimo arhitekturo sistema za oddaljeno spremljanje pacientov MyDataHub, ki nastaja v sklopu projekta EkoSmart. Sistem sestoji iz zaledne aplikacije, zgrajene na osnovi mikrostoritev, certifikatne agencije, kriptirane podatkovne baze, avtentikacijskega ter avtorizacijskega strežnika in mDH naprav, ki jih uporabljajo pacienti za zajem vitalnih znakov. Namen sistema je zagotavljati varno povezljivost med napravami mDH in ostalimi sistemi.

1. UVOD

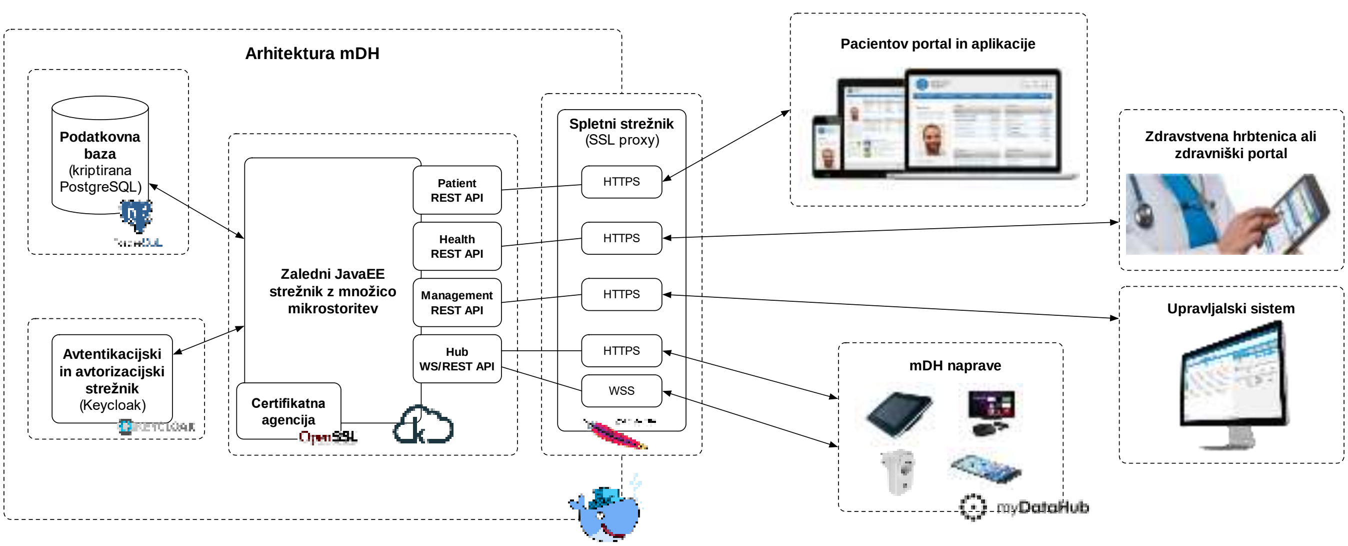
V Evropi je prisoten trend staranja prebivalstva [1] ter naraščanja bolnikov s kroničnimi boleznimi [2]. Slednje predstavlja veliko družbeno in ekonomsko breme in kliče po inovativnih IKT rešitvah, ki bi razbremenile medicinsko osebje ter posledično zmanjšale čakalne vrste s pomočjo oddaljenega spremljanja pacientov. Kot odgovor na nastalo stanje se je na trgu že pojavilo veliko različnih rešitev (npr. OpenTeleHealth [3]). Med drugim tudi v sklopu projekta EkoSmart nastaja rešitev MyDataHub (mDH), ki bo omogočala oddaljeno spremljanje pacienta s poudarkom na zajemu vitalnih znakov z uporabo različnih merilnih naprav. V prispevku je predstavljena arhitektura sistema mDH in vmesniki. Pri zasnovi arhitekture je bil glavni poudarek na varovanju osebnih podatkov in zagotovitvi varnega kanala za prenos podatkov.

2. ARHITEKTURA mDH

Sistem mDH sestoji iz zaledne aplikacije, zgrajene na osnovi mikrostoritev, certifikatne agencije, kriptirane podatkovne baze in avtentikacijskega ter avtorizacijskega strežnika. Namen sistema je zagotavljati varno povezljivost med napravami mDH, ki jih uporabljajo pacienti za merjenje svojih vitalnih znakov, in ostalimi sistemi. Slednji zagotavljajo delovanje celostne zdravstvene storitve od začetka telemedicinske obravnave, tehničnega in zdravstvenega nadzora, do zaključka ali predaje naprave drugemu uporabniku. Za zunanje sisteme predstavlja mDH enotno točko za vso realnočasovno ali odloženo komunikacijo s pacienti ter za dostop do njihovih podatkov. Zaradi ustreznega zagotavljanja varnosti mDH vključuje lastno certifikatno agencijo in nabor štirih programskih vmesnikov, ki so ločeni glede na funkcionalne zahteve zunanjih sistemov. Vsakega od programskih vmesnikov in primerov zunanjih sistemov na kratko predstavimo v sledečih razdelkih (2.1, 2.2, 2.3 in 2.4).

2.1 Pacientov portal in aplikacije

Vmesnik `/patient` omogoča dostop do vseh podatkov vitalnih znakov, ki jih je pacient ustvaril s pomočjo naprav mDH. Preko portala jih lahko dopolni z dodatnimi kontestualnimi podatki, deli z drugimi ali omogoča dostop do njih svojim družinskim članom. V primerjavi z napravo mDH, so lahko na portalu na voljo naprednejše vizualizacije in morebitne avtomatske interpretacije meritev ali napredek.



Slika 1: Arhitektura integriranega sistema, ki omogoča komunikacijo z mobilnimi zdravstvenimi napravami pacientov in integracijo z zunanjimi sistemi z namenom zagotovitve celostnih zdravstvenih storitev.

2.2 Zdravstvena hrbtenica ali zdravniški portal

Povezava z zdravniškimi sistemi (vmesnik `/health`) je poleg naprav mDH eden ključnih za doseganje višje dodane vrednosti v okviru elektronskih in mobilnih storitev v zdravstvu. Integracija z zdravniškimi sistemi omogoča zdravnikom, da nadzorujejo svoje paciente, so o njihovem poslabšanem stanju avtomatsko obveščeni, preverjajo njihove podatke, neposredno komunicirajo z njimi in jim oddaljeno določajo zahteve po merjenju vitalnih znakov.

2.3 Upravljalski sistem

Preko vmesnika `/manage` je omogočeno celovito upravljanje z arhitekturo mDH. Upravljalski sistem definira storitve, ki zdravnikom in pacientom zakrijejo postopke vzpostavitve novih mDH naprav, reklamacij, menjav, beleženja aktivnosti, zagotavljanja sledljivosti in skalabilnost glede na predvidene potrebe. Preko vmesnika je možno mDH integrirati v obstoječi večji sistem in ga tako upravljati programsko. Prav tako je na voljo razvit upravljalski portal mDH, ki podpira osnovno delovanje in nadzor vseh storitev mDH.

2.4 Naprave mDH

Naprave mDH skrbijo za zajem podatkov iz senzorjev ali merilnikov vitalnih znakov in povezavo s sistemom mDH. Preko vmesnika `/hub` sta izpostavljena dva tipa storitev - HTTPS REST in WSS. Websocket povezava med napravo in sistemom je vzpostavljena ves čas, ko je hub povezan v Internet, saj tako omogoča oddaljen nadzor in pošiljanje novih zahtevkov ali neposredno avdio-video komunikacijo z zdravnikom. Preko te povezave hub tudi pošilja nove rezultate meritev, ki jih v primeru nepovezljivosti hrani do 30 dni in so poslane takoj ob vzpostavitvi povezave. Storitve tipa REST pa omogočajo vzpostavitev nove mDH naprave, pošiljanje večjih binarnih datotek (na primer EKG meritve) ali posodobitve programske opreme. Vsaka mDH naprava ima dodeljen lasten odjemalski certifikat, preko katerega lahko dostopa do vseh storitev. V primeru komprimitiranja naprave pa se lahko ta certifikat doda na črno listo in tako onemogoči vzpostavljanje povezave z mDH sistemom.

3. ZAKLJUČEK

V prihodnosti lahko pričakujemo porast sistemov in aplikacij, ki bodo omogočale zajem podatkov o našem zdravstvenem stanju ter podatke posredovale v zaledni sistem, kjer bodo na voljo zdravniku. Pri zasnovi arhitekture takega sistema je potrebno posebno pozornost nameniti zasebnosti in varnosti. V prispevku smo predstavili arhitekturo sistema mDH, ki nastaja v okviru projekta EkoSmart. Z mDH lahko pripomoremo k optimizaciji zdravstvene oskrbe in uspešnosti zdravljenja.

4. ZAHVALA

Raziskave/delo je delno sofinancirano s strani Ministrstva za izobraževanje, znanost in šport in Evropske unije iz Evropskega sklada za regionalni razvoj (ESRR).

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[3] OpenTeleHelath. Dostopno na: http://www.opentelehealth.com/

Razvoj zapestnice za pomoč starejšim

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POVZETEK
Razvoj zapestnice za pomoč starejšim narekuje uporabo najnovejših tehnologij in dognanj na področju umetne inteligence, da bi lahko zadovoljili želje in potrebe uporabnikov. Razvoj na področju elektronike in umetne inteligence omogoča izdelavo zapestnic, ki bodo omogočale samodejen klic na pomoč ob nevarnih situacijah. V tem delu so predstavljene ključne funkcije, ki jih zapestnica lahko nudi in kako te vplivajo na uporabnikovo izkušnjo. V drugem delu so predstavljene zahteve, ki so sestavljene na podlagi uporabniških izkušenj in mnenj strokovnjakov na tem področju.

Ključne besede
zdravje, starejši, zapestnica

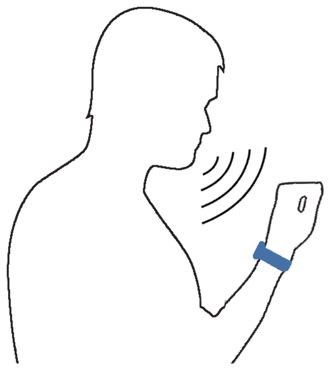
1. UVOD
Trend staranja prebivalstva v razvitih državah narekuje iskanje novih rešitev tako na družbenem, socialnem, poslovnem ter finančnem, kot tudi na tehnološkem področju. Razvoj novih tehnologij omogoča izboljšanje kakovost življenja starejšim, vendar mora biti način implementacije prilagojen posebej njim.

Naprave namenjene starejšim morajo biti prilagojene njihovim željam, sposobnostim ter morajo reševati težave, ki jih imajo. Ena izmed glavnih težav starejše populacije je, da je kljub temu, da je velik del te populacije povsem sposoben samostojnega bivanja v svojem gospodinjstvu, prisiljen življenja v varovanih domovih, saj se bojijo, da jim v primeru ko bodo potrebovali pomoč, ta ne bo na voljo. Pri starostnikih, ki živijo sami v svojem gospodinjstvu je namreč verjetnost, da ob kritičnih situacijah ne bodo zmogli izvesti klica na pomoč večja kot pri ostali populaciji. Prav tako so lahko alarmantne spremembe v njihovem obnašanju, ki jih starostniki sam ne opazijo. Vse te težave so rešljive z uporabo sodobnih tehnologij.

Pri pregledu sorodnega dela, smo naleteli na nekaj rešitev [1, 2, 3, 4, 5], ki že nudijo funkcionalnost klica v sili, nekatere imajo tudi možnost lokalizacije in samodejne detekcije padcev, medtem ko nismo našli rešitve, ki bi obenem merila tudi uporabnikovo aktivnost. Pregledane naprave imajo različno dolgo življenjsko dobo baterije, ki se giblje od 36 ur pa vse do 30 dni. Oblika omogoča nošnjo v žepu, pripeto na pas ali kot verižico okrog vratu, nismo pa je našli v obliki zapestnice. V nadaljevanju so predstavljene funkcionalnosti in zahteve za razvoj zapestnice.

2. FUNKCIJE
Na podlagi zbranih mnenj strokovnjakov in uporabnikov, smo prišli do nabora funkcij, ki jih mora zapestnica omogočati. Te so: (1) zvočna komunikacija, (2) ročno proženje alarma, (3) detekcija padcev, (4) lokalizacija in (5) merjenje aktivnosti.

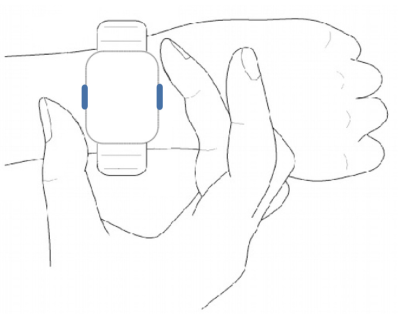
2.1 Zvočna komunikacija
Zapestnica omogoča zvočno komunikacijo med uporabnikom in klicnim centrom oz. drugo osebo, ki ji lahko v krizni situaciji nudi pomoč. Izbrana zvočna komunikacija je starejšim uporabnikom enostavna za uporabo (velika večina uporabnikov zna uporabljati vsaj stacionarni telefon) ter omogoča komunikacijo ne glede na namen vzpostavitve povezave. Prav tako je razlog za izbor v enostavnosti implementacije in majhnih zahtevah v hitrosti povezave, ki je potrebna med napravo in klicano napravo. Za enako izbiro so se odločili tudi vsi sorodni produkti, ki smo jih pregledali.



Slika 1: Govorna komunikacija.

2.2 Ročno proženje alarma
Razvita zapestnica mora omogočati klic v sili ob zahtevi uporabnika. Ta funkcionalnost omogoča klic na pomoč ob vsaki nevarni situaciji, kot je npr. slabost, nesreča, pomoč drugi osebi ipd. Tak pristop omogoča hiter klic na pomoč in omogoča hitrejše posredovanje pristojnih organizacij ali posameznikov. Čas med nesrečo in obvestilom nujne pomoči je namreč pri starejših v primerjavi z veščimi uporabniki sodobnih tehnologij lahko precej daljši. V nekaterih primerih pride celo do tega, da starejši ne zmore priti do mobilnega ali stacionarnega telefona, s katerim bi poklical na pomoč.

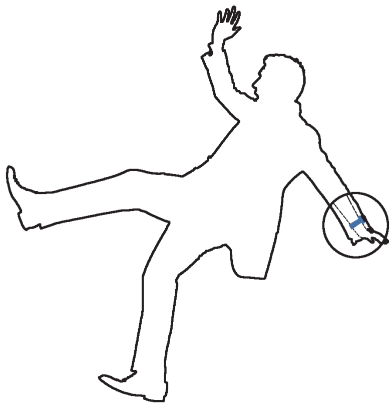
Z namestitvijo komunikacijske naprave na zapestje navidezno skrajšamo razdaljo med uporabnikom in potrebno pomočjo, saj se ta nahaja na uporabnikovem zapestju. Da bi zmanjšali število neželenih klicev, je potrebno gumb implementirati na pravem mestu, oziroma dodati več gumbov, ki šele ob hkratnemu pritisku sprožijo alarm.



Slika 2: Ročno proženje alarma.

2.3 Detekcija padcev

Detekcija padcev nadgrajuje pomanjkljivosti ročnega proženja alarma, saj obstaja možnost, da v primeru padca uporabnik ni sposoben aktivirati ročnega klica na pomoč. V takih primerih lahko zapestnica samodejno zazna padec ter samodejno pokliče na pomoč. S to funkcionalnostjo dodatno povečamo nabor morebitnih nevarnih dogodkov ob katerih zapestnica nudi pomoč uporabniku.



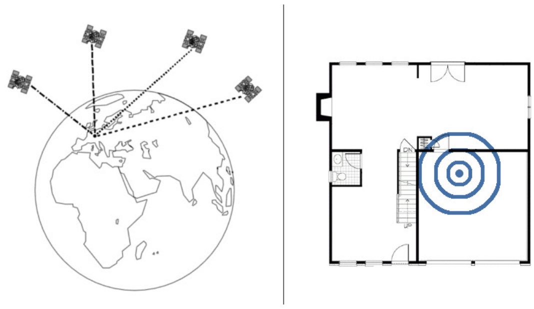
Slika 3: Detekcija padcev z uporabo zapestnice.

Trenutni sistemi zaznavajo padce s precej nizko točnostjo. V [6] poročajo o rezultatih realnih testov, v katerega je bilo vključenih 18 uporabnikov v obdobju 4 mesecev, pri čemer je bil kar v 8% zaznan padec, čeprav le tega ni bilo, dejanski padci pa so bili zaznani le v 25%. Ti podatki kažejo o velikem deležu napačno proženih alarmih, ki so lahko za uporabnika zelo moteči, ter o majhnem številu pravilno razpoznanih padcih, kar v realnosti nudi le malo pomoči uporabnikom.

Kljub temu je s hitrim razvojem umetne inteligence mogoče pričakovati, da bomo lahko ta problem boljše rešili že v bližnji prihodnosti [7]. Glavna težava je pridobitev zadostne količine podatkov o padcih, saj je njihova pojavitev redka, vendar je z velikim številom naprav in uporabnikov mogoče pridobiti zadosten vzorec padcev. Ti bodo služili kot učni in testni podatki na podlagi katerih bo v prihodnosti mogoče zgraditi algoritme za boljše zaznavanje padcev.

2.4 Lokalizacija

Pozicioniranje ali lokalizacija uporabnika je uporabna funkcija, ki močno poenostavi iskanje osebe v primeru kritičnih situacijah. Za enkrat sta predvideni dve funkcionalnosti v povezavi z lokalizacijo: (1) lociranje uporabnika ob klicu na pomoč in (2) lociranje uporabnika, ob izginotju ali nenavadni odsotnosti.



Slika 4: Globalna in lokalna lokalizacija.

Prva lokalizacija se proži ob ročnem ali avtomatskem klicu na pomoč, pri čemer klicanemu pošlje sporočilo s koordinatami uporabnika. Na ta način je mogoče locirati uporabnika, brez njegovega govornega opisa lokacije. To lahko bistveno skrajša čas za iskanje osebe v nevarnosti.

Druga funkcionalnost omogoča lociranje uporabnika, v kolikor se pojavi sum na izginotje, zaradi česar bi lahko bil uporabnik v nevarnosti. Najbolj ranljivi so predvsem dementni ljudje, saj lahko pride do tega, da zaidejo in se ne znajo vrniti v svoje bivalno okolje. Obe funkcionalnosti enostavno rešujeta precej težke situacije, ki so brez lokalizacije težko rešljive.

2.5 Merjenje aktivnosti

Spremembe v aktivnosti uporabnika lahko nakazujejo na zdravstvene težave, zaradi česar je potrebna pomoč uporabniku. Z meritvijo uporabnikove aktivnosti je mogoče zaznavati odklone od normalnih okvirov ter pravočasno ukrepati. Podatki o uporabnikovi aktivnosti lahko služijo tudi za oceno uporabnikove fizične pripravljenosti ter za svetovanje glede pravilne količine gibanja, ki je primerna za posameznega uporabnika.

V zadnjem času se je na trgu pojavilo veliko število zapestnic, ki omogočajo štetje števila korakov, merjenje spanca [8], merjenje aktivnosti [9] in podobno. Med raziskavo sorodnih naprav pa nismo naleteli na nobeno zapestnico, ki bi vsebovala zgoraj opisane funkcionalnosti in bi poleg tega nudila merjenje aktivnosti. Prav tako nismo našli zapestnice, ki bi omogočala ugotavljanje sprememb v gibanju.

Ob zaznavi odklona uporabnikove aktivnosti, je predvideno obveščanje skrbnika, ki lahko preko klicne povezave preveri ali osebno preveri, če je z varovancem vse v redu. Ta funkcionalnost omogoča zgodnje odkrivanje težav ter njihovo odpravljanje, kar lahko pripomore k hitrejšemu okrevanju. Poleg tega je mogoče zaznati tudi prevelike napore uporabnika, ob čemer se lahko uporabnika opozori ter vpraša če potrebuje pomoč pri opravilu, ki ga počne. Ta funkcionalnost omogoča personalizirano svetovanje uporabniku s čemer je mogoče na dolgi rok izboljšati zdravje in dobro počutje uporabnika.

3. ZAHTEVE

V tem poglavju so predstavljene zahteve, ki temeljijo na v prejšnjem poglavju opisanih funkcionalnostih. Glavne zahteve so razdeljene na tri podpoglavja in sicer: (1) območje delovanja, (2) enostavnost uporabe in (3) interakcija z uporabnikom.

3.1 Področje delovanja

V splošnem ločimo naprave, ki so namenjene lokalni (npr. varovani domovi) ali globalni uporabi. V primeru lokalne uporabe, sistem navadno potrebuje dodatno infrastrukturo, ki omogoča locirati uporabnika znotraj objekta. V primeru globalne uporabe je navadno uporabljena satelitska navigacija, ki omogoča lociranje kjerkoli na svetu, če naprava prejema signal z vsaj treh navigacijskih satelitov. V splošnem je globalna uporaba bolj primerna, saj uporabnika ne omejuje, da se giblje le v varovanem območju. Slabost satelitske navigacije je v tem, da ne deluje v zaprtih prostorih. V nasprotju z globalnim lociranjem, je slabost lokalnega lociranja omejitev območja varnega gibanja ter potreba po dodatni infrastrukturi, kar vpliva tudi na ceno sistema.

Mogoča je tudi kombinacija obeh tipov senzorjev. V primeru ko se oseba nahaja znotraj svojega bivalnega okolja, se to zazna z uporabo lokalne navigacije, medtem ko se osebo, ki je zunaj, locira z uporabo satelitske navigacije. Še vedno pa so problematični vsi ostali zaprti prostori, ki nimajo potrebne infrastrukture za lokalizacijo. V takšnih primerih celoten sistem sloni na verbalni komunikaciji med uporabnikom in klicnim centrom.

3.2 Enostavnost uporabe

Enostavnost uporabe je prilagojena starejšim uporabnikom z namenom, da je možnih nepravilnosti pri uporabi čim manj. Prva nepravilnost, ki jo želimo preprečiti je, da bi uporabnik pozabil nositi napravo. V tem primeru uporabnik morda ne bo mogel poklicati na pomoč, saj bo naprava preveč oddaljena od mesta, kjer se nahaja. Da bi zmanjšali možnost pozabljanja nošenja naprave, smo napravo predvideli kot zapestnico, ki se nosi na zapestju. Poleg tega mora ta omogočati več dnevno, več tedensko ali celo nekaj mesečno uporabo, brez da bi jo uporabnik moral polniti. Na ta način ima uporabnik manj možnosti, da pozabi napravo, saj jo le redko odstrani z zapestja. Da bi še dodatno zmanjšali potrebo po odstranitvi zapestnice, je potrebno to narediti vodoodporno, s čimer jo lahko uporabnik nosi tudi pri aktivnostih, ki vključujejo vodo.

Druga nepravilnost je nošenje zapestnice s praznim akumulatorjem. Tudi če smo rešili težavo z nošnjo zapestnice, je ta v primeru ko ima prazen akumulator, neuporabna. V ta namen mora zapestnica samodejno opozarjati uporabnika na stanje akumulatorja in potrebo po polnjenju. Zelo dobrodošlo je brezkontaktno polnjenje, ki zmanjša možnost nepravilnega polnjenja ter prenehanja delovanja. Poleg tega je uporabniku veliko bolj enostavno položiti napravo na brezžični polnilec, kot priključiti polnilni kabel. Ko se zapestnica napolni lahko uporabnika o tem obvesti ter ga s tem spomni, da si zapestnico ponovno nadene na roko.

3.3 Interakcija z uporabnikom

Interakcija uporabnika z napravo mora biti enostavna in hitra ter intuitivna za starejše uporabnike. Uporabljeni so lahko zvočni, svetlobni ali vibrirajoči efekti, ki uporabniku enoznačno nakažejo stanje naprave oziroma akcijo, ki se vrši. Prav tako je količina nepotrebnih elementov zmanjšana na najmanjšo možno vrednost, s čimer postane uporabniku bolj intuitivna in ga različne možnosti ne zmedejo. Zelo pomembno je, da zapestnica nudi hiter odziv ter pridobi uporabnikovo zaupanje, da bo v kritičnih situacijah pravilno delovala.

4. ZAKLJUČEK

Pri razvoju zapestnice za starejše je potrebno paziti na mnogo dejavnikov, ki lahko močno vplivajo na uporabnost in učinkovitost le te. Nekatere podatke za načrtovanje je mogoče pridobiti od uporabnikov samih, v pomoč pa pridejo tudi njihovi skrbniki, ki znajo bolj objektivno oceniti in ovrednotiti težave, ki jih imajo starejši.

5. ZAHVALE

Raziskava je bila izvedena v okviru projekta "Ekosistem Pametnega mesta (EkoSmart)" in je sofinancirana s strani Republike Slovenije in Ministrstva za izobraževanje, znanost in šport ter Evropske unije iz Evropskega sklada za regionalni razvoj (ESRR).

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Aplikacija tehnologije BLE za avtomatično zaznavanje prisotnosti oseb in predmetov

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POVZETEK

Vedno več je prenosnih elektronskih naprav, ki imajo v sebi vmesnik Bluetooth Low Energy (BLE). Te naprave je možno uporabiti za avtomatsko zaznavanje prisotnosti ljudi ali predmetov v prostorih, kar je uporabno za več aplikacij od poslovnih do osebnih. V prispevku prikažemo izkušnje pri uporabi tehnologije BLE v ta namen in nekaj možnosti uporabe te tehnologije.

Ključne besede

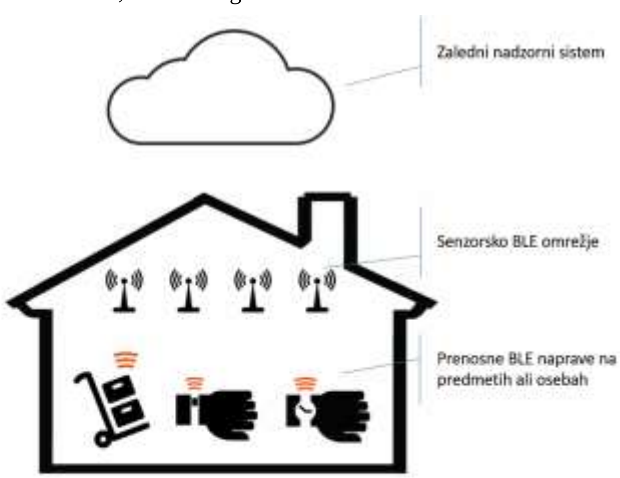
BLE, zaznavanje prisotnosti, zapestnice, pametne ure, spremljanje gibanja, senzorska omrežja

1. UVOD

Večina raznih informacijskih sistemov trenutno zaznava prisotnost oseb ali predmetov preko namenskih sistemov za avtomatsko identifikacijo ali preko ročnega vnosa prisotnosti. Večinoma se uporabljajo čipi ali kartice RFID.

S pojavom vedno več prenosnih naprav, ki imajo v sebi vmesnike Bluetooth Low Energy (BLE), je za identifikacijo možno uporabiti BLE naprave, ki jih nosijo ljudje ali predmeti na sebi [3]. Domet naprav BLE, padajoča cena in široka dosegljivost teh naprav še povečujejo možnost takih rešitev.

Za celovito uporabno rešitev za tako vrsto identifikacije je potrebno postaviti omrežje fiksnih senzorjev BLE, ki bodo zaznavali premične identifikatorje BLE in njihovo prisotnost javljali v nadzorni sistem. Tako rešitev lahko umestimo v več različnih področij, tako v poslovno kot v osebno uporabo: Pametni dom, Pametne zgradbe ali Pametne tovarne.



Slika 1. Shema celotnega sistema

V okviru projekta EkoSmart smo raziskali tehnologijo BLE za namen identifikacije oseb in predmetov, njeno uporabo in zmožnosti integracije v razne rešitve ter postavili prototip sistema za avtomatično zaznavanje premičnih objektov v poslovnem okolju.

2. Sestavni deli rešitve

2.1 Prenosni identifikator BLE

Kot prenosni identifikator, ki označuje osebo ali predmet, smo uporabili različne prenosne naprave z vgrajeno tehnologijo BLE in sicer: a) osebna zapestnica za sledenje fizičnih aktivnosti XiaoMi MiBand, b) značka Chipolo BLE, in c) novejši pametni telefon Android. V poslovnem svetu je najbolj primerna naprava mobilni telefon z BLE. V privatni sferi pa je najbolj primerna zapestnica BLE ali pametna ura z vmesnikom BLE. Za označevanje predmetov pa je najbolj primerna značka Chipolo. Vse izbrane naprave delujejo na akumulatorsko baterijo, ki jo je potrebno občasno napolniti, eno polnjenje pa zadošča za uporabo od enega dneva (pametni telefon) do nekaj let (Chipolo), kar močno vpliva na uporabnost naprav.

2.2 Fiksno senzorsko omrežje BLE

Naloga fiksnih senzorjev BLE je zaznavati prisotnost naprav BLE in v nadzorni sistem javljati unikatne naslove MAC in časovne žige, ko je bila posamezna naprava BLE identificirana. Za namen prototipa smo senzor BLE vgradili v Špica Time&Space fiksni registrator Zone Touch.

Slika 2. Fiksni terminal Zone Touch z vgrajenim senzorjem BLE

Izbrali smo tak modul BLE, da se je lahko tehnično vklopil v napravo (USB vmesnik) s hkrati dovolj nizko ceno (velikosti 10 EUR). Prototipna naprava se v zaledni sistem povezuje preko vmesnika Ethernet. Naprava zaznava vse avtorizirane, prisotne in dostopne naprave BLE in v zaledni sistem javlja svojo identifikacijsko oznako, naslov MAC zaznane prenosne značke BLE in časovni žig. Naprava opravlja osnovno filtriranje, da zalednega sistema ne preobremenjuje s preveč podatki.

2.3 Baza podatkov

Podatki o prisotnosti objektov iz vseh senzorjev se morajo hraniti v centralni bazi podatkov. Za prototipne potrebe se podatki hranijo v posebni prototipni bazi podatkov, kjer je zabeležena identifikacija točke, kjer je bil objekt zaznan, naslov MAC zaznane značke BLE in časovni žig dogodka.

V eni od prototipnih postavitev na IBM Innovation centru v Ljubljani se ti podatki shranjujejo v IBM Bluemix platformi v oblaku.

3. Odkriti in odprti problemi

V okviru raziskav in izdelave prototipa smo odkrili nekaj težav, ki jih moramo v bodoče še nasloviti in poskušati najti primerne rešitve.

3.1 Kaj je dogodek?

V praksi se dogaja, da senzor BLE zazna časovno zelo kratko prisotnost značke BLE. Odločiti se je potrebno, ali lahko tako kratko prisotnost štejemo kot dogodek ali ne. Lahko da gre za nehoteno zaznavanje človeka, ki se je samo sprehodil mimo senzorja in ga niti ne bi bilo potrebno zaznati. Problem je možno reševati na več načinov: s časovnim filtriranjem, z nastavljanjem dometa senzorja BLE, s postavitvijo več sprejemnikov BLE, s pokrivanjem celotnega prostora z BLE ali s poslovnimi pravili[4].

3.2 Kakšna je smer gibanja predmeta?

Nekatere aplikacije zahtevajo določitev smeri gibanja predmeta. Pri kontroli pristopa ali registraciji delovnega časa je pomembno, ali gre zaposleni v prostor ali iz prostora. Podobno je pri sledenju logističnih enot. Tehnologija BLE sama po sebi ne zmore zaznati smeri gibanja in bi bilo potrebno smer določiti s pomočjo dveh točk BLE v prostoru in s pametno interpretacijo časovnih žigov pri zaznavanju značk BLE. Zaradi časovnih zakasnite in težke kontrole nad razdaljo zaznavanja značk BLE je metoda časovnih zakasnitev precej nezanesljiva za ugotavljanje smeri gibanja.

3.3 Sprejemljivost avtomatičnega zaznavanja oseb

Povečana skrb za zasebnost ljudi povzroča zadržanost oseb glede avtomatičnega sledenja njihove prisotnosti. Ljudje ne želijo biti avtomatično zaznavani, razen če od tega nimajo izrazitih koristi. Glavna korist, zaradi katere so se ljudje pripravljeni odreči delu zasebnosti, je varnost. Tehnologijo avtomatičnega zaznavanja oseb smo tako do sedaj uporabili le pri sledenju vhoda oseb v rudnik, ki je izrazito nevarno okolje. V tem primeru so se bili upravitelj rudnika in rudarji ter ostali zaposleni v jami pripravljeni odreči zasebnosti, pa še tu je prihajalo po odpora posameznih ljudi [5].

4. Možne aplikacije

4.1 Avtomatična registracija delovnega časa

Sistemi za registracijo delovnega časa večinoma delujejo preko izrecne prijave zaposlenih s pomočjo osebnih kartic RFID na razdaljo nekaj cm od čitalca RFID. V primeru pogostih prihodov in odhodov v službo ali pri prehajanju med različnimi kategorijami delovnega časa (različna stroškovna mesta) bi bilo zaposlenim precej bolj enostavno pripraviti avtomatično registracijo prehodov. Tako bi lahko delovni čas lahko precej bolj natančno razdelili med različen kategorije, na primer priprava na delo, hoja med prostori, delo v proizvodnji, odmor, delo v skladišču, administracija, delo na stroju A, delo na stroju B, delo na nalogi C itd. [6]

4.2 Kontrola pristopa

V primeru, ko so določena vrata v poslovnih prostorih zaprta in je prehod dovolj le avtoriziranim osebam, se ta vrata sedaj navadno odpirajo s pomočjo osebne kartice RFID, podobno kot pri registraciji delovnega časa. Identifikacijo pooblaščene osebe pred vrati bi s pomočjo sistema BLE zaznali avtomatsko in vrata avtomatsko odklenili.

4.3 Evidentiranje prisotnosti pošiljk

Ena od konkretnih možnosti uporabe je tudi v logistiki, kjer bi značke BLE namestili bodisi na vozičke, palete ali druge transportne enote, bodisi na same pošiljke ali artikle. Uporaba tehnologije BLE na pošiljkah ali artiklih je še predraga in zato neprimerna. Uporaba na vozičkih pa je že poslovno sprejemljiva, saj se z BLE označeni vozički uporabljajo večkrat oz. se vračajo k lastniku in gre za t.i. zaprt krog. [2]

4.4 Spremljanje gibanja doma

Starejši v domačem okolju bi uporabljali vsak svojo osebno zapestnico BLE, vsak prostor v njihovem domu bi bil opremljen z senzorjem BLE, skrbniki bi imeli vpogled v grobo gibanje svojih oskrbovalcev. Nadzorni sistem bi lahko avtomatično ugotavljal trende pri gibanju in sam alarmiral skrbnike v primeru sprememb v načinu bivanja in gibanja. [1]

5. Zahvala

Projekt EkoSmart, v okviru katerega so nastali opisani rezultati, je delno sofinanciran s strani Ministrstva za izobraževanje, znanost in šport. Naložbo sofinancirata Republika Slovenija in Evropska unija iz Evropskega sklada za regionalni razvoj.

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Technology for training and assessment of precise movements in persons with Parkinson's disease

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ABSTRACT

We have developed a system for training and assessment of precise movements with upper extremities. The system consists of mainly commercially available hardware components and is intended for home use or telerehabilitation in persons with Parkinson disease. Small range motion with upper extremity and movements with fingers were recorded with miniature 3D camera. The person was expected to collect virtual cubes within the virtual environment. The system was preliminarily tested in neurologically intact person and in patient with Parkinson's disease. The kinematics of the hand and fingers were analyzed off-line and characteristic features were extracted to build the assessment procedure. The major objective of the project is targeted towards the development of novel instrument for the assessment that is closer to the existing validated clinical instrument (e.g. Box & Block Test).

Keywords

virtual reality, kinematics, upper extremity, Parkinson's disease, telerehabilitation

1. INTRODUCTION

Parkinson's disease (PD) is a slowly progressive degenerative disease of the extrapyramidal system [1]. The disease may affect people at the age between 35 and 60 years. Typically affects daily activities, participation and quality of life. The patients with PD are mainly subject to drug treatment and rarely receive comprehensive rehabilitation including physiotherapy and occupational therapy. There are also contradictory reports about the successfulness of physiotherapy [2].

However, in the forthcoming project we propose that intensified training of upper extremity skills and finger movements may increase the person's ability to focus on motor function [3] keeping the same or even decreased dose of the medicine. Telerehabilitation as a service may keep the person active and taking less medicine.

2. METHODOLOGY

The hand, palm and finger movements were tracked by small 3D camera (Leapmotion Inc, USA). The entire kinematics of the fingers and palm were used for calculation of the virtual hand in the designed virtual environment (Unity3D, Unity Technologies, CA, USA). We have designed a simple task, 10Cubes, where the person was asked to pick and place 10 virtual cubes in the virtual wooden chest. These cubes were randomly spread over the area, leaving the participants to choose their own strategy of putting all the 10 cubes in the chest within 2 min.

We have extracted the kinematics of the hand while moving in the free space and when grabbing the cube; the time of holding the cube, the pick & place time, the average time required for cube placement, number of unsuccessful trials and number of cubes successfully placed in the chest. Besides, the high-frequency and low amplitude hand movements in the random directions were observed and the tremor of the hand was estimated. Additionally validated clinical instrument Box & Block Test (BBT) was carried out.

Figure 1. 10Cubes, a 2D games, also convenient for home based physiotherapy or telerehabilitation.

The system was preliminary tested in one neurologically intact person and a person with PD in order to estimate the feasibility of the approach (Figure 1).

3. RESULTS

A real-life test demonstrated that the neurologically intact subject grabbed each cube and placed in the chest without failures, while the person with PD occasionally dropped the cube, grabbed it again or even misplaced the cube (Figure 2,). The healthy participant scored 62 and patient with PD only 42 with the BBT.

4. DISCUSSION

The preliminary tests were successful, demonstrating that major differences in kinematics and strategy exists between the healthy person and the person with PD. The person with PD was able to put all the 10 cubes in the chest only in his fifth attempt. During the task we recorded several unsuccessful trials like misplacement of the cube, cubes falling out of the hand, causing tremendous hand tremor and other measurable components supported by literature [5].

However, in the near future we plan a larger inpatient hospital trial with >20 patients with PD and 1-2 trial on patient's home. In these trials we plan to perform also clinical test [4] before and after the training tasks and record the medication plan.

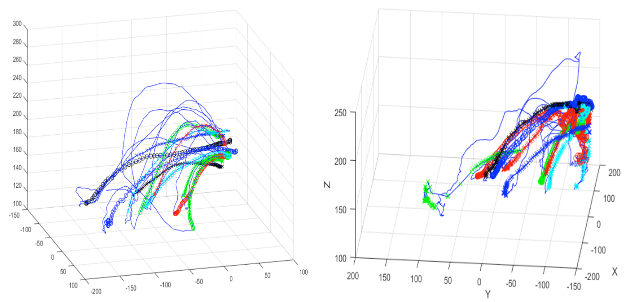

Figure 2. Pick & place of 10cubes: each cube has its own color; left: healhty person, right: person with PD

5. ACKNOWLEDGMENTS

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Smart Dentistry and Smart Tooth Brushing

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ABSTRACT
In this paper, we describe some smart dentistry tools and applications developed in the scope of the EkoSmart project.

General Terms
Smart medicine

Keywords
Smart dentistry, smart tooth brush, serious games, kinect

1. INTRODUCTION

Latest advances in information, communication and health technologies triggered a paradigm shift in modern medicine – the transition to so called smart medicine. The predicted trends in dentistry like increasing digitization [1] show that key technology trends emerging in smart medicine like personalized and precision medicine, gamification based treatment, artificial intelligence, 3D printing, nanotechnology, robotics, Internet of things (IoT) and semantic health records should also be integrated into future/smart dental care [2].

The bibliometric analysis performed with VOSviewer software (Leiden University, Netherlands) [3] of 2567 papers related to smart dentistry retrieved from the Scopus bibliographical database (Elsevier, Netherlands) using the search string *smart* or *personalized* or *precision* or *G4H* or *"artificial intelligence"* or *"3D print*"* or *nanotechnology* or *robotic** or *IoT* or *"semantic health record"* showed a fast growing trend in research endeavors. The research was mainly focused on the following themes:

- Smart materials and brackets
- Computer aided design and 3D printing
- Digital impression
- Smart dental implants, abutments and crowns
- Periodontal diseases and smart therapy

The analysis showed that smart dentistry in general is following smart medicine trends however there are substantial gaps especially concerning smart tooth brushing, gamification and use of artificial intelligence.

2. SMART TOOTH BRUSHING

The area of smart toothbrushes has recently had quite some technological leaps forward. In the frontier in the field of smart toothbrushes, Oral-B SmartSeries, has in 2016 allowed us to monitor the duration, location and pressure of brushing, using a smartphone, in 2017 the toothbrush Kolibree Ara has moved the measurement of mentioned physicalities to the toothbrush, in order to store and measure everything even in the absence of a smartphone. They capture the data using a 3D sensor, then they process the data using artificial intelligence. Onvi Prophix went even a step further, for around 400 USD (almost two times the price of other smart toothbrushes) they are offering a smart toothbrush with four different adaptors and an HD camera that is recording the brushing process using a phone app. Grush has an interesting solution that can be compared with ours. Using Intel's module, it captures data of this smart toothbrush, this data is than used to change brushing your teeth into a game.

All the toothbrushes mentioned before only measure the position and brushing time. Our toothbrush, however, also measures pressure and acceleration, and thus allows us to grade additional parameters for proper cleaning. The other major difference between the before mentioned smart toothbrushes and our solution is that all commercially available toothbrushes have an electrically driven head, while our toothbrush is conventional and therefore its use is more flexible and the price considerably lower.

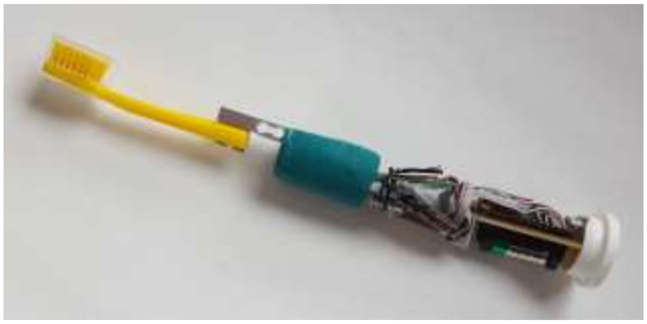

Fig 1 Smart toothbrush prototype

The prototype toothbrush is shown in Fig.1 (without housing). In the Fig.2, the complete prototype with the 3D mobile application, demonstrating the movements of the toothbrush, are given.

Fig 2 Smart toothbrush prototype with the mobile application

The next prototype will be 3D-printed, the preparatory model is depicted in the Fig 3.

Fig 3 3D model prepared for 3D printing

The functionality and usability of the smart toothbrush can be further extended with a Kinect application. The main application functionality is the visual assistance for correct positioning of body, head and arm in the beginning of and during tooth brushing and together with data from the toothbrush to detect "anomalous movements" (Fig 4). The application supports finding correct starting position, provides appropriate relativisation of the perception of movement of the brush and head, and enables time synchronization of the smart toothbrush sensors with Kinect. The exchange of data is performed by Bluetooth connection, with time-coordinated recording of the body position and collection of toothbrush data.

Fig 4 The Kinect application (palm distance from the mouth - violet dot (full circle) means that the palm is positioned correctly in front of the head; the position of the palms in front of the mouth - a light green circle surrounding the mouth indicates the area in which the palm needs to be positioned (the violet dot must be within this circle); position of the wrist in front of the mouth - yellow section of the circle marks the right position of the wrist; the position of the arm - the green section of the circle indicates the right hand position; the position of the head and body; - a green circle section indicates the right position of the head and body)

2.1 Gamification

Serious games are games that aren't designed only for the sake of entertainment [4]. Serious games for health care can offer new and potentially highly effective paradigm for behaviour change, influence outcome and increase knowledge [5]. In paediatrics, serious games can be used for different purposes. Through interactive experiences, they can offer children: goals, challenges, problem solving, experience and intense moments that provide a high level of motivation [6]. Based on the positive experience in using games for health we developed a serious dentistry game which based on the outputs from our smart toothbrush configures the game playing platform and motivates children to brush their teeth regularly and in the correct way.

Fig 5 The initial scenario of a serious dental game

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Prototipi aplikacij za prenos mobilnih EKG meritev od uporabnika senzorja do zdravnika

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POVZETEK

Pri prenosu podatkov od pacienta do informacijskega sistema zdravstvene ustanove se soočamo z več izzivi. Lokalno shranjevanje podatkov meritev, kot je npr. zajem elektrokardiogramskega (EKG) signala z uporabo merilnika Savvy EKG, predstavlja namreč dodaten in dostikrat nepotreben korak. Takšno lokalno meritev je nato namreč potrebno prenesti do zdravstvenega osebja, da jo lahko obravnava. Z uporabo samodejnega shranjevanja meritev v pacientov zdravstveni karton (EHR) lahko takšen vmesni korak odstranimo in zdravstvenemu osebju poenostavimo dostop do pacientovih meritev. Z razvojem prototipa za zajem EKG meritev na Savvy EKG prenosnem merilniku in prenos surovih neprekinjenih meritev ter PDF poročil v Think!EHR platformo smo prikazali avtomatski in predvsem varen način prenašanja podatkov iz zunanjih sistemov v centralno platformo. Razvili smo model za shranjevanje EKG podatkov in Representational State Transfer Application Programming Interface (REST API) vmesnike za prenos podatkov. Z uporabo prototipa integracije prikaza surovih EKG podatkov pa lahko zdravnik na enostaven način išče podatke pacienta v zdravstvenem informacijskem sistemu.

KLJUČNE BESEDE

Integracija medicinskih naprav, EKG, Savvy, zdravstveni informacijski sistemi, REST API.

1. PROTOTIPI

Skupina partnerjev na tej nalogi, ki obsega Inštitut Jožef Stefan (IJS), Marand, SRC, Saving in Univerzitetni klinični center Ljubljana (UKC) ter Medicinsko fakulteto Univerze v Ljubljani (MF LJ), je pripravila skupino prototipov, ki skrbijo za dostopnost mobilnih elektrokardiogramskih (EKG) meritev, s tem ko jih samodejno prenašajo od pacienta do zdravnika.

V okviru raziskovalnega dela smo si zadali izdelavo naslednjih prototipov:

- prototip za shranjevanje surovih EKG podatkov in EKG poročil v Portable Document Format (PDF) obliki na Think!EHR platformi skupaj z vmesniki za shranjevanje in dostop do teh podatkov (Marand);
- razvoj podatkovnega modela za shranjevanje EKG podatkov: analiza in postavitev modela za shranjevanje EKG podatkov v oblikah S2 in PDF skupaj z metapodatki (Marand);
- postavitev vmesnikov API za dostop in upravljanje z EKG podatki na Think!EHR platformi (Representational State Transfer Application Programming Interface – REST API), ki omogoča shranjevanje, branje in upravljanje z EKG podatki (Marand);
- prototip za zajem podatkov EKG meritev na Savvy EKG prenosnem merilniku in prenos surovih podatkov neprekinjenih meritev [1] ter PDF poročil v Think!EHR platformo [2] (IJS, Marand);
- prototip za prikaz PDF EKG poročil v zdravstvenih informacijskih sistemih ISOZ21 in BIRPIS21, pri čemer je vir podatkov Think!EHR platforma, kjer zdravstveni informacijski sistem poizveduje po poročilih za izbranega pacienta (SRC, Marand);
- prototip integracije prikaza surovih podatkov EKG meritev v zdravstvenem informacijskem sistemu., pri čemer zdravstveni informacijski sistem poišče surove EKG podatke pacienta prek centralne Think!EHR platforme in jih prikaže s pomočjo VisECG aplikacije (SRC, Marand, IJS).

2. PREGLED SORODNEGA DELA IN OBSTOJEČE PODOBNE REŠITVE

V zalednih zdravstvenih informacijskih sistemih že obstajajo določeni integracijski vmesniki, ki omogočajo komunikacijo z EKG sistemi. Prav tako obstajajo prenosni merilniki EKG za daljše časovno obdobje, kot je npr. Holter. Prednost predlagane rešitve je v tem, da omogoča povezavo med Savvy EKG merilnikom [3] in platformo za shranjevanje medicinskih podatkov Think!EHR [2], od koder so podatki lahko brezšivno integrirani z zalednimi zdravstvenimi sistemi, ki jih prikazujejo zdravstvenemu osebju na enoten način. Ker so meritve na voljo šele po njihovem zaključku, sistemu dodajamo tudi možnost aktivne udeležbe pacienta. Slednji lahko med meritvijo doda komentar svojega počutja ali opombo o zaznani nepravilnosti v delovanju srca. Sistem za komentar avtomatsko ustvari poročilo s kopijo dela EKG signala v časovnem intervalu nekaj minut pred in po pacientovem komentarju. To poročilo tudi takoj posreduje v Think!EHR platformo, od koder je v skoraj realnem času na voljo zdravniškemu osebju.

3. OPIS PROTOTIPOV

Izdelani prototipi so namenjeni zdravnikom in njihovim pacientom, ki potrebujejo spremljanje EKG izven okolja zdravstvenih ustanov. Savvy EKG je prenosni medicinski pripomoček za trajno in natančno spremljanje srčnega ritma ter opredelitev morebitnih odstopanj od normalnega [3]. Razvit je bil v sodelovanju z raziskovalno-razvojno skupino Laboratorija za vzporedne in porazdeljene sisteme, Odseka za komunikacijske sisteme na Institutu Jožef Stefan. Ustreza evropskim zdravstvenim standardom. Ima certifikat CE za celovito zasnovo in za vse sestavne dele. Savvy je preprost za uporabo. Zaradi brezžičnega delovanja, majhnosti in uporabljenih materialov je nemoteč tudi med delom, gibanjem in športom.

S prototipom za zajem EKG meritev na Savvy EKG prenosnem merilniku in prenos surovih neprekinjenih meritev ter PDF poročil v Think!EHR platformo smo vzpostavili pomembno transportno pot za EKG meritve. Do sedaj so se meritve, pridobljene iz Savvy EKG merilnika, shranjevale na pacientovem mobilnem telefonu ali računalniku in niso imele ustaljene poti do zdravniškega osebja, ki bi bilo usposobljeno za njihovo pregledovanje in obdelavo. Prototip predstavlja izboljšavo v tem, da omogoča enostavno in sprotno prenašanje zajetih meritev do ciljnega zdravniškega osebja. Odvisno od okolja, v katerem se Savvy EKG uporablja, lahko pacient, njegov skrbnik, ali pa medicinsko osebje poveže pacientovo mobilno napravo, ki sprejema podatke iz EKG merilnika, prek internetne povezave v pacientov elektronski zdravstveni karton (EHR). Ko je povezava vzpostavljena, meritve samodejno shranimo v elektronski zdravstveni karton. Na pacientovo željo (npr. ko se ne počuti najbolje oziroma kako zazna nepravilno bitje srca ali kako drugo motnjo v počutju) sistem izdela tudi avtomatsko poročilo s kratkim, vendar detajlnim izsekom meritve in ga shrani v elektronski zdravstveni karton.

Prototip za shranjevanje surovih EKG podatkov in EKG poročil v PDF obliki na Think!EHR platformi omogoča skupaj z vmesniki za shranjevanje in dostop do teh podatkov shranjevanje podatkov EKG meritev zajetih s Savvy EKG merilnikom. V ta namen smo razvili podatkovni model za shranjevanje EKG podatkov. Analizirali in postavili smo model za shranjevanje EKG podatkov v S2 in PDF obliki skupaj z metapodatki in definirali predlogo (angl. *template*) za EKG, ki vsebuje in strukturira podatke, ki jih dobimo s samega aparata. Predloga bo uporabna tudi za EKG meritve iz drugih virov in jo je mogoče razširiti z dodatnimi podatki, ki jih želijo spremljati in jih bodo definirali zdravniki. Postavljen je bil vmesnik REST API za dostop in upravljanje z EKG podatki na Think!EHR platformi in dodaten vmesnik REST API vmesnik za njihovo shranjevanje, branje in upravljanje. Na ta način omogočajo definirani vmesniki za dostop do teh podatkov enoten, vendar prilagodljiv način za shranjevanje in dostop do teh podatkov.

Prototip za prikaz PDF EKG poročil v zdravstvenih informacijskih sistemih povezuje Think!EHR platformo, ki shranjuje EKG zapise z zdravstvenima informacijskima sistemoma ISOZ21 in BIRPIS21. Zdravstveni informacijski sistem pridobi zapise EKG poročila pacienta iz Think!EHR platforme s pomočjo poizvedbe in ga prikaže v sami aplikaciji. Na ta način ima zdravnik dostop do podatkov EKG v svoji delovni aplikaciji, ki jo že uporablja, zato učenje uporabe nove programske opreme ni potrebno.

Prototip integracije prikaza surovih EKG podatkov v zdravstvenem informacijskem sistemu omogoča, da zdravnik na enostaven način poišče surove EKG podatke pacienta, ki so shranjeni v Think!EHR, ti pa se prikažejo s pomočjo zunanjega prikazovalnika VisECG [3]. Prikazovalnik VisECG je prilagojen za prikaz meritev izmerjenih na Savvy ECG, ki so časovno neomejene (v praksi so navadno dolge med nekaj ur do enega tedna) in niso primerne za obstoječe komercialno dostopne prikazovalnike. Prikazovalnik podpira tudi prikaz dogodkov, ki jih določi pacient ob boku EKG signal, tj. povezavo med prikazanim EKG signalom in EKG poročilom, ki je prav tako dostopno na Think!EHR platformi.

Z razvojem prototipom smo pokazali, da je zadan cilj avtomatskega prenosa EKG podatkov z merilne naprave v zdravstveni informacijski sistem, ki ga zdravniško osebje že uporablja, zelo smiseln in povsem izvedljiv.

4. ZAHVALA

Prispevek je nastal v okviru raziskovalnega dela na projektu EkoSMART [4], ki ga sofinancirata Republika Slovenija in Evropska unija iz Evropskega sklada za regionalni razvoj.

5. REFERENCE

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Particle Accelerators as Medical Devices

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Abstract

Particle accelerators have many applications; one of these that is gaining popularity is their use in medicine for cancer therapy. Proton and Carbon Ion therapy machines are used to accelerate a beam of particles and to deliver it very accurately into the tumor area. This kind of treatment is called Proton, Ion or simply Particle Therapy, and it presents several advantages over classic radiotherapy.

The accelerator machines involved in particle therapy are fairly modest either in power and complexity; yet the distance between the lab and the hospital is great – especially in paper work. One of the tasks that need to be fulfilled is to demonstrate that the machine is safe and effective, as required by the standards and regulations. The purpose of this article is to present a starting point for understanding what it takes to make a Particle Therapy Machine that is compliant with regulations.

1. Medical Devices

A particle accelerator, though complicated by itself, it is not enough to conduct ion therapy on patients, and it cannot be considered a "medical device". Why? Because an accelerator is a machine that generates raw beam, without means of controlling or quantifying dose and position, and from a medical perspective is useless and even dangerous. The system that we call a "Particle Therapy Machine" is composed of different subsystems; in general: one to generate the beam, one to carry and direct it to the treatment area (for example, beamline and gantry), one to measure and control its delivery (dose delivery/scanning), one to accurately position the patient (robot and X-ray imaging), one to control the operation and execution of the treatment (treatment control system), and various systems for control and safety. They altogether constitute a "medical device", as such it will have to be approved prior to its placement on the market. It is clear, for example, that it does not make sense to market a power supply magnet or a "dose control system" alone as medical devices since they do not have an intended use in medical treatment. And even if its purpose as a component of a therapy machine is undeniable, as in the case of a dose delivery system, it is not possible to judge its safety or effectiveness without knowing the properties of the remaining components of the system. Nonetheless, quite often manufacturers of components and parts for medical accelerators deliver products that are "certification ready", meaning that the component meets all applicable standards and regulations and that all necessary documentation is provided to the manufacturer of the Particle Therapy Machine.

2. Safety and Effectiveness

There are two distinct and equally important aspects of medical devices that every medical device needs to fulfill:

1. It must be safe.
2. It must be effective.

It's easy to understand why a Particle Therapy system needs to be safe: it is of no use to have a machine that cures cancer, while it is very likely to injure a patient every once in a while. At the same time, it is important for it to be effective, i.e. it is capable of fulfilling its medical purpose. Again, a system that it is safe but it does not do what it is supposed to do is useless. Imagine a wheelchair (also a medical device, though a simple one) that is tightly screwed to the floor: it may be as safe as it gets, but it does not allow the patient to move around, as it is supposed to.

That is why the laws regulating the market of medical devices take care of these two aspects. These are addressed in different ways. The manufacturer must demonstrate that his device is safe and effective, as required by the country where the device is to be sold. To prove safety, a lot of documentation must be provided: extensive test reports, detailed design documents, compliance with applicable standards, and so forth. In contrast, effectiveness is proven either by doing clinical trials and investigations involving animals or humans, or by claiming that the device in question is similar to other devices already being used, and demonstrating it by pointing to scientific articles or other literature.

3. Medical requirements

The regulatory requirements that a medical device or component needs to fulfil are different from country to country, but quite often they end up being quite similar, since it is common that countries around the world recognize the use of international standards in their essence as a valid (and often necessary) mechanism to comply with their (local) regulations. All components of a Particle Therapy Machine can be very different in operation and purpose. Some come into contact with the patient or are installed within the treatment area, some not. Some are mechanical and have moving parts, others can be only electrical control and processing units. Some use high power or voltage, others not. Some contain or consist of software, some are fully analog or discretely digital. And the list goes on. There are lots of different regulatory requirements whose applicability depends on all these factors. But there are general things that are required for all "medical components". Regardless of the above mentioned technical factors, a Quality Management System (such as [1]) must be established, a Risk Management (as [2]) process must be defined and executed, and the safety and effectiveness of the component must be proven.

4. Industrial requirements

Do all the subsystems or components of a Particle Therapy Machine need to be designed and manufactured according to the regulatory requirements for medical devices, or is there any possible exceptions? This is an important question, since devices that follow these are much more expensive than ordinary industrial stuff. The rule is that some of the components or subsystems may not need to comply with the applicable medical standards, as soon as it is possible to demonstrate that their malfunction can never lead to an unacceptable risk, for the patient and for other people involved. Even in cases where one of the subsystems is inherently critical to the safety or the essential performance of the whole system, it is possible to mitigate the potential risk by implementing alternative safety measures. The logic behind this approach is that we cannot really trust industrial ("non-medical") devices since they were not designed and manufactured following quality processes required by medical standards, therefore it is assumed that they can contain bugs or can fail at any time. The mechanism to assess the initial risk and the suitability of the chosen risk mitigation measures is the Risk Management, usually at the system level.

A common example from the Particle Therapy industry is to build the beam generation subsystem (the particle accelerator itself) as an industrial device, and then to include in the system safety components (built as medical devices) that constantly monitor the beam parameters such as energy, current and position, and shutoff the beam if any of these is out of tolerance. This strategy may help to save resources, but not always, since some complex industrial subsystems require safety measures sometimes so complex, that it is necessary to build a whole redundant instance of the original system, and this only to monitor the behavior of the original component. As an example, let's imagine an ion therapy system in which, besides the particle accelerator, the system that measures and controls the delivery of the dose to the patient is also a non-medical device. In that case, the only possible way to mitigate the risk of patient overdose due to a failure would be to have an additional medical component that measures and monitors the delivered beam. Such redundancy would be unnecessary.

That is why we recommend writing the medical compliance strategy very early in the design process. (For those of you more interested in this aspect, I recommend taking a look at the standard IEC 60601-1, section 16, and the informative Annex I).

5. Medical Software and Verification & Validation

Today, every relatively complex medical device contains at least some software. We all know that software is special, very different in nature and behavior to hardware. Even digital hardware systems composed of discrete logic are not comparable to software. The two main reasons for this are the complexity of software, with its enormous number of possible internal states, and the usual software development workflow itself, which is in practice more organic and less constrained than hardware design. The first factor determines that it is practically impossible to test a software module in all its internal states, leaving a room for latent bugs. The second factor also influences reliability, because since the nature of software allows for quick changes or last-minute fixes (that can go unnoticed), there is always a temptation to do it without the necessary care and to inadvertently introduce bugs.

If these two aspects are not addressed properly, software cannot be considered reliable enough for medical devices, especially when there is a risk to people associated with it. That's way the regulations and standards for medical devices take special care of software: to ensure that, although the possibility of bugs cannot be totally eliminated, their probability can be reduced and its associated risk mitigated; with good processes, proper testing, risk management and validation. There is an international standard that deals with this: "IEC62304: Medical device software -- Software life cycle processes."

But software cannot exist without the associated hardware, and its proper operation in the context of the whole machine cannot be judged without testing them together. Yet, in a system that is as complex as a Particle Therapy Machine, there are many different subsystems or components that may contain software, and it is impractical or impossible to execute the full set of tests for every software module, all integrated and operating in the final machine. That is why this is never done in that way, and there is always a strategy to hierarchize and segregate testing into different levels, according to the system level architecture and the "V-model" (Figure 1), in order to make testing effective and practicable. This is the purpose of the set of activities usually referred to as "Verification and Validation": to *Verify*, at different system levels, that the build system works as specified, and to *Validate* that it is capable of fulfilling its intended purpose. More about verification and validation of Programmable Electrical Medical Systems can be found in the standard IEC60601-1, section 14, and informative annex H.

Figure 1: V-model

6. Purpose of Processes and Standards

Sometimes I hear, mostly amongst engineers and physicists, arguments about whether following the standards, regulations and processes can really enhance safety and effectiveness, or is it just a "placebo" to create an appearance of safety, which somehow relieves the engineering conscience from the responsibility of thinking. The argument is valid and it has to be taken seriously. I find that for some people, for example, passing a list of tests automatically means that the device has no bugs, or that the relentless application of risk management can give you a 0-1 type of indication about the degree of safety of a device. As a consequence of the previous misconceptions, there are people that do what is called "safety by paperwork", which means tweaking the documentation and doing 'assessments' until it is proven that the device is safe enough to meet the regulations. It is always possible to fool the system, and it is not in the scope of quality systems, processes and technical requirements to completely avoid it. Yet, what standards and regulations do over anything else is to establish clear responsibilities and minimum requirements, so – when things go wrong – no one can say "I didn't know".

On the other hand, it is important to understand that a good process helps you to keep organized through the development lifecycle. When projects are late or about to go over budget, there is a natural temptation to rush and skip steps. This may appear to save some time, but can also lead to dangerous mistakes. Having a well-established process naturally helps to resist the temptation. Furthermore, processes define what steps to take if there is an unexpected problem. And if the processes are wisely designed, they not only enhance safety but even make the development more efficient by keeping pace, consistency and making sure that no aspect or requirement is left neglected.

7. Conclusion

Building a Particle Therapy system is a technical challenge by itself. To make it compliant with standards and regulations it is yet another challenge, which is sometimes underestimated. Our experience shows that it is best to start designing the medical compliance strategy together with the machine itself and to already have solid processes established when the development and implementation start. Smart processes not only help to design a safe device and get through compliance; they may also increase productivity and decrease the uncertainties and defects, which may be, at the end of the day, the differentiators for staying in the game.

8. References

[1] ISO 13485:2003: Medical devices -- Quality management systems -- Requirements for regulatory purposes (https://www.iso.org/standard/36786.html)
[2] ISO 14971:2000: Medical devices -- Application of risk management to medical devices (https://www.iso.org/standard/31550.html)

MOBILNO SPREMLJANJE OKOLJSKIH DEJAVNIKOV IN NJIHOVEGA VPLIVA NA ZDRAVJE

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1. UVOD

V projektu EkoSmart, ki je sofinanciran s strani Ministrstva za izobraževanje, znanost in šport ter Evropskega sklada za regionalni razvoj, bomo v razvojnem centru Nela razvili inteligentni sistem za spremljanje okoljskih dejavnikov. Zavedamo se, da danes povprečni človek preživi približno 80-90% svojega časa v notranjih prostorih, kjer pa kakovost zraka ni vedno ustrezna. Zato je z vidika ohranjanja udobja in zdravja človeka, ključnega pomena spremljanje okoljskih parametrov, katere lahko z enostavnimi ukrepi tudi ustrezno obvladujemo. Cenovno dostopni senzorji in mobilna aplikacija, bodo predstavljali dve ključni komponenti inteligentnega sistema za monitoring okoljskih parametrov. Ključna inovativnost projekta – avtomatska regulacije okoljskih pogojev v prostoru, pa bo še dodatno pripomogla k obvladovanju in vzpostavitvi idealnih okoljskih pogojev za bivanje.

2. SENZORIKA

Kot ključne parametre, ki lahko vplivajo na človekovo počutje in zdravje, smo določili temperaturo zraka, relativno vlago, hitrost zraka, osvetljenost, koncentracija CO_2, koncentracija VOC (nevarne organske spojine v zraku), radon. Na podlagi definiranih tehničnih karakteristik smo izvedli testiranja senzorjev različnih proizvajalcev, ki so dostopni na trgu.

Izbor senzorjev je temeljil na podlagi rezultatov izvedenih laboratorijskih testiranj, izvedenih na podlagi tehničnih protokolov, skladnih s standardom ISO 17025. Ustreznost delovanja senzorja smo spremljali predvsem z vidika ustrezne točnosti in stabilnosti. Za pripravo končnih poročil z rezultati o izvedenih meritvah smo uporabili inovativni laboratorijski informacijski sistem.

Tekom projekt smo testirali tudi delovanje različnih načinov komunikacije za posamezne senzorje in sicer I2C, Modbus, RS 485, RS 232, wi-fi, analogno odčitavanje Pt100/Pt1000, 0-10V, 4-20mA, s spremljanjem dometa pri različnih okoljskih obremenitvah. Rezultati testiranj so pokazali, da je Modbus še vedno najbolj stabilen princip komunikacije.

3. MOBILNA APLIKACIJA

Mobilna aplikacija bo pri uporabniku predstavljala enega izmed ključnih izbirnih parametrov. Zato smo tekom razvoja, prilagajanja in nadgradnje sistema, poleg zahtevanih tehničnih karakteristik, upoštevali tudi enostavno in logično infografiko, ki bo uporabniku na atraktiven način predstavila le ključne informacije. Spodaj so podani primeri izbora grafičnih elementov

Tabela 1: Tehnične karaketristike izbranih senzorjev

Parameter, veličina	**Merilno območje**	**Odčitavanje**	**Točnost**
Temperatura	od -20 °C do 60 °C	0,1 °C	0,2 °C
Relativna vlaga	od 0 % do 100 %	1 %	2,5 %
Zračni tlak	od 500 mbar do 1150 mbar	1 mbar	2 mbar
Osvetljenost	do 100.000 lux	0,25 lux	
Nivo CO_2	do 10.000 ppm (vol)	20 ppm 1 %	30 ppm 5%
Nivo VOC	450 ppm - 65.000 ppm (equiv.)	1 ppm	
Hitrost zraka	0 do 2 m/s	0,001m/s	0,001 m/s
Senzor odprtih vrat	Odprto/zaprto	1/0	/
Radon	0.1 ~ 99.99 pCi/l	0.5cpm/pCi/l	< 10%

Senzor za temperaturo	Pomoč
Senzor za koncentracija CO_2	Nastavitve
Senzor za hitrost zraka	Alarm

Kot ključne lastnosti mobilne aplikacije smo opredelili: izpis on-line meritev in pregled zgodovine, izpis min/max/povprečne vrednosti, drevesna struktura (pregled po lokacijah), alarm (sms, e-mail), izdelava poročil, modularna izvedba.

Z definiranjem koncepta povezovanja database – service - client ter z nadgradnjo MS SQL serverja smo vzpostavili ustrezno okolje za beleženje, shranjevanje in obdelovanje podatkov izmerjenih vrednosti. Prikaz on-line meritev, ki je prikazana na spodnji sliki, uporabniku omogoča vpogled trenutnih vrednosti.

Slika 1: Meritve v okolju.

4. ZAKLJUČEK

Nadaljnji razvoj bo temeljil predvsem na razvoju sistema za pregled zgodovine meritev, izpisu poročil, alarmiranja in načinu uporabniškega dostopa. Poleg tega se bomo osredotočili na procese, ki bodo predstavljali korak k doseganju avtomatske regulacije okoljskih pogojev.

ZAHVALA

Delo je nastalo v okviru programa EKOSMART.

Application for Viral Hepatitis Infection Risk Assessment

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ABSTRACT

Globally, an estimated 330 million people are chronically infected with hepatitis viruses. With the aim to provide information on the risks for acquiring infection and educate on its signs and symptoms, a web application was developed for raising awareness in general as well as high-risk populations. The website contains a questionnaire and informational web pages, with the main focus to help the users disclose their potential exposures to viral hepatitis infection during their past life and brings about prevention measures to avoid it in the future. Thus the application serves as an educational as well as a preventative tool, helping the users learn more about the dangers and causes of viral hepatitis infections and, in case of exposure, refer to proper medical services. It uses a robust system that provides anonymity and also delivers the content to the user in a responsive manner.

Keywords

Viral hepatitis, infection, web application, questionnaire, diagnosis, risk level assessment, informative, sexually transmitted infections

1. INTRODUCTION

Hepatitis is an inflammation of the liver tissue as a result of infectious or noninfectious causes. In more than half of the cases it is caused by hepatitis viruses that have currently been estimated to affect 330 million of people worldwide [1]. Viral hepatitis is caused by one of the five hepatitis viruses: hepatitis A virus (HAV), hepatitis B virus (HBV), hepatitis C virus (HCV), hepatitis D virus (HDV) and hepatitis E virus (HEV) [2]. It is estimated that less than 1% of the population in Slovenia is infected with HBV and around 0.4% with HCV [3]. Infections by HBV, HCV and HDV can be transmitted by infected blood, sexual intercourse or from mother to child, whereas HAV and HEV are mainly transmitted by contaminated food or water. Viral hepatitis may be present as an acute or a chronic disease. Infection with each of the five hepatitis viruses can result in acute disease which can be symptomless or presents with symptoms of nausea, fatigue, abdominal pain and jaundice [4]. The natural course of acute HBV and HCV infection can lead to a chronic one. Due to common lack of signs and symptoms, patients with chronic viral hepatitis infection are the main source of spreading the disease, mostly by risk behavior. Furthermore, chronic HBV and HCV infection may lead to develop cirrhosis and hepatocellular carcinoma which can lead to liver failure and death [2]. The main problem with hepatitis virus infections is that the patients typically do not exhibit symptoms until the disease has already developed to an advanced stage, at which point it becomes difficult to treat. The problematic element of this is that a symptomless infected person can also transmit the virus to other people. Since it is possible to successfully treat or at least manage patients with viral hepatitis infections, it is important to identify the infected individuals as soon as possible and act accordingly. People often seek medical information online, therefore it is important that all relevant information is available in a centralized location. Here, we present a web application that aims to educate users about viral hepatitis infections and to assess possible risks of infection. The application is a follow-up of an application to educate about and assess risks for sexually transmitted infections ASPO [5], built on an improved platform with modified goals. We discuss the implementation and the functionality.

2. PROCESS/METHODOLOGY

Creating a website that provides medical information requires use of scientifically proven facts to build user's trust. Website design and transparency of the developers also play an important contribution in this aspect. Therefore, the site has been built from the bottom up with external libraries that don't collect any user information. To address transparency, the project description and information is accessible on the main site, with references to the individuals that have helped build it. The users can immediately recognize that the site was also officially endorsed by reputable sources by seeing logos accompanying the main site. The other part of the initial design is that the site had to be simple and clearly indicate from the very start what it is offering. Server-side logic is managed by Django [6], a python based web framework. Another part of achieving user trust is that the site cannot track or use any data that the user has provided, either voluntarily or involuntarily (e.g. recording IP address, cookies, tracking data). As a result, the site does not use any cookies and only stores information from the questionnaire if the user has agreed to it (for the purpose of potential statistical analysis in future).

2.1 ETHICAL CONCERNS

When building the question base, we had to make sure to include questions that would include an informative narrative, but also would not capture any of the personal information which could be used to identify the user. Even though we don't need or use any user data, we believe they could still be useful for statistical and health studies. We've decided to implement a simple solution, to put a question at the end of the questionnaire which would ask for the user's permission to anonymously use the answers they have provided through solving the questionnaire. This required to change our database logic a bit since we thought it would be best if this particular question would append to a questionnaire, as opposed to it just being treated like another question. The only elements that are stored in the actual database are a unique user id (which only translates to the sequence of the users as they've taken the questionnaire) and their recorded answers.

2.2 SAFETY/ANONIMITY

It is important that the users feel secure while using the website, since many of the questions tackle sensitive personal information. As the site does not use any cookies, none of the user information is stored locally. The website also uses a secure connection (HTTPS) to the server to make sure that all of the traffic is encrypted. The end answers are stored on a server without any identifiable information where only authorized personnel have actual access to the physical machine.

3. SYSTEM

3.1 TECHNICAL CONSIDERATIONS

When we began building the new system we had to consider if it would be wise to keep the old code base from a previous project, ASPO [5]. Due to differences, this project would require a completely different approach and we had to warrant different needs that this project will inevitably require. We had ultimately decided to keep the frontend largely the same and to focus on addressing the issue of too many connections crashing the server.

We were also dealing with a different rule set for questions, now the questions had to display a comment depending on the answer that the user had picked. There is a possibility of multiple comments on the same question as well as different answers leading to the same comment. An additional problem arose as we had to change the functioning algorithm of displaying the questions in the first place.

Finally, instead of a generic screen at the end which would only tell you an arbitrary risk level, the new website outlines everything you have clicked and presents a list of behavior (based on your answers) that could be considered promiscuous or risky. We approached this problem by scratching everything we had done for the original project and focused on building a new system with these new requirements.

3.2 FRONTEND

The frontend consists of a Bootstrap CSS [7] base which is mainly used for its ability to work on different devices while maintaining its integrity. The interactive part of the website (questionnaire, switching menus, loading subpages) is built primarily using AngularJS [8], which serves and loads the files as they are requested. The questionnaire itself is transferred once when it is started and the rest is taken care of by AngularJS, which properly switches between questions and comments. This way, even if the user disconnects in between, the questions and their answers are temporarily stored in the scope variable. When the questionnaire is finished, the user locally receives the response and only in the case if they have agreed to store anonymous answers into the database, the connection to the server is established again. The response consists of summarized comments that have appeared through the questionnaire, relating to possible exposures to an infection. If the user had any risk factors, the background is colored orange or green (risk factors might include not being vaccinated, travelling to different countries without proper precautions, eating uncooked food, piercings, etc.). The page includes several menus, each being divided into multiple submenus, based on context. Each page is accompanied by a static background.

Figure 1 Screenshot of the webpage

3.3 BACKEND

The majority of the work was done on the backend of the application. We looked at a few different possible web frameworks that could have been used, but ultimately, we've decided on Django because of its familiarity, simplicity and adaptability with other libraries we would be using throughout the project. The first part was creating the database that would hold all of the necessary information (page layout, questions and answers, unique identifiers, etc.). While the initial premise was relatively simple, as the project evolved we had to address different concerns and keep adding more intricacies to the working logic. An example of this would be addressing different types of answers. They could've either been a multiple choice, single choice or a completely custom input. While we don't use any custom inputs, it was important to assure that the database would be scalable if the need arose. Some of the other elements that we had to keep in mind were an adaptable quantity of questions, different methods of input and most importantly, the ability to change the underlying system at any time. The most important part was that the system had to be designed in a way which could be operated without the need of a computer expert. The way this works is that every answer has a parameter which disables a particular question based on its unique identifier. This means that before the next question is loaded, we check if that question has been disabled by another answer previous to that and with that, we don't display it and skip right onto the next one. This system allows anyone to manipulate the rules and the order of these questions, provided they have the access to the database.

Regarding the REST (Representational state transfer) interface, we've decided to use Django REST framework [9], which serves as an intermediary between the information that consists in the database and a URL, which allows both for a way to access it from an outside, secure source, as well as allow the system to reach it through internal means, after which it can be de-serialized and properly displayed as the questions appear. REST is a system commonly used to simplify the connection between the database and the program itself. The service itself provides a predefined set of operations in order to access, modify or change data that is on the server.

The next part of the backend are the static pages. Django allows for a fine distinction between dynamically and statically loaded pages. For example, the problem was that both AngularJS and static pages are mainly descriptions of different diseases and guidelines of what to watch out for if you want to avoid an infection. There is also a set of pages containing the information about where to find the proper treatment in case if you want to get tested or treated for the general hepatitis infections. Static pages load up as soon as the user requests that particular subpage and they are fetched from the server and transferred to client. AngularJS then displays them, providing the information that the user has requested.

4. QUESTIONNAIRE

The full questionnaire consists of 28 questions in total with the intent of reducing these questions as much as possible, so the user is not required to go through every single one of them in order to get the final risk assessment. There are several questions where the answers trigger/disable sub-questions, therefore reducing the total number of questions that the user has to take. For example, by answering "No." to the question "Have you travelled somewhere in the past three months?" the questionnaire would omit questions about travel.

Following some general demographic questions, the 4th question asks the user about their specific interests, related to groups of possible risks - travel, lifestyle, exposure to hepatitis infection in the past, and medical issues. Based on the answer, the questions from the group of interest are displayed first.

Each question can either be a "checkbox" or a "radio" type question, where the former allows the user to select multiple choices and the latter allows the user to only select one. We have discussed the possibility of open-ended answers (where the user would input their own values), but have decided against it as we felt like the constraints work better in terms of providing useful feedback for analysis.

Some of the questions also have image components to them. These provide a visual representation of what the question is currently asking. All of these types of questions have maps included in them that show where the infection of a particular disease is most prevalent. For example, a question like "Have you been born in any of the countries where hepatitis A is prevalent?", would have an image showing the different infection rates for countries around the world.

The final and the most important part of the questionnaire is that we wanted it to have both an educational, as well as an informational component. That would allow for the user to see which of their answers/actions have an inherent risk to them. This is most obviously seen in the comments that show up depending on what the user has answered. Sometimes they are purely informational (e.g. "A vaccine for hepatitis B will decrease your likelihood of contracting the disease"), while in other cases they can be educational as well (e.g. "In order to make sure you are treated against a particular hepatitis infection, you need to have a sufficient amount of anti-bodies"). These comments are aggregated and at the end shown back to the user.

Some question/comment examples:

Q: "Are you vaccinated for Hepatitis B?"

1. Yes, I was vaccinated within the national program for children before entering school (born after 1992)

2. Yes, I was vaccinated individually

3. No (We suggest to get vaccinated for hepatitis B and checking if the vaccination was successful after the third dose. In order for the vaccine to be effective, a small margin of the population has to be vaccinated more than three times.)

Q: "Are you or your parent born in the countries where hepatitis B infections are common?"

1. Yes (There exists a higher chance of infection if you or your parents are born in a country where hepatitis B is common.)

2. No

5. SUMMARY

As number of viral hepatitis cases have risen up in the past few years, we have combined modern technology alongside with modern design principles and the latest knowledge about viral hepatitises to create a web application for informing users about the topic. Awareness and risk assessment are very important as they influence more people to get tested for viral hepatitis infections and get appropriate treatment in case they have the disease. We have several goals, the first and the utmost important one is to decrease the number of newly discovered patients with end stage diseases. Since viral hepatitis can be treated if discovered early enough, that can also prevent the disease from spreading. Another element of this is information, as spreading it will allow people to be more aware of the proper precautions, which will hopefully reduce overall exposure to hepatitis infections. If enough users agree to it, we also hope to collect enough relevant medical data that will allow for further analysis on addressing this growing problem. With gathering this epidemiological data, we hope to help more easily identify those with a higher risk factor and urge them to seek treatment in the earlier stages of the disease. By introducing this website, we hope to allow the users to access useful and verified information all in one place.

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Spletno svetovanje študentom v stiskah

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POVZETEK

V članku opisujemo študentski projekt »Spletno svetovanje študentom v stiskah«. V okviru projekta študenti ob pomoči pedagoškega mentorja in strokovnega sodelavca iz raziskovalnega zavoda interdisciplinarno proučujejo in razvijajo metode za zgodnje odkrivanje stresa in nudenje pomoči preko spleta.

Aplikacija, ki je še v razvoju, bo omogočala enostaven dostop do strokovno zasnovanih storitev pomoči v primerih, ko se študent sooča s stresom ali s telesnimi ali duševnimi težavami kot posledicami stresa. Aplikacija bo sprva na razpolago študentom Univerze v Ljubljani, ki pogosto sodelujejo z Institutom »Jožef Stefan«, kasneje pa bo dostopna tudi za druge visokošolske ustanove in univerze v regiji ter širše družbeno okolje.

Opisane so tehnične specifikacije in druge karakteristike sistema.

Ključne besede

Spletno svetovanje, stres, stresna situacija, prepoznavanje stresa, obvladovanje stresa, študent, asistent.

1. UVOD

Stres je fiziološki, psihološki in vedenjski odgovor posameznika, ki se poskuša prilagoditi in privaditi potencialno škodljivim ali ogrožajočim dejavnikom, ali drugače stresorjem. Stres prinese spremembe s katerimi se moramo soočiti, to pa počne vsak na svoj način, ki se mu zdi najbolj primeren. [1]

V Evropi trpi zaradi duševnih motenj vsaj enkrat v življenju tretjina prebivalstva. Ta procent se zaradi družbenih sprememb, nezaposlenosti, pritiska na srednji razred itd., viša. Uspešne prakse v tujini kažejo, da postaja obravnava psihičnih težav vse bolj interdisciplinarna in podprta z novimi informacijskimi tehnologijami, ki se kljub zavedanju možnega tveganja, čedalje bolj širijo na vse ravni podpore. Takšni pristopi so še posebej zanimivi za mlade generacije, ki se jih najpogosteje poslužujejo. Počasi se uporaba prenaša tudi na starejše generacije in zajema celotno družbo.

Stresno življenje je značilnost moderne, hitro razvijajoče se, uveljavitveno usmerjene družbe. Ko študenti vanjo resno in odgovorno vstopajo, morajo izpolnjevati visoke zahteve iz okolja, hkrati pa se soočati z lastnimi dvomi, sposobnostmi in interesi. Zato so v tem obdobju strategije spoprijemanja s stresnimi situacijami izrednega pomena. Marsikdaj se prav tedaj izkažejo za neučinkovite, kar lahko pripelje do blažjih ali hujših duševnih stisk in zdravstvenih težav, ki se z neukrepanjem še poglabljajo. [2]

Zdravstveni podatki kažejo, da so težave zaradi stresa eden izmed ključnih izzivov prihodnosti. [3, 4]

2. NAMEN PROJEKTA

S spletnim svetovanjem študentom v lokalnem okolju se želi spodbudili preventivno ukvarjanje z mentalno higieno in tudi omogočili lažji dostop do strokovne pomoči v primeru osebnih težav in duševnih stisk. V splošnem bo rešitev prispevala k zmanjševanju stigmatizacije ljudi s težavami v duševnem zdravju. Konkretno bo rešitev pomagala študentom naučiti se ustrezno pristopati k stresnim situacijam in imela pozitivne učinke na zvišanje zadovoljstva in motivacije za študij ter splošno v vsakdanjem življenju. Spodbujanje razvoja konstruktivnih strategij spoprijemanja s stresom bo pozitivno doprineslo tudi k zaposlitvenim možnostim in tudi zadovoljstvu delodajalcev.

Tekom projekta se razvija sodelovanje, komunikacija in izmenjava znanj med akademskimi in raziskovalnimi ustanovami ter neposreden prenos tega znanja na študente. Študentje pridobljeno teoretično znanje uporabljajo pri reševanju praktičnih in aktualnih družbenih problemov. Pridobivajo dragocene izkušnje in s tem boljše možnosti za hitro prvo zaposlitev, kar prispeval k zmanjševanju brezposelnosti med mladimi. Predvsem pa se vzpostavilo tvorno sodelovanje med tehnično in družboslovno stroko.

V okviru projekta študenti proučujejo različne inovativne rešitve za izzive družbenega okolja v katerem živijo in na takšen način osvojijo nov način razmišljanja, ki povečuje njihovo ustvarjalnost in kreativnost. To pa je dobra podlaga za kasnejši razvoj novih inovativnih storitev z visoko dodano vrednostjo.

3. OPIS VSEBINE PROJEKTA

Pri obvladovanju stresa si lahko med drugim pomagamo z različnimi tehnološkimi pripomočki ali storitvami kot npr. zapestnica za stres in spletno svetovanje.

V okviru projekta se razvijajo računalniški algoritmi za prepoznavo stresa (npr. na podlagi spremembe srčnega utripa, spremembe v govoru ipd.), kar je zahteven in še ne dovolj dobro rešen problem. Izdeluje se spletna aplikacija, ki bo predstavljala strokovno osnovano psihosocialno prvo pomoč za študente v stiski. S tem bo študentom omogočen prvi strokovno osnovan svetovalno terapevtski stik, za katerega se jim ne bo potrebno vključiti v socialno zdravstveni sistem. Za to je potrebno analizirati in izbrati ustrezen psihoterapevtski pristop, opredeliti ključne koncepte, način kategorizacije in oblikovati ustrezne scenarije dialoga, vaje ter napotke. Načrtovani spletni svetovalec bo študente opremil z osnovnimi strategijami za diagnostiko in obravnavo njihove težave, jim zagotovili ustrezne informacije in jih po potrebi napotili v ustrezne inštitucije. Aplikacija bo študente tudi preventivno usmerjala k zdravemu načinu življenja s splošnim izobraževanjem o stresu, načinih spoprijemanja, tehnikah sproščanja, pomembnosti prave socialne podpore, vpliva (ne)zdrave prehrane in športne aktivnosti.

Tekom izvajanja projekta bo na osnovi teoretičnih izhodišč zastavljena klasifikacija študentskih težav povezanih s stresom, opisi simptomatike in ustrezne obravnave, razvit vprašalnik za diagnosticiranje in klasificiranje težav ter pripravljen osnovni načrt svetovanja z nalogami za uporabnike z različnimi težavami. Preizkušeni bodo različni pristopi avtomatske detekcije stresa. S tem bo razvita prva verzija aplikacije, ki bo študente s težavami zaradi stresa vodila skozi njihovo problematiko, jih učila, ozaveščala, motivirala, jim ponujala prilagojene domače naloge. Aplikacija bo vključevala tudi povezavo z bazo terapevtov in svetovalcev ter osebnih storitev, ki bodo vključeni po potrebi v program pomoči. Vse bo na uporabniku prijazen in prilagojen način integrirano v spletno okolje. Aplikacija bo testirana in pripravljena za osnovno uporabo.

4. ZASNOVA OZ. SPECIFIKACIJA SISTEMA

Groba zasnova sistema je prikazana na sliki 1. Uporabnik lahko najprej izpolni spletni vprašalnik, ki oceni stopnjo stresa uporabnika. Na podlagi doseženega rezultata se uporabniku, v primeru velikega stresa, priporoči direkten pogovor s terapevtom. Če pa se iz vprašalnika zazna blažjo stopnjo stresa, se predlaga pogovor s spletnim pogovornim svetovalcem. Ob potrditvi se preusmeri pogovor na spletni obrazec, ki omogoča vnos teksta in prikaz pogovora s virtualnim svetovalcem.

Slika 1. Shema sistema za spletno svetovanje študentom v stiski

Pogovorni svetovalec prejeti tekst najprej posreduje modulu za predprocesiranje teksta, ki naj bi odstranil bolj pogoste besede, ki ne prinašajo dodatnih informacij. Preverili bomo tudi možnost dodajanja funkcionalnosti urejanja sintaktičnih napak v tekstu.

Naslednji korak v pogovornem svetovalcu je klasifikacija v pravo kategorijo stresa. Sistem poskuša preko zaznavanja ključnih besed in fraz klasificirati tekst v določeno kategorije stresa, saj je mogoče na podlagi te informacije uporabniku posredovati specifična vprašanja, naloge ali voden scenarij, ki naj bi pomagal pri spopadanju s tovrstno obliko stresa. Pri razpoznavanju smo uporabljali platformo API.AI [5], ki je namenjena analizi naravnega jezika (Natural language processing). V sistem se vnese kategorije v katere želimo klasificirati tekst, nato se poda učne primere pogovorov, ki so značilni za tovrstno kategorijo. V API. AI se kreira novega agenta, za katerega lahko, z uporabo strojnega učenja in pravil, ustvarimo enostaven model, ki je sposoben klasifikacije podanega teksta v naravnem jeziku. Ta agent nato lahko

Preko anketnega vprašalnika se je identificiralo vsebinske kategorije stresa pri študentih po pogostosti, od najpogostejše do najmanj:

1. Študij – Urnik predavanj, stres med izpitnimi obdoblji.
2. Denar – Preslabo plačano delo, odvisnost od staršev ali sistema.
3. Odnosi – Največkrat s starši ali partneji.
4. Osamljenost – Oddaljenost od doma, prejšnjih prijateljev ali pomanjkanje hobijev.
5. Samopodoba/samozavest – Nezadovoljstvo s samim seboj.
6. Bolezen – Pri študentih ali družini, depresija, anksioznost itd.
7. Družinske tragedije – Smrt starša, sorodnikov.
8. Selitev v mesto – Predvsem iz manjšega kraja v Ljubljano.

Vse kategorije se bo v nadaljevanju izvajanja projekta vneslo v agenta znotraj API.AI in vsaki kategoriji dodalo množico učnih primerov (teksta), ki so značilni za tovrstno kategorijo stresa. Predvidevamo, da pri pogovoru o problemih s študijem bo v tekstu več besed ali zvez, kjer so omenjeni urniki, predavanja, izpiti, naloge ipd. Strojno učenje bi moralo take značilne, ključne koncepte zaznati in jih vključiti v odločitveni model za to kategorijo.

5. PRIMER POGOVORA

Uporabniku je ob prihodu na stran ponujena možnost izpolnjevanja vprašalnika, ki oceni njegovo stopnjo stresa. Del pripravljenega vprašalnika je prikazan na Sliki 2. Uporabniku se postavi množica vprašanj, kjer je mogoča izbira enega ali več predpripravljenih odgovorov. Aplikacija ovrednoti odgovore in rezultat prikaže uporabniku v grafični obliki. Uporabniku nato ponudi direkten pogovor s terapevtom ali pa pogovor s spletnim svetovalcem.

Slika 2. Del anketnega vprašalnika za ugotavljanje stopnje stresa.

Pogovor med uporabnikom in spletnim svetovalcem poteka v naravnem jeziku. Uporabnik postavi vprašanje in sistem mu odgovori, svetuje ali poda naloge glede na določen scenarih.

V prvi fazi se najprej na osnovi uporabnikovega opisa problema klasificira miselna napaka. Primer pogovora:

Uporabnik: *Živjo*

Svetovalec: *Pozdravljeni, kako vam lahko pomagam?*

Uporabnik: *Kaj znaš?*

Svetovalec: *Sem virtualni svetovalec, ki vam lahko svetu preko pogovora. Prosim napišite težave ali probleme s katerim se soočate in poskušal bom zaznati miselno napako ter ustrezno prilagoditi pogovor in naloge. Sem še v razvoju in zato vsega še ne znam.*

Uporabnik: *Naslednji teden začnem s študijem in se bojim, da se ne bom vklopil in našel novih, pristnih prijateljstev.*

Svetovalec: *Iz podanega opisa problema je mogoče razbrati, da pri vas obstaja nagnjenost k pretiranemu osredotočanju na (negativno) prihodnost, temu strokovno rečemo Napovedovanje prihodnosti, kar preprečuje delovanje, sprevrže se v samo izpolnjujočo prerokbo.*

Svetovalec: *Ali se vam zdi, da je to značilno za vas?*

Uporabnik: *Da*

V primeru, da sistem ne zmore klasificirati opisa v nobeno izmed napak prosi uporabnika, naj mu podrobneje, oziroma drugače opiše problem. Na primer:

Uporabnik: *Živjo*

Svetovalec: *Pozdravljeni, kako vam lahko pomagam?*

Uporabnik: *Saj ne vem kako razložiti zadeve, ker so občutki mešani in se počutje spreminja enkrat na dobro, drugič na slabo.*

Svetovalec: *Ali lahko prosim opišete kakšno situacijo, ki vas spravlja v stresno situacijo.*

Ko sistem klasificira opis uspe klasificirati, zahteva potrditev s strani uporabnika. V primeru, da uporabnik zavrne predlagano napako, ga svetovalec pozove naj še na drug način opiše probleme s katerimi se sooča. Ko uporabnik potrdi ustreznost opisa njegovega razmišljanja sistem uporabi določen scenarij, to je pogovor, ki pomaga uporabniku, da spremeni svoj način razmišljanja. Kratek primer:

Svetovalec: *Če bi ocenili na lestvici od 1 do 10 (1 pomeni »me sploh ne obremenjuje«, 10 »neizmerno me obremenjuje«). S katero številko bi ocenili vaše trenutno stanje?*

Uporabnik: *6*

Svetovalec: *Zapišite sedaj situacijo čez 1 leto, pomislite, da se še vedno ni nič spremenilo. Vse ostaja enako, vaše težave so še vedno tukaj, morda še v večji razsežnosti, kot so bile pred letom dni. (vzemite si čas preden zapišete).*

Uporabnik: *To bi bilo nevzdržno, saj se že zdaj dnevno obremenjujem s tem in si predstavljam, da bi to precej vplivalo na moje takratnje počutje.*

Svetovalec: *In sedaj si zamislite isto situacijo čez 5 let, še vedno ne naredite nobene spremembe, ker verjamete, da tako ali tako nima smisla. Venomer se sprašujete, kako bi bilo, če bi se odločili in se podali na drugo pot, če bi poizkusili narediti nekaj drugače. Stres, ki ga doživljate sedaj je narasel za petkratno vrednost?*

Svetovalec: *Napišite mi, kako živite, kako se počutite, kako izgledate po toliko letih neprestanega stresa, premišljevanja, kaj bi bilo, če bi si dovolili narediti drugače?*

…

Scenarij pogovora se lahko še nadaljuje in uporabniku posreduje nasvete ali naloge. Vsak scenarij, zbirka nalog ali pogovorov je za vsako kategorijo ali miselno napako različna in se sproži po uspešni klasifikaciji. Ta mehanizem daje upravljavcem širok nabor možnosti spopadanja z različnimi tipi stresa.

6. ZAKLJUČEK

Predstavljen je bil projekt za spletno svetovanje študentom v stiskah, ki se še izvaja. S projektom bo nastala osnovna verzija aplikacije za svetovanje študentom. Aplikacija se bo nato integrirala z drugimi obstoječimi spletnimi funkcionalnostmi na področju svetovanja.

Spremljalo se bo odzive uporabnikov in po potrebi rešitev korigiralo. K osnovni rešitvi se bo kasneje razvijalo še dodatne funkcionalnosti ter se jo promoviralo v okviru širše regije in celotne države. Ko bo aplikacija dodelana do ustrezne stopnje, se jo bo integriralo tudi v Nacionalni inštitut za psihoterapijo, ki deluje v okviru prijavitelja projekta.

Delo, opravljeno v okviru tega projekta, bo sestavni del obsežnejše, splošno zasnovane spletne aplikacije za zdravstveno svetovanje državljanom.

7. ZAHVALA

Projekt »Spletno svetovanje študentom v stiskah« je delno financirala Evropska unija, in sicer iz Evropskega socialnega sklada, v okviru Operativnega programa za izvajanje evropske kohezijske politike v obdobju 2014-2020 kot neposredna potrditev operacije - programa »Projektno delo z negospodarskim in neprofitnim sektorjem v lokalnem in regionalnem okolju – Študentski inovativni projekti za družbeno korist 2016 – 2018«, 10. prednostne osi »Znanje, spretnosti in vseživljenjsko učenje za boljšo zaposljivost«, 10.1 prednostne naložbe »Izboljšanje enakega dostopa do vseživljenjskega učenja za vse starostne skupine pri formalnih, neformalnih in priložnostnih oblikah učenja, posodobitev znanja, spretnosti in kompetenc delovne sile ter spodbujanje prožnih oblik učenja, tudi s poklicnim svetovanjem in potrjevanjem pridobljenih kompetenc« in 10.1.3 specifičnega cilja »Spodbujanje prožnih oblik učenja ter podpora kakovostni karierni orientaciji za šolajočo se mladino na vseh ravneh izobraževalnega sistema«.

Izvajalec javnega razpisa je bil Javni štipendijski, razvojni, invalidski in preživninski sklad Republike Slovenije.

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Upgrade of AH-Model with Machine Learning Algorithms

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ABSTRACT

The goal of this research is upgrading of AH model with introduction of classification algorithms to explain connection between human well-being and efficiency.

Three different algorithms (JRip, SVM, decision trees) were implemented and tested on the same data with samples of 10, 100 and 2031. JRip predicted correctly about two thirds of connections. It is not sensitive on choosing different training and learning sets and accuracy was achieved at a sample of 100. It, however, does not offer useful explanation about well-being's influence on efficiency. SVM algorithm is not useful for this kind of data; predicted error rate is too high.

Decision tree algorithm offered the best output. It identified relations between particular elements of well-being and efficiency. Obtained results are reflection of the work place characteristics (data was collected in real work places) and identify relation between elements of well-being and efficiency which is understandable to user.

Decision tree algorithm upgrades AH model with description of relationship between QAA data and workers' performance-efficiency.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems - *human factors,* I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems - *medicine and science,* J.4 [**Computer Applications**]: Social and Behavioral Sciences - *psychology*

General Terms

Algorithms, Human Factors, Measurement, Reliability.

Keywords

AH-model, classification algorithms, JRip, SVM, decision trees.

1. INTRODUCTION

Aim of this paper is to compare different AI approaches to data mining; more specifically to individual behavior modeling. This comparison is executed on data collected from standardized Questionnaire of Actual Availability (QAA). The goal of data analysis, performed on this data, is to better understand individual's behavior – that is to better understand connection between different individual's attributes and influence of availability on prediction of performance on real working situation.

Data is collected with Questionnaire of Actual Availability from AH-model (psychometric data) [1]. It is comprised of subjective self-assessment of workers; workers assessed their psychophysical condition. Besides their assessment of psychophysical condition and well-being their actual work performance-efficiency was also noted.

The goal of data analysis is to determine the influence of perceived well-being and self-estimation of actual availability on workers' performance. This paper tries to determine which data mining algorithm best predicts actual work performance from perceived well-being.

2. CLASSIFICATION

Classification process involves training (learning) and test sets. Individual instance (in the training set) usually contains one target value (which identifies the class – leaf in a data tree) and several additional attributes. End goal of decision tree algorithm is to produce a target value (leaf identifier) based only on attributes. In this sense, classification problem can be examined (as illustration) on example of two classes where the algorithm is tasked with separation of classes based on available examples. Algorithm should produce and identify function (segregation function), based from training data, that works well on unseen examples (test data). Successfulness of segregation algorithm is determined by its ability to perform on test data [2].

2.1 SVM Algorithm

Based on statistical learning theory, Support Vector Machines is a method of supervised learning used for classification and regression [3]. SVM creates non-overlapping partitions of data employing all attributes of particular instance (e.g. individual). In order to produce linear partitions, data is segmented in a single pass. Although similar to probabilistic approaches (they are based on maximum margin linear discriminants), SVM do not take into account possible co-dependencies between attributes.

In contrast to traditional neural networks SVM algorithms do not suffer problems with generalization (SVMs have no tendency to over fit the data as a result of optimization measures). Consequently, SVMs seem to promise great empirical performance [4]. Structural risk minimization (SRM) [5], which is the basis of SVMs, seems to be superior to Empirical Risk Minimization (ERM) [6] (traditional approach employed by neural networks). In contrast to ERM, which optimizes the training data, SRM optimizes the upper bound on the expected risk. Consequently SRM has much greater generalization ability.

SVMs present data patterns in higher dimension than the original space (defined by attributes of particular entity). Segregations of two categories (hyperplane separating two patterns) can be achieved by nonlinear mapping to a sufficiently high dimension [4].

2.2 Decision tree algorithm

Decision trees are implementation of divide and conquer principle [7]. Differences between different implementations of decision trees are in how to approach and execute division into smaller problems. Decision trees based classifiers divide the data into smaller groups (where each node of a tree represents a criteria for data segmentation) until desired homogeneity of a subgroup is achieved (this subgroup is represented as a leaf containing class majority). Classification is achieved by following the classification criteria (nodes in the tree) until a desired group is reached (represented as a leaf in the tree) [7].

2.3 JRip propositional rule learning

JRip is rule-based machine learning method called propositional rule learning and is based on association rules with reduced error pruning. Data, analyzed by propositional rule learner, is split into growing and pruning set (learning and testing set). An initial rule is formed on the growing set (learning set) and then repeatedly optimized (simplified) by the pruning set (testing set). For each stage of pruning (optimization) the set of rules with greatest error reduction is chosen as the rule. Optimization ends when additional alternations (optimizations) of rules yield additional error instead of error reduction. JRip implementation of propositional rule learner is an optimized version of Incremental Reduction Error Pruning (IREP) proposed by William W. Cohen [8].

3. Results

All three algorithms are compared for three different numerousness: 10, 100 and 2062. For each sample each algorithms is tested ten times to assure different random generated learning sets.

3.1 JRip propositional rule learning algorithm

n = 10:

100% correctly classified instances. In all ten trials, the result is the same: 100% correctly classified instances.

Let denote efficiency measured as 1, it means the best efficiency, with E1, efficiency measurement value 2 with E2, and so forth to measurement value 5 denoted with E5. In table 1 are presented results of the AI model generated with JRip classification algorithm for the instances of the test set. This presents expected results of the generated model for real-world data.

Table 1 Classification correctness with JRip method for n=10

	Classified as E1	as E2	as E3
E1	5	0	0
E2	0	3	0
E3	0	0	2

n=100:

68% correctly classified instances, 32% incorrectly classified instances. The best matching is with efficiently 2. In all ten trials, results are in the interval between 66-71% for correct classification and in the interval between 29-34% for incorrect classification.

Table 2 Classification correctness with JRip method for n=100

	Classified as E1	as E2	as E3	as E4
E1	19	18	0	0
E2	3	49	0	0
E3	0	10	0	0
E4	0	1	0	0

n=2031:

72% correctly classified instances, 28% incorrectly classified instances. The best matching is with efficiency 2 and 1. In all trials the intervals are between 70-72% for correct classification and 28-30% for incorrect classification.

Table 3 Classification correctness with JRip method for n=2031

	Classified as E1	as E2	as E3	as E4	as E5
E1	402	267	3	1	0
E2	120	873	46	2	0
E3	1	109	157	7	0
E4	3	11	6	21	0
E5	0	1	0	0	2

The algorithm JRip is not sensitive in choosing different training and learning set. The first adequate level of accuracy is achieved at n=100.

3.2 SVM Algorithm

n=10:

The algorithm does not work. Number of parameters is too big for this sampling size and algorithm fails with error "'cross' must not exceed sampling size".

n=100:

SVM algorithm returns similar results as JRip propositional rule learning algorithm, it returns classification correctness table. For n=100 are only 17% correct predictions for efficiency 1, 2, and 3.

Table 4 Classification correctness with SVM algorithm for n=100

	Classified as E1	as E2	as E3	as E4	as E5
E1	7	4	0	0	0
E2	6	8	1	0	0
E3	0	2	2	0	0
E4	0	0	0	0	0
E5	0	0	0	0	0

n=2031:

Only 20% of correct predictions, mostly for efficiency 2.

Table 5 Classification correctness with SVM algorithm for n=100

	Classified as E1	as E2	as E3	as E4	as E5
E1	145	69	1	1	0
E2	59	223	38	3	0
E3	2	16	43	8	1
E4	0	0	0	0	0
E5	0	0	0	0	0

The algorithm SVM is not applicable for analyzed data. Correct prediction is poor without useful information for user.

3.3 Decision tree algorithm

Problem of decision tree can be complexity of a tree which is a result from decision tree algorithm. To overpass this problem, it is possible to check a visual representation of the cross-validation results. It gives a geometric presentation of values of complexity parameter (cp) related with tree size and expected relative error. The cp value is the input value for tree pruning algorithm that reduce tree size and increase expected correctness of proposed decisions, but decisions has less detail argumentations.

n=10:

Resulting tree is not complex enough to require pruning. There is distinction in identification of psychical well-being on efficiency 1. There is also identification of psychical impact on efficiency 2. Decision tree is simple; the only influential item is psychical well-being.

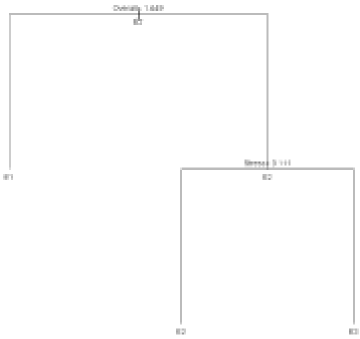

Figure 1 Not pruned decision tree for n=10

n=100:

In 46% of overall estimation of well-being below 1,649 is related mostly with efficiency 1 and some of them with efficiency 2. In 54% of overall estimation of well-being are above 1,649 and they are related mostly with efficiency 2, only a little of them with 1, 3, and 4. There is a complex decision tree presenting influence of other elements of well-being.

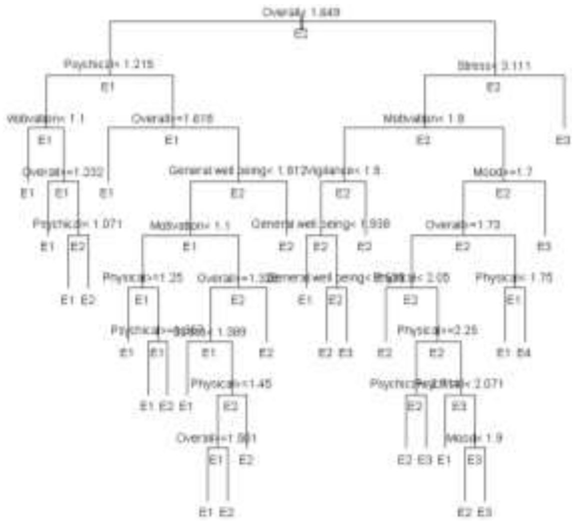

Figure 2 Not pruned decision tree for n=100

Tree pruning is implemented to decrease relative error and to simplify decision tree. The cp=0.051 is used for pruning parameter according to adequate size of tree and adequate relative error

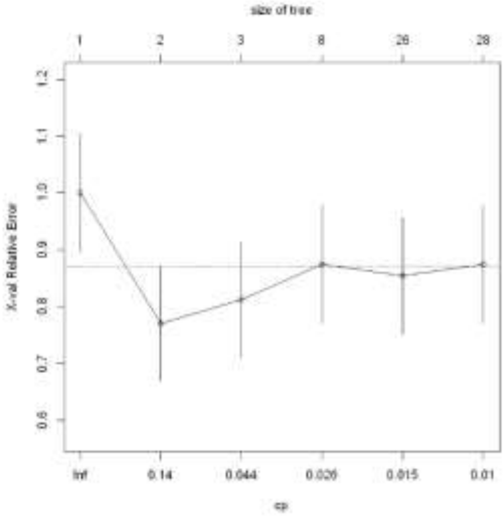

Figure 3 Visual representation of the cross-validation results for n=100

After the pruning of the decision tree influential elements are defined – another important influential factor is stress. Pruned decision tree is clear and offers possibility for identification of influential elements of well-being on efficiency, mostly on 1 and 2.

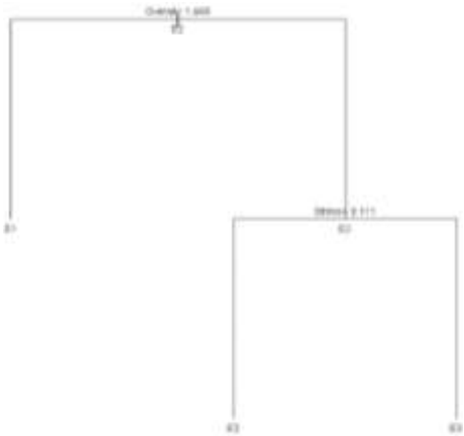

Figure 4 Pruned decision tree for n=100

n=2031:

In 36% there is psychical well-being below 1.4295 determining efficiency 1. In 49%, psychical well-being below 2,4295 predict efficiency 2. In 15% psychical well-being above 2,4295 predict efficiency 3. The same as for n=100, tree pruning is implemented to decrease relative error and to simplify decision tree.

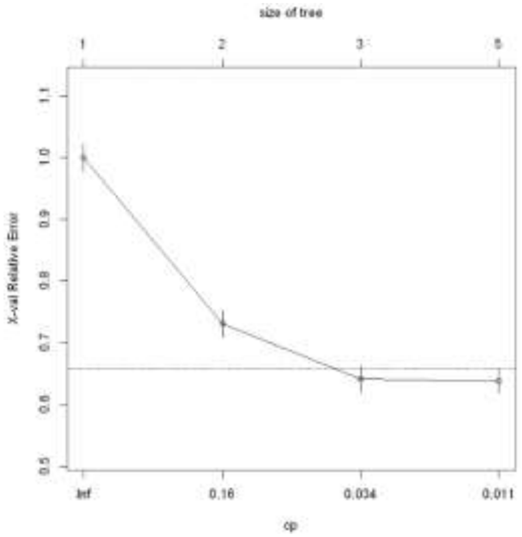

Figure 5 Visual representation of the cross-validation results for n=2031

Similar as for n=100, value cp=0.051 is used for pruning parameter according to adequate size of tree and adequate relative error. After pruning of decision tree psychical well-being below 1,429 is crucial in prediction of efficiently 1. Efficiency 2 is predicted with psychical well-being below 2,429. If psychical well-being is above 2,429 the efficiency is 3. The correct prediction for 3 is 15%.

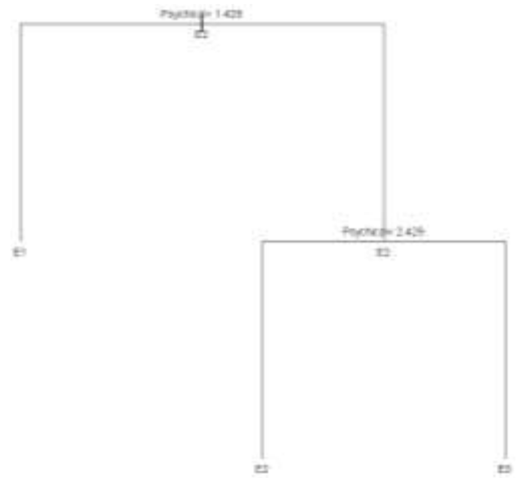

Figure 6 Pruned decision tree for n=2031

The decision tree algorithms identifies relations between elements of well-being and efficiency. User gets possibility for implementation and interpretation.

4. Conclusion

Comparison of three algorithms answers a question: Which algorithms is the most suitable? According to the analysis JRip is too dependent on sampling of learning sets. It correctly predicts efficiency 1 and sometimes 2 but does not identifies influential elements of well-being.

SVM algorithm is not applicable for this kind of data.

The decision tree algorithm is the most suitable for implementation of QAA data from AH. It offers identification of the most influential well-being element on efficiency with distinguished limits. From the aspect of end user – psychologist or human factor specialist it offers an upgrade to the AH model. Upgrade of AH model with decision tree algorithm offers clear limits of expected values of efficiency depend on well-being perception. Due to the nature of data (QAA data was collected at workplaces with psychical workloads) obtained results reflect workplace characteristics, perception of well-being and their influence on efficiency.

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Wireless Sensor Prototype for Industrial Harsh Environments

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ABSTRACT

The overall goal of the ECSEL project MANTIS is to provide a proactive maintenance service platform architecture based on Cyber Physical Systems. Proactive maintenance can be regarded as upgrade of conventional preventive and predictive maintenance and goes further by focusing on problem causes. In this way, problems are settled before they actually occur. The MANTIS project comprises eleven distinct industrial partners and deals with maintenance use cases in different environments (e.g., industrial machines, vehicles, renewable energy assets). An important issue of the MANTIS project is provision of reliable communication. In this paper we present a solution of wireless pressure sensor developed for possible replacement of the existing cable-connected sensors in a harsh industrial environment.

Categories and Subject Descriptors
C.2.1 Network Architecture and Design; Wireless communication, C.3 Special-Purpose And Application-Based Systems; Real-time and embedded systems

General Terms
Measurement, Performance, Reliability

Keywords
Cyber-Physical Systems, proactive maintenance, sesnsors

1. INTRODUCTION
Cyber-Physical Systems (CPS), which represent the next generation embedded intelligent ICT systems, are characterized by large numbers of tightly integrated heterogeneous components, which may dynamically expand and contract with each other. Multiple sensors and actuation units that gather, process, exchange and use information bring together the world of computing and communications with the physical and biological worlds [1]. CPS components are collaborative, autonomous and provide computing and communication, monitoring/control of physical components/processes in various applications. The concept of CPS is being widely applied in indistry, energy economy, health care, to mention just the few most prominent examples.

While CPS are known to be difficult to analyze due to their increasing complexity, the maintenance of CPS-based industrial systems represents a great challenge. In the near future, maintenance of industrial systems will change from traditional monitoring, based on the detection of malfunctions, to advanced techniques that prevent malfunctions by predicting the faults. To this day, four different maintenance plans are used: reactive maintenance, preventive maintenance, predictive maintenance and proactive maintenance [2].

In the case of reactive maintenance, the equipment is replaced or repaired only after it breaks. This approach has the advantage of minimizing the manpower to keep things running. Disadvantages are unpredictable production capacity and high overall maintenance costs.

In preventive maintenance, maintenance tasks are performed periodically, based on specific time period or the amount of working hours of machine use. The drawback is that the production is stopped during the maintenance. On the other hand, the equipment lifetime is prolonged and the probability of malfunction is reduced [3].

Predictive maintenance or condition-based maintenance, relies on physical measurements of the equipment conditions, such as temperature, vibration, noise, lubrication and corrosion [4]. When these measures reach a certain threshold, preventive maintenance task is applied.

Proactive maintenance benefits from the preventive and prediction methods and goes further by focusing on problem causes. In this way, problems are settled before they actually occur. Proactive maintenance is a constant process of operation improvement that starts at the early design phase and comprises the whole periodic life cycle analysis. By employing prediction methods it relies on constant condition monitoring and evaluation to avoid machine failures. Condition monitoring is achieved through extensive sensor data collection and analysis [5].

The overall goal of the MANTIS project (http://www.mantis-project.eu/) is building a maintenance service platform that will enable proactive maintenance strategies in different environments (e.g., industrial machines, vehicles, renewable energy assets). For this purpose, advanced data monitoring, communication and analytics is required. Since the maintenance service platform will operate in different environments including harsh conditions, ensuring reliable communication is one of the major issues. In the following we present a solution of wireless pressure sensor developed for possible replacement of the existing cable-connected sensors in a harsh industrial environment.

2. WIRELESS SENSOR PROTOTYPE

2.1 Sensor

Sensor prototype is based on HYB pressure transducer for differential wet-wet applications. It is a new generation of ceramic pressure sensors made with low temperature cofired ceramic (LTCC) technology using piezo-resistive principle to detect the pressure. The LTCC material is compatible with many types of aggressive media like water, hydraulic oils, diesel and others, which makes the sensor suitable for pressure measurements in harsh environments. Special protection of the piezo-resistors also makes this sensor suitable for wet-wet applications. High performance and accuracy are achieved with the special sensor construction, which allows this sensor to be used in many applications, and with its compact and convenient design it is very suitable for OEM users requiring use in harsh environment. The output signal from the sensor is analog and digital. The HPSD 7000 analog output signal is amplified and temperature compensated from 0 to 70°C with signal conditioning electronics.

Figure 1: HPSD 7000 pressure sensor

The digital output signal is available via standard I2C communication with default slave address 0x78 (1111000b). Pressure and temperature output signals form HPSD7000 pressure sensors are 15 bit values from the data acquisition output register. Data transfer is initiated by I2C master with the start condition. followed by 7 bit slave address (factory default is 0x78) and data direction bit R/W (for read data R/W=”1”). Slave confirms this address with acknowledge (A) bit followed by pressure data as 2 byte value, MSB first and temperature data as 2 byte value, MSB first. Master must confirm each received byte with acknowledge bit and terminate the data transfer by sending the stop condition.

Master receives pressure data as a 15 bit values which can be converted to actual pressure value with pressure units in mbar using simple linear transformation using data from the datasheet for Pmin, Pmax, Dmin and Dmax, where valuses are min pressure (mbar), max pressure (mbar), max digital pressure (counts) and min digital pressure (counts), respectively.

$$S = \frac{Dmax - Dmin}{Pmax - Pmin}$$

$$P = \frac{D - Dmin}{S} + Pmin$$

2.2 Power management

Sensor is powered by small Lithium battery charged via standard USB connector, commonly used as a mobile phone charging device. The electronics is supplied at 3,3V. The Lithium battery has own protection circuit to avoid over-charge, over-discharge, over-current and short circuit conditions which may permanently damage the battery cell. The cell voltage could be over 3,3V and below 3,3V during the discharge cycle. This requires Buck-Boost DCDC converter. Due to low power overall consumption, the synchronous buck boost converter was selected with maximum efficiency 97% at lower currents in the range of 100mA. The device operates from 0.65V to 4.5V input supplying max. 200mA of current from single battery cell. No other power management was implemented on the prototype. The power switching was done with usual mechanical SPST switch.

2.3 Wireless interface

The wireless part of the sensor is based on ESP8266 from Espresiff in the form factor of small WiFi Module. It is a self-contained SOC with integrated TCP/IP protocol stack with additional interfaces to give the device access to WiFi network. The module has a powerful enough on-board processing and storage capability that allows it to be integrated with the HPSD7000 sensor through its GPIOs. Its high degree of on-chip integration allows for minimal external circuitry and occupying minimal PCB area.

2.4 Software

WiFi module operates as an Access Point by setting up a network of its own, allowing other devices to connect directly to the sensor. The WiFi client connects to the SOC and exchange packets via User Datagram Protocol (UDP). This represents lowest possible load to the sensor, client and allows low latency. The drawback is lack of control mechanisms when packets are not delivered. The tradeoff between data loss and latency seems to be optimal for such short range peer-to-peer communication.

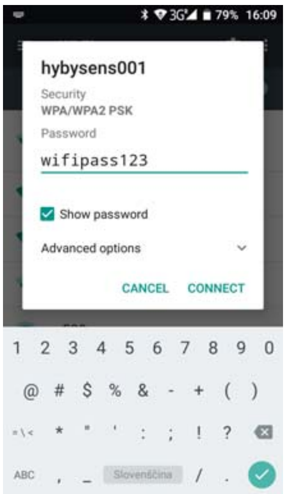

Figure 2: Communication start dialog

Prototype was tested using smart phone with installed “UDP terminal” application. First, the phone is connected to the access point using default password.

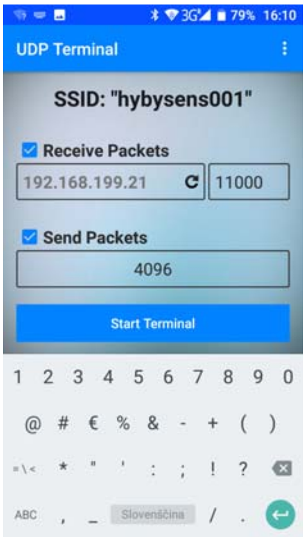

Figure 3: UDP terminal application

Then UDP terminal application is started. Packets are sent from phone to sensor on port 4096 and received by phone on port 11000.

When the letter “P” is sent with UDP packet on port 4096, the sensor returns pressure readout on port 11000. It is up to the client application to calculate the pressure from the readout.

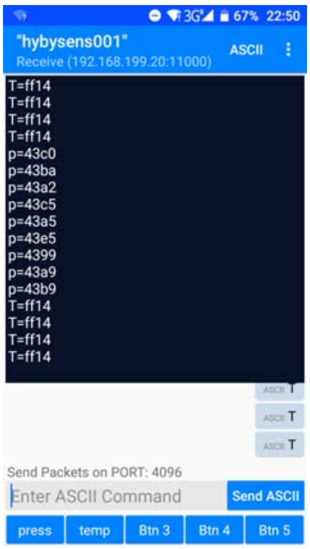

Figure 4: Pressure sensor readouts

2.5 Hardware prototype

The prototype was developed and tested using multi-module stack shown in Figure 5.

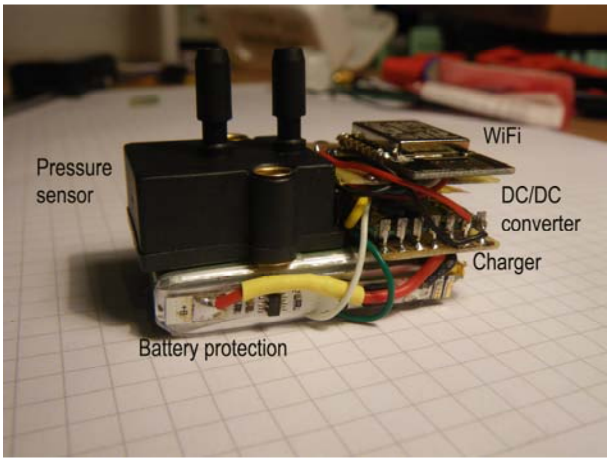

Figure 5: Wireless pressure sensor prototype

Preliminary prototype was assembled inside 3D-printed plastic housing as shown in Fig. 6.

Figure 6: 3D model of the housing, which was printed using 3D printer and PLA plastic material

2.6 Extending the range of the wireless module

The on-board antenna has potentially low range, especailly indoors. Some preliminary experiments have shown the indoor range of about 20m when sensor and client were placed in the same room. When obstacles, like human body, wall, doors or other objects were placed in the signal propagation path, the range was significantly lower.

Possible improvement is additional antenna. The module used in the prototype was ESP8266-12E with PIFA (Planar Inverted »F« Antenna) integrated on the module itself. Modules with the same functionality and connector for external antenna exist. Most widely used is module ESP8266-05, which has »u.Fl« type of antenna connector. Such small connector is not suitable for direct antenna connection and requires some adapter. The adapter has u.Fl connector on one side and SMA or similar connector on the other side of the coaxial cable. The SMA connector is more suitable for integration on the sensor housing and sealed against external environment.

One example is shown in Fig. 7. Advantage of such adapter is the possibility to attach external antenna for 2,4GHz or connect remote antenna with coaxial cable between SMA connector and antenna location.

Another option to improve the wireless sensor range is to use larger patch antenna, which is placed outside the housing. Advantage of this lies in easier sealing against environment (dust, moisture, water). The main disadvantage is larger dimension.

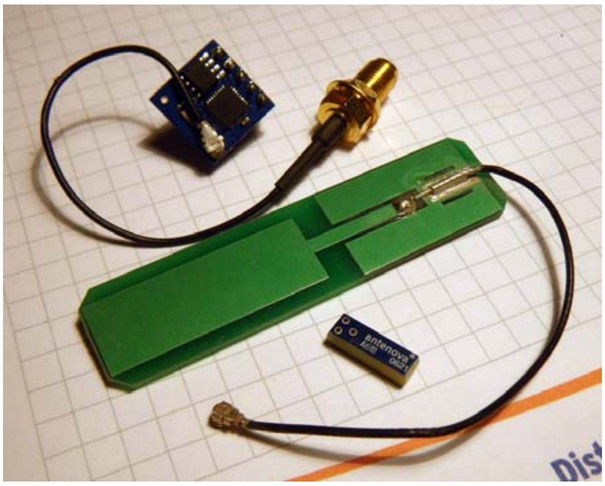

Figure 7: External antenna options: adapter cable (above), larger patch antenna (middle) and SMD solderable antenna (below).

3. CONCLUSIONS

The presented pressure sensor prototype has been developed for the proof of concept for possible replacement of wired sensors in existing industrial use case installations. Initial test is planned to be carried out at Philips shaver production plant.

4. ACKNOWLEDGMENTS

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[3] Swanson, L., "Linking maintenance strategies to performance", International Journal of Production Economics, 18 April 2001, Vol. 70, Issue 3, pp 237-244.

[4] Eade, R., "The importance of predictive maintenance", Iron Age New Steel 13 (9), 1997, pp 68-72.

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Napovedovanje časovnih vrst za podporo energetski optimizaciji stavbe

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POVZETEK

V naslednjem sestavku predstavljamo komponento sistema za optimizacijo upravljanje energije, ki napoveduje proizvodnjo in porabo električne energije. V ta namen je bil izveden demonstracijski projekt za sistem večstanovanjske zgradbe, ki (i) je priključen na električno omrežje in sistem daljinskega ogrevanja, (ii) je priključen na fotovoltaično elektrarno, (iii) vsebuje toplotno črpalko z zalogovnikom za ogrevanje stanovanj in (iv) vsebuje baterije. Namen celotnega projekta je demonstracija sistema za optimizirano usmerjanje energetskih tokov, kjer želimo doseči ali maksimirano lastno rabe energije ali minimizacijo stroškov. Medtem ko je izvajanje prve strategije razmeroma enostavno, pa je za drugo potrebno planiranje delovanja sistema v prihodnosti na osnovi predvidevanj. V ta namen smo razvili komponento za napovedovanje proizvodnje električne in porabo električne ter toplotne energije.

Ključne besede

Poraba energije, proizvodnja energije, toplota, elektrika, napovedovanje, strojno učenje, sončna elektrarna

1. UVOD

Napredno upravljanje energije v stanovanjskih objektih z možnostjo shranjevanja energije pomeni vključevanje posebnih metod, ki omogočajo izvedbo kratkoročnega in srednjeročnega planiranja razporejanje energije. Planiranje je pomembno predvsem zaradi nadzora upravljanja energijskih tokov, katere je mogoče upravljati skladno s cenovno ali energetsko učinkovitimi strategijami.

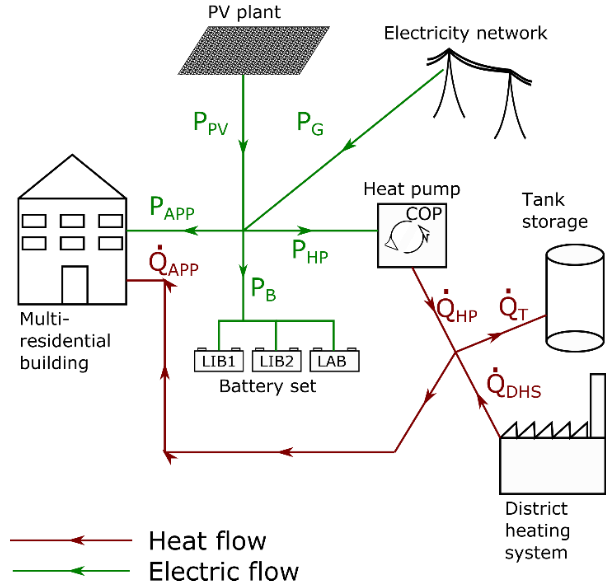
V ta namen smo za demonstracijski projekt [1] izdelali modul za napovedovanje determinističnih in stohastičnih časovnih vrst, ki predstavljajo proizvodnjo in porabo električne energije, ter porabo toplotne energije. Pri zasnovi modela napovedovanja smo si pomagali s simulacijo delovanja sistema na osnovi podatkov, pridobljenih na primerljivem objektu. Namen izvedbe je priprava napovedanih vrednosti, ki predstavljajo vhod v fazo optimizacije [2], ki pa ni tema tega prispevka.

Sorodne raziskave opisujejo različne metode napovedovanja časovnih porabe energije, na primer primerjava različnih implementacij z nevronskimi mrežami [3] ali kratkoročno napovedovanje z poznavanjem vremenskih podatkov [4]. Drugi so uporabili različne podporne podatke, kot na primer podatki o delovanju električnih naprav [5] in aktivnosti uporabnikov, medtem ko so v [6] potrdili, da se napovedljivost porabe zelo razlikuje glede na stanovanja in uporabnike in da je kratkoročno napovedovanje na urni ravni bolj natančno z napovedovanjem porabe posameznih naprav, medtem ko je napovedovanje za nekaj dni v naprej natančnejše na agregiranem sistemu celotnega objekta.

Drugo poglavje opisuje energijsko shemo sistema ter na kratko opiše energijske komponente sistema. Tretje poglavje opisuje postopek modeliranja sončne elektrarne in izvedbo napovedi ob predpostavki, da je znana napoved sončnega obsevanja. Četrto poglavje opisuje postopek za izvedbo napovednega modela za porabo električne in toplotne energije ob predpostavki, da je poznana zgodovina porabe za obdobje zadnjih nekaj dni in napoved zunanje temperature. Peto poglavje je namenjeno prikazu rezultatov in vrednotenju izvedenih modelov, v zadnjem poglavju je podan zaključek.

2. ENERGIJSKA SHEMA SISTEMA

Slika 1 prikazuje energijsko shemo sistema. Zelena barva predstavlja električne P, rdeča pa toplotne $\dot{Q}$ moči. Puščice označujejo smer tokov, pri čimer so dejanske smeri $P_G, P_B, \dot{Q}_T$ lahko tudi nasprotne. Kot vidimo iz slike, je stanovanjska zgradba porabnik tako električne, kot tudi toplotne energije. Sončna elektrarna predstavlja vir energije. Električno omrežje lahko predstavlja vir lahko pa tudi porabnik energije. Sistem daljinskega ogrevanja predstavlja vir energije. Na koncu so še baterije kot hranilniki električne energije in zalogovnik kot hranilnik toplote.



Slika 1: Energijski tokovi v sistemu

V povezavi s planiranjem nas zanima predvsem, kakšna bo poraba energije stanovanj in kakšna bo proizvodnja elektrike v bližnji prihodnosti. Primer: če želimo zagotoviti maksimalno samozadostnost zgradbe, potem je potrebno napolniti baterije in zalogovnik ravno toliko, da bo zadosti energije za potrebe zgradbe, čim več ostale energije pa želimo prodati. Poraba stanovanjske zgradbe je stohastičnega tipa, za katerega nimamo fizikalne formulacije, medtem ko je proizvodnja elektrike odvisna od samih dimenzij elektrarne in od sočnega obsevanja.

V naslednjih dveh poglavjih bosta opisana postopka za napovedovanje porabe energije in proizvodnje električne energije.

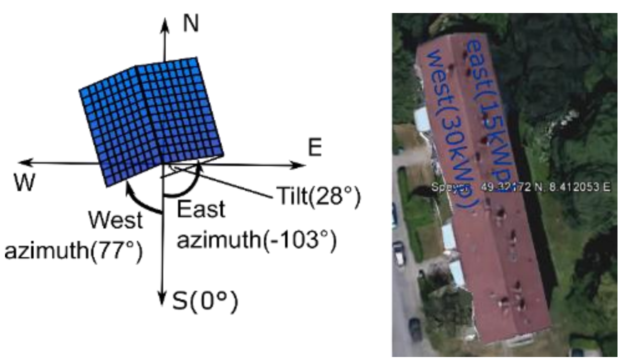
3. MODELIRANJE SONČNE ELEKTRARNE

Model za napovedovanje proizvodnje energije smo izdelali na osnovi nazivnih parametrov sončne elektrarne in podatkov o geolokaciji elektrarne. Pri razvoju modela napovedovanja smo privzeli naslednje dinamične podatke, ki jih bo model potreboval za izvedbo napovedi:

1. napoved sončnega obsevanja na horizontalno površino $I_s\ [W]$
2. povprečna dnevna proizvodnja energije sistema $E_d\ [kWh]$
3. povprečna dnevna količina sončnega obsevanja na enoto površine, ki jo prejme sistem $H_d\ [kWh/m^2]$

Točko 1 - napoved sončnega obsevanja na horizontalno površino je mogoče pridobivati preko vremenskega servisa, na primer Meteomedia[1] na urni ravni. Podatke za točki 2 in 3 pa pridobimo za celo leto s pomočjo spletne aplikacije PVGIZ[2], kjer vnesemo geolokacijo elektrarne in podatke o azimutu ter naklonu strehe.

Shema sončne elektrarne je prikazana na Sliki 2. Desna stran slike kaže satelitski posnetek strehe. Elektrarna je razdeljena na vzhodno stran z nazivno močjo 15 kWp in zahodno stran z nazivno močjo 30 kWp. Leva stran slike prikazuje azimut vzhodnega in zahodnega dela elektrarne ter naklon strehe.



Slika 2: Koti sončne elektrarne

Koeficient učinkovitosti posamezne strani elektrarne izračunamo kot razmerje med sončnim obsevanjem na elektrarno in prejeto energijo, pomnoženo z nazivno močjo elektrarne Enačba (1).

$$k_{EHd,inst} = \frac{E_{d,tilt}}{H_{d,hor}} \times P_{inst}, \qquad (1)$$

kjer je $E_{d,tilt}$ povprečna dnevna proizvodnja energije za elektrarno z naklonom *tilt*, $H_{d,hor}$ je povprečna dnevna količina sončnega obsevanja na enoto horizontalne površine, P_{inst} pa je nazivna moč elektrarne. Če označimo koeficienta učinkovitosti obeh strani elektrarn kot $k_{EHd,15}$ in $k_{EHd,30}$, pri izračunu pa upoštevamo vrednosti, izračunane z aplikacijo PVGIZ za $E_{d,tilt,15}$, $E_{d,tilt,30}$, $H_{d,hor}$ ter nazivni moči posameznih strani $P_{inst,15}$ in $P_{inst,30}$ kot 15 kWp in 30 kWp, potem je skupna učinkovitost vsota, podana z Enačbo (2).

$$k_{EHd} = k_{EHd,15} + k_{EHd,30} \qquad (2)$$

Napoved moči proizvodnje glede na napovedano sončno obsevanje na horizontalno ploskev $I_{s,n}$ napovemo v skladu z Enačbo (3).

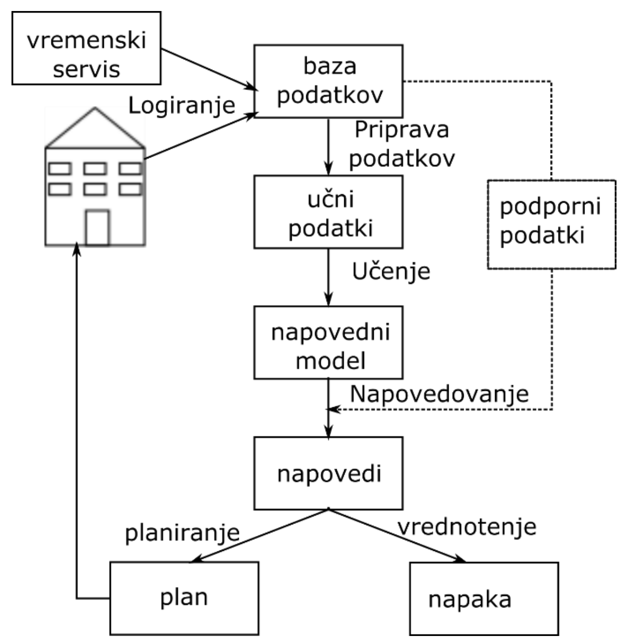
$$P_n = k_{EHd} \times I_{s,n} \qquad (3)$$

Napoved sončnega obsevanja $I_{s,n} \left[\frac{kWh}{m^2}\right]$ je za dotično lokacijo mogoče pridobiti preko vremenskega servisa, na primer Meteomedia.

4. MODELIRANJE PORABE ELEKTRIČNE IN TOPLOTNE ENERGIJE

Napoved porabe električne in toplotne energije v stanovanjskih objektih predstavlja problem, ki ga ni mogoče enostavno zapisati kot enoznačen matematični zapis. Poraba električne in toplotne energije je odvisna od človeških zahtev, ki pa se med posamezniki razlikujejo.

Za potrebe optimizacije planiranja shranjevanja energije v baterijah in zalogovniku smo problem napovedovanja porabe energije zasnovali na osnovi stohastičnega modela, generiranega s pomočjo metod umetne inteligence. Postopek izvedbe napovednega modela in izvajanja napovedi je prikazan na Sliki 3.



Slika 3: Proces stohastičnega napovedovanja časovnih vrst

[1] Meteomedia - spletna storitev za napoved vremenskih podatkov za geografsko lokacijo (http://wetterstationen.meteomedia.de/), zadnjič pridobljeno: 20.9.2017

[2] PVGIZ - Spletna aplikacija za izračun proizvodnje električne energije (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php), zadnjič pridobljeno: 20.9.2017

4.1 Priprava učnih podatkov

Med delovanjem sistema je potrebno z logiranjem pridobivati zgodovino z datumom in časom opremljenih podatkov o porabi toplotne in električne energije ter podatke o zunanji temperaturi ter jih shranjevati v bazo podatkov. Ker so podatki o električni in toplotni porabi pridobljeni iz električnih števcev in kalorimetrov v obliki energije, jih je potrebno filtrirati, kar obsega:

- izbor zapisov z enakimi časovnimi koraki,
- izračun diferenc za prevod energije v moč,
- skaliranje za zapis v kW,
- brisanje ekstremnih vrednosti in drugih nepravih podatkov.

Postopek priprave učnih podatkov obsega tudi dodajanje atributov, ki določijo dan v tednu, mesec, tip dneva (delavnik / prost dan), čas v dnevu (dopoldan / popoldan).

4.2 Učenje, napovedovanje in vrednotenje

Učenje napovednega modela smo izvedli s pomočjo modula za napovedovanje časovnih vrst v sklopu programskega okolja Weka [3]. Pri tem smo preizkusili delovanje naslednjih algoritmov:

- metoda podpornih vektorjev
- k-ti najbližji sosed z vrednostmi k: 3, 5, 7 in 10
- linearna regresija
- Gaussovi procesi
- metoda naključnih gozdov

Za potrebe vrednotenja delovanja algoritmov smo izvedli simulacijski postopek, ki zajame celotno zgodovino meritev in izvede postopek priprave učno množico podatkov. Za vsakega od zgoraj navedenih algoritmov strojnega učenja v prvem koraku izbere podatkovne instance za prvih 14 dni in testne podatke na naslednji dan, izvede strojno učenje, izdela napovedi in jih shrani. Potem za vsak naslednji dan poveča učno množico za en dan, izvede učenje, izdela napovedi ter jih doda dotedanjim napovedim. Postopek tako iterativno ponavlja, dokler ne naredi napovedi za zadnji dan podatkov.

Po končanem postopku smo vse napovedane vrednosti porabe primerjali z merjenimi vrednostmi in izračunali še srednjo absolutno napako, srednjo relativno napako ter koren srednje kvadratne napake. Na ta način smo pridobili informacijo o uspešnosti posameznih algoritmov napovedovanja in jo uporabili kot podlago za izbor primernega algoritma za delovanje na realnem objektu. Rezultati bodo predstavljeni v naslednjem poglavju.

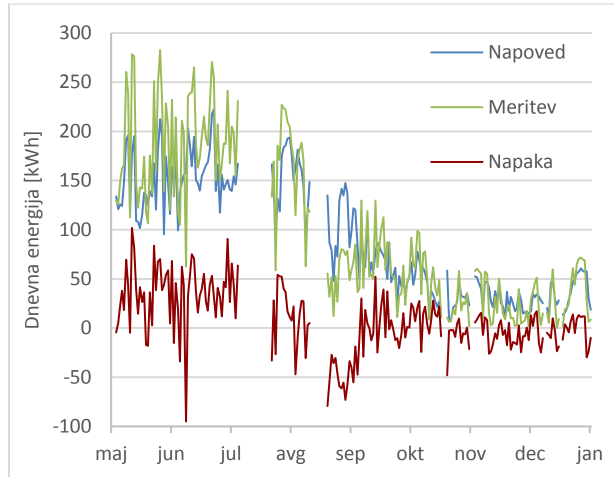
5. Rezultati in diskusija

Sledeče poglavje predstavlja rezultate vrednotenja modela za napoved proizvodnje sončne elektrarne. Za tem sledi primerjava algoritmov za napovedovanje porabe električne in toplotne energije. Nazadnje bo na kratko predstavljeno še delovanje sistema na realnem objektu, kjer smo simulator priredili za delovanje v produkcijsko verzijo.

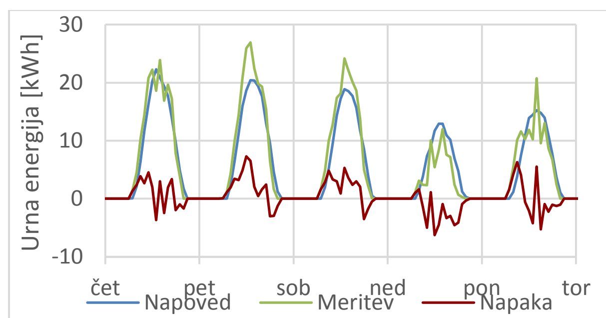
5.1 Vrednotenje modela sončne elektrarne

Model sončne elektrarne smo vrednotili tako, da smo primerjali proizvodnjo, napovedano z našim modelom na osnovi napovedanega sončnega obsevanja in izmerjeno proizvodnjo sončne energije. Slika 4 prikazuje rezultate napovedovanja proizvodnje sončne elektrarne. Napovedane in merjene vrednosti so prikazane kot dnevne integrale moči v času – torej dnevne vsote energije. Napaka je prikazana kot razlika med napovedano in dejansko proizvedeno energijo. Prazni prostori na grafu pomenijo izpad meritev zaradi vzdrževalna ali druga dela, ali zaradi napak v komunikaciji in v teh obdobjih ni bilo pridobljenih podatkov, ali pa so bili napačni. Slika 5 prikazuje primer urnih napovedi za obdobje med 1.9.2016 in 5.9.2016.

Rezultati kažejo na zadovoljivo napovedovanje, pri čimer je potrebno upoštevati geografsko razliko med podano vrednostjo sončnega obsevanja za lokacijo vremenske postaje in lokacijo elektrarne. Na proizvodnjo vplivajo tudi dimniki in drevo, ki mečejo senco na elektrarno, predvsem pa je sončna elektrarna močno občutljiva na stopnjo oblačnosti.



Slika 4: Prikaz vsote dnevnih vsot napovedi, dnevnih vsot meritev proizvodnje in napake (maj 2016 – januar 2017)



Slika 5: Prikaz urnih napovedi proizvodnje, meritev proizvodnje ter napako za obdobje med 1.9. in 5.9.2016

Napake dnevnih vsot napovedi so razmeroma nizke in ker sistem vsebuje baterije, se urne napake kompenzirajo tekom dneva in posledično natančnost urnih napovedi ne pomeni zadovoljivo delovanje, ki bo potrebno pri kasnejši izvedbi planiranja nakupa, prodaje in hranjenja električne energije.

5.2 Vrednotenje in primerjava algoritmov za napoved porabe energije

Primerjava algoritmov je prikazana v Tabeli 1. Posamezni stolpci vsebujejo različne izvedbe algoritmov. Za vsako od množic napovedi, ki so bile izvedene z različnimi algoritmi smo izračunali naslednje tipe napak: koren srednje kvadratne napake, srednjo kvadratno napako, srednjo napako, srednjo absolutno in srednjo odstotno absolutno napako ter standardni odklon napake. Stolpci so obarvani tako, da zelena barva prikazuje boljše rezultate, rdeča pa slabše.

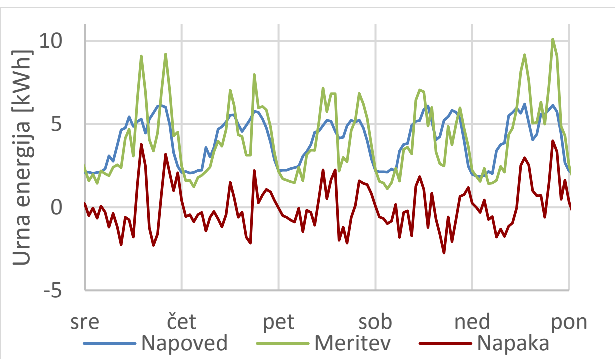
Tabela 1: Primerjava algoritmov za napovedovanje električne in toplotne energije

	Metoda podpornih vektorjev	Linearna regresija	kNN, n=3	kNN, n=4	kNN, n=5	kNN, n=6	**Naključni gozdovi**	Gaussovi procesi
koren sr. kvadratne napake	1.838	1.883	1.978	1.958	1.929	1.919	**1.685**	1.766
sr. kvadratna napaka	3.379	3.545	3.914	3.835	3.723	3.681	**2.841**	3.119
sr. napaka	0.060	-0.154	0.043	0.012	**-0.001**	**-0.001**	-0.124	-0.112
sr. absolutna napaka	1.403	1.430	1.507	1.493	1.473	1.465	**1.282**	1.350
standardni odklon napake	1.837	1.877	1.978	1.958	1.929	1.919	**1.681**	1.763
sr. odstotna abs. napaka	28.80%	31.39%	31.35%	31.50%	31.36%	31.43%	**28.15%**	28.97%

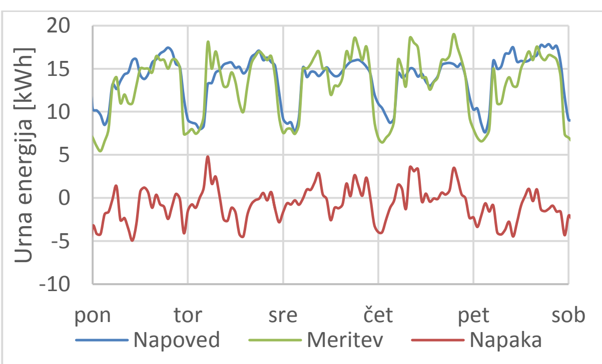
Najboljši algoritem je označen z poudarjenimi črkami v tabeli. Podatki, ki smo jih uporabili za vrednotenje algoritmov, so bili pridobljeni v obdobju med 26.6.2016 in 24.10.2016.

Že prvi pogled na tabelo pokaže, da najboljše rezultate izkazuje algoritem naključnih gozdov po skoraj vseh kriterijih. Ta algoritem se v primerjavi z drugimi, predvsem 5. in 6. najbližjim sosedom, izkaže kot slab le v kategoriji srednje napake. Dober rezultat kaže tudi algoritem Gaussovi procesi, kar je ugodno zaradi hitrega učenja modela v primerjavi z naključnimi gozdovi.

Kljub temu, da je kategorija srednje napake pomembna, saj se podobno kot pri proizvodnji tudi poraba energije tekom časa kompenzira zaradi hranilnikov energije, smo se za implementacijo na realnem modelu odločili za implementacijo algoritma naključnih gozdov na realni sistem. Slika 6 prikazuje urne napovedi porabe električne energije za obdobje med 10.8. in 14.8.2016. Slika



Slika 6: Prikaz urnih napovedi porabe električne energije za obdobje med 10.8. in 14.8.2016



Slika 7: Prikaz urnih napovedi toplotne energije za obdobje med 21.11. in 25.11.2016

6. ZAKLJUČEK

V prispevku je opisan postopek modeliranja in uporabe napovednih modelov za proizvodnjo in porabo električne in porabo toplotne energije. Modeliranje proizvodnja električne energije je izvedeno na osnovi matematičnega modela preko logičnih fizikalnih relacij saj je odvisna od sončnega obsevanja. Poraba električne in toplotne energije pa je poleg stanja vremena – zunanje temperature odvisna tudi od uporabnikov stanovanja, kar je razlog za izvedbo stohastičnih napovednih modelov, ki uporabljajo metode strojnega učenja. V prispevku so poleg modeliranja prikazane tudi metode za izbor algoritma strojnega učenja. Rezultati prikazujejo uspešno izvedbo na realnem objektu.

7. ZAHVALA

Izvedbo raziskav in razvoja so omogočili podjetje Hitachi Chemical, ltd. v sklopu projekta »Self-consumption HEMS with PV and battery demonstration project«, projekt EcoSmart in Agencija Republike Slovenije za Raziskovalno dejavnost v sklopu programa »Spodbujanje zaposlovanja mladih doktorjev znanosti« in projekta ARRS-MDR-ZP-2017-02.

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Avtomatizacija in digitalizacija vrta

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POVZETEK

Prispevek opisuje razvoj sistema digitalizacije in avtomatizacije agrikulturnih oziroma vrtnih površin. Sistem je sestavljen iz treh glavnih delov. Oddaljeni moduli imajo priključene senzorje za temperaturo in vlago zraka, vlažnost zemlje ter osvetljenost okolice. Oddaljeni moduli imajo tudi funkcijo avtomatičnega zalivanja. Glavni modul sprejema podatke iz oddaljenih modulov in jih posreduje strežniku. Na strežniku je podatkovna baza za shranjevanje podatkov in spletna stran za pregled teh podatkov.

Splošni izrazi
Agrokultura, meritve, pošiljanje podatkov, testiranje.

Ključne besede
Digitalizacija, avtomatizacija, senzorika, baza podatkov.

1. UVOD

V dobi hitro spreminjajočega sveta se spreminjajo tudi najbolj osnovne človekove dejavnosti, kot je pridelava sadja in zelenjave. S tem povezani postopki se poskušajo avtomatizirati, okoljski parametri pa zajeti z računalniki oziroma digitalizirati. Podatki digitalizacije se selijo na splet. Tam se spremljajo in iz njih razbirajo razmere zraka, sonca in zemlje, kjer se vzgajata sadje in zelenjava. Iz teh podatkov je razvidno, kako se razmere spreminjajo preko dneva, skozi letne čase in kako se skozi leta spreminjajo podnebne razmere. Na začetku je bil namen avtomatizacije poljedelskih in vrtnih površin zmanjšati in poenostaviti delo pridelovalcev in oskrbnikov. Sistemi so bili preprosti in nepovezani, namenjeni so bili predvsem intervalnemu zalivanju površin, kar pa ni bilo vedno usklajeno s pomembnimi zunanjimi dejavniki, kot sta trenutna namočenost zemlje in osončenost zemljišča. Vpliv enega in drugega je lahko za rastline uničujoč, v prvem primeru povzroči gnitje, v drugem učinek povečevalnega stekla na moč sončnih žarkov. Kasneje so se sistemi izboljšali in začeli upoštevati zunanje dejavnike ter se jim prilagajati. Nadzorovali so izvajanje različnih potrebnih aktivnosti - poleg zalivanja so ogrevali tople grede, optimizirali vlago v zraku, zastirali sonce s premičnimi strehami, …

Agrikultura je največja in za človekov obstoj ena izmed najbolj pomembnih panog. Pod besedo agrikulturo spadata kmetijstvo in poljedelstvo. Z namenom kvalitetne avtomatizacije in digitalizacije smo izdelali sistem, ki je prilagodljiv glede na velikost in število agrikulturnih površin, prav tako pa sistem uporabniku na prijazen način ponuja podatke, ki mu omogočajo kvalitetno vzgojo zdravega sadja in zelenjave.

2. PARAMETRI ZA NADZOR AGRIKULTURNIH POVRŠIN

Pri izbiri parametrov, ki smo jih želeli nadzorovati na agrikulturnih površinah, smo se odločali na podlagi dveh kriterijev pomembnost [1]: za rast in razvoj rastlin in obstoju senzorjev za merjenje tega parametra. Npr. parameter pH (kislost ali bazičnost zemlje) je pomemben za zdrav razvoj rastline, a senzor, ki bi ga meril, ni preprost za uporabo. Potrebno ga je namreč vsake toliko časa kalibrirati z različnimi raztopinami \cite{ph}, nezanemarljiva pa je tudi izrazito višja cena v primerjavi z ostalimi senzorji. Izbrani parametri, ki so bili smiselni pri našem projektu, so:

- svetloba; spada med najpomembnejše dejavnike za rast in zdrav razvoj vsake rastline. Rastlina s pomočjo svetlobe ustvarja fotosintezo, biokemijski proces, ki ji omogoča, da le-to pretvori v energijo za lastno rast
- temperatura; prav tako eden izmed nepogrešljivih dejavnikov za rastlino. Večina rastlin uspeva med 0°C in 50°C. Optimalna temperatura skozi dan, skozi noč in najvišja še sprejemljiva temperatura za rastlino pa so različne za posamezne rastline
- vlaga zraka; je količina razpršene vode v zraku, ta količina pa je povezana s temperaturo zraka. Toplejši zrak ima zmožnost zadržati več vode kot hladnejši
- vlaga zemlje; je količina vode v zemlji, prav tako pomembna za obstoj rastline. V primeru, da je vlaga zemlje visoka dlje časa, obstaja nevarnost, da rastlina zgnije. Če je vlage premalo, pa rastlina ne more vsrkati dovolj vode in odmre zaradi pomanjkanja

3. DELOVANJE SISTEMA

3.1 Oddaljeni moduli

Oddaljeni moduli delujejo na Arduino mikrokrmilniku in so namenjeni temu, da se postavijo na vrtne površine in brezžično glavnemu modulu pošiljajo podatke, ki jih beležijo s pomočjo vgrajenih senzorjev. Prav tako omogočajo samodejno zalivanje vrtov z vgrajenim relejem, ki preko ventila sproža dovod vode do namakalnih sistemov. Uporabljeni senzorji na oddaljenih modulih:

- senzor FC-28; za merjenje vlage zemlje
- senzor DHT-11; za merjenje vlage zraka in temperature okolice
- foto upor; za merjenje osvetljenosti
- modul nRF24l01; za brezžično komunikacijo z glavnim modulom

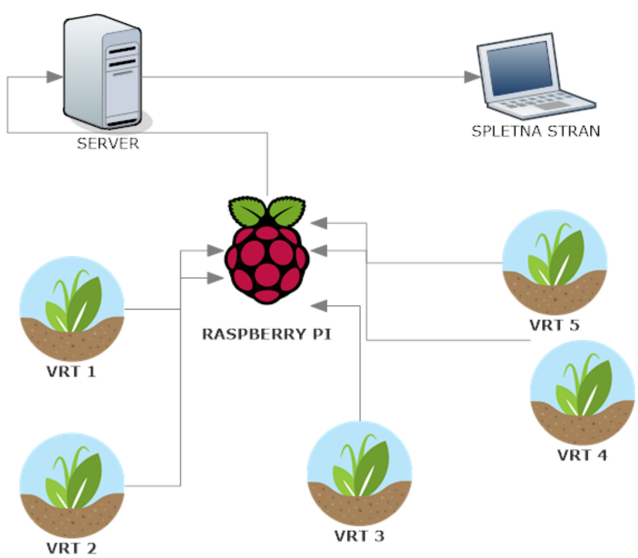
3.2 Glavni modul

Glavni modul deluje na mini računalniku Raspberry Pi [2], na katerem teče programska koda, napisana v programskem jeziku Python. Ta sprejema podatke iz oddaljenih modulov, nato pa jih posreduje naprej na strežnik. Podatke iz oddaljenih modulov pridobiva s pomočjo serijske komunikacije, saj je preko USB vodila povezan na Arduin-a, ki s pomočjo modula nRF24l01 [3] komunicira z oddaljenimi moduli. Glavni modul uporablja:

- senzor DHT-11; za merjenje vlage zraka in temperature okolice
- senzor BMP085; za merjenje zračnega pritiska

3.3 Strežnik in spletna stran

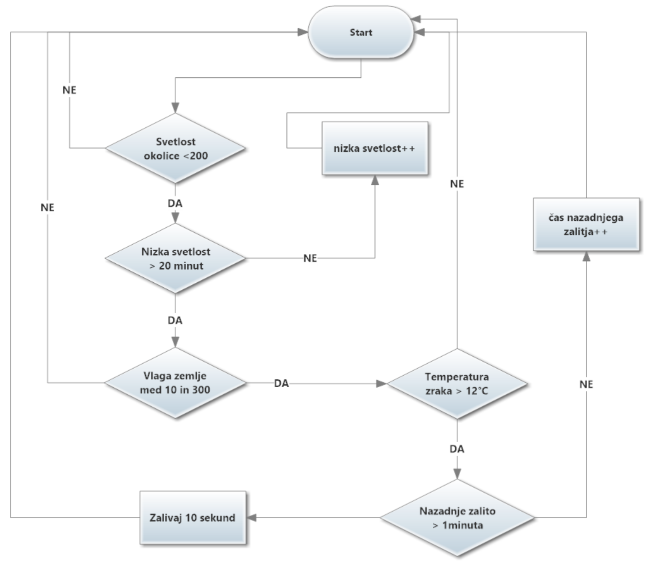
Tretji del predstavlja strežnik, na katerem je podatkovna baza, ki shranjuje podatke, katere dobiva iz glavnega modula. Na strežniku se nahaja tudi spletna stran, ki končnemu uporabniku na preprost način prikazuje relevantne podatke iz njegovih vrtov. Ti podatki, ki jih lahko spremlja od kjerkoli, mu omogočajo pregled nad trenutnim dogajanjem na njegovem vrtu. Ti uporabniku pomagajo pri odločitvah za možne izboljšave na vrtu. Poenostavljen prikaz vidimo na sliki 1.



Slika 1: Poenostavljen prikaz delovanja

3.4 Samodejno zalivanje

Naš oddaljen modul ima tudi možnost namakanja zemlje, ki se zgodi pod določenimi pogoji, ki so prikazani na sliki 2. Sistem deluje s pomočjo solenoidnega ventila. To je vodni ventil, ki ga lahko po želji vključimo ali izključimo z dovodom električnega toka. Ta ventil deluje na 12V napetost, zato je bila potrebna baterija s takšno napetostjo. Dovod napetosti, da se ventil odpre, se regulira s 5V relejem, ki smo ga lahko upravljali direktno iz Arduina-a. Na začetek in konec ventila smo namestili nastavek za povezavo na navadno vrtno cev, katere en konec gre na dovod vode, drugi konec cevi pa se priključi na nastavek za zalivanje, npr. škropilnik, porozna cev za namakanje. Kot alternativa solenoidnega ventila za manjše vrtove oziroma lončnice je priključitev na majhno vodno črpalko.



Slika 2: Posplošen prikaz algoritma za zalivanje

4. STREŽNIK IN SPLETNA STRAN

4.1 Strežnik

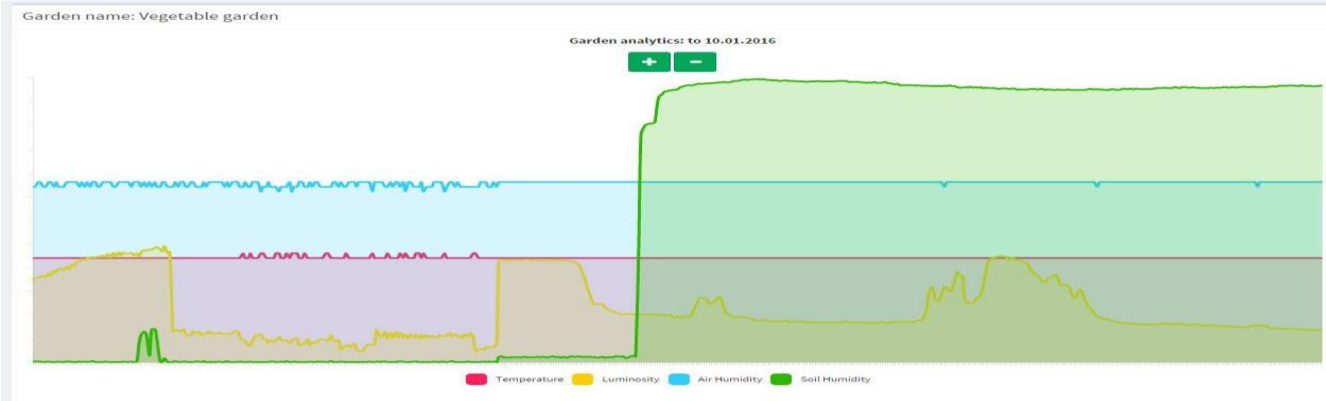
Glavna funkcija našega strežnika je pridobivanje podatkov iz oddaljenih modulov, jih shraniti v podatkovno tabelo in nato posredovati spletni strani, ki jih prikaže. Naš strežnik temelji na ASP.NET [4] platformi, programski jezik, ki smo ga uporabljali je C#, za programersko okolje smo uporabili Microsoft-ov program Visual Studio.

4.2 Spletna stran

Spletna stran je namenjena prezentaciji podatkov iz vrtov uporabniku. Želeli smo, da je spletna stran:

- preprosta za uporabo
- pregledna in nenasičena
- daje uporabniku le pomembne podatke
- uporabna tudi na mobilnih napravah

Kot že omenjeno, naša spletna stran pridobiva podatke iz modulov preko GET ukaza iz strežnika. Ta ukaz se sproži ob zagonu spletne strani. Od podatkov iz glavnega modula spletna stran uporabi le zadnji vnos v podatkovno tabelo. To dobimo s pomočjo SQL ukaza TOP in jih sortiramo po datumu. Ti podatki so le informativne narave. Iz oddaljenih modulov se uporabi za grafični prikaz le nekaj zadnjih podatkov (ob zagonu spletne strani zadnjih 500 podatkov), število le-teh lahko določimo s pomočjo znaka + in - ob grafu ter s tem spreminjamo časovni razpon na grafu. Preberejo se še podatki kot so koordinate in ime vrta. Prikaz grafa enega izmed vrtov, med zalivanjem, na sliki 3.



Slika 3: Graf enega izmed vrtov

Spletna stran je narejena v AngularJS, ki je odprtokodno ogrodje za izdelavo dinamičnih spletnih strani. V našem projektu smo uporabili precej knjižnic in en API za pridobivanje podatkov. API je namenjen pridobivanju trenutnih vremenskih razmer. API deluje tako, da spletni naslov spremenimo na naše koordinate vrta. Ta pa nam nazaj v obliki XML sporoča trenutne razmere. V našem projektu uporabimo trenutno temperaturo, ki jo lahko primerjamo z izmerjeno s strani naših modulov in trenuten opis vremenskih razmer, npr. oblačno, megleno, ...

4.3 Elektronsko obveščanje uporabnika

V naš projekt smo dodali še elektronsko obveščanje skrbnika vrta v primeru, ko vlažnost zemlje pade pod določeno kritično vrednost. To se lahko zgodi v treh primerih:

- možnost mehanske napake - ni dovoda vode, ker se le-ta nekje v sistemu prekine
- nepovezanost oddaljenega modula z ventilom, ki sprošča dovod vode ali pa se ventil pokvari
- izsušitev zemlje, kadar ni vode v vodovodnem sistemu

Sistem obveščanja se sproži, kadar senzor pokaže vrednost med 50 in 10. To pomeni, da je zemlja suha. Ne more pa se sprožiti, če pade vrednost pod 10, ker to z veliko verjetnostjo pomeni, da je bil modul iztaknjen iz zemlje. Ko dobimo podatek iz modula, da je na vrtu zemlja suha, se na elektronski naslov pošlje sporočilo, da je na točno določenem vrtu (npr. tomato garden) močno padla vlažnost zemlje. To elektronsko sporočilo se pošilja na največ triurne intervale, da ne poplavimo elektronskega nabiralnika. Elektronski naslov je lahko drugačen za vsak vrt posebej, kar je uporabno, če imajo vrtovi različne oskrbovalce, saj s tem vsakemu posebej pošlje sporočilo samo za njegov vrt.

5. TESTIRANJE

Projekt smo testirali na čiliju, vrsti paprike, ki je občutljiva rastlina in za zdrav razvoj zahteva ugodne pogoje. Odločili smo se za vrsto Carolina Reaper, ki je v času izdelave tega projekta najmočnejši čili na svetu. Semena smo sprva posadili v skupen lonček, ko pa so rastlinice razvile po dva para listkov, smo jih po štiri do pet razdelili v štiri različne testne lončke. Vsi lončki so imeli isti vir svetlobe in čas osvetlitve - žarnica, ki je gorela 12 ur na dan, s čimer smo simulirali idealno osvetlitev, ki jo ta vrsta rastline potrebuje. Lončki so se med seboj razlikovali le glede na režim namakanja. Poimenovali smo jih s črkami od A do D:

- skupina A - namakanje je bilo samodejno s pomočjo našega algoritma zalivanja
- skupina B - ročno zalivanje glede na podatke, ki jih je uporabnik izvedel iz naše spletne strani
- skupina C - ročno zalivanje vsak tretji dan ob isti uri
- skupina D - ročno zalivanje "po občutku"

6. REZULTATI

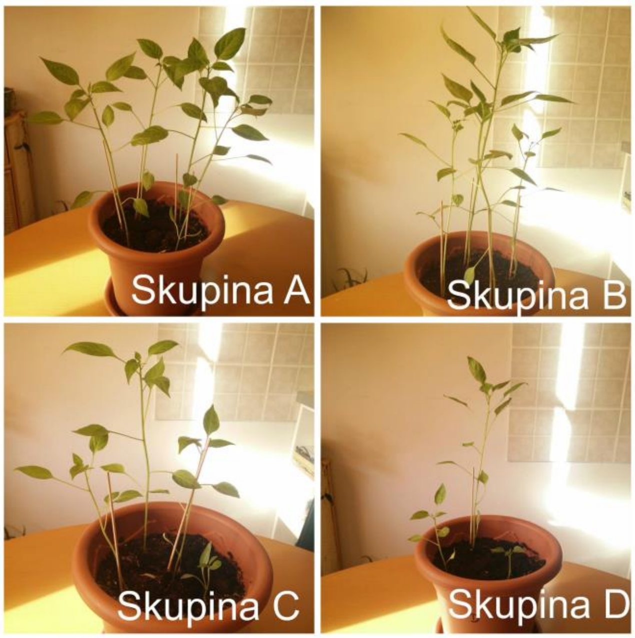
Rezultate testiranja smo analizirali po dveh mesecih, tako da je vsak lonček imel dovolj časa za rast in razvoj. Rezultati pa so sledeči:

- skupina A; Vse štiri rastline so razvile podobno velikost, kar nam sporoča, da je bila voda enakomerno razporejena po celotnem lončku. Vse rastline so zdrave, kar nam pove, da so bili pogoji za rast dobri. Zemlja ni bila nikoli preveč razmočena in nikoli presuha. S to skupino smo bili zadovoljni, saj nam je v praksi pokazala, da je naš algoritem zalivanja pravilno in dobro deloval.
- skupina B; Razvile so se vse štiri rastline, vendar so bile dokaj različne glede višine. Ena izmed njih je izstopala, ostale so bile precej nižje, a še vedno nekoliko manjše kot rastline v skupini A. Večina rastlin iz te skupine je bila zdravega izgleda, le najvišja je, zaradi hitre rasti, imela tanko in krhko steblo. Predvidevamo, da je do opisane razlike prišlo iz dveh razlogov. Po eni strani ročno zalivanje lahko privede do neenakomerne navlaženosti zemlje. Tako smo včasih zalili vse rastline enako, včasih pa je bila kakšna bolj, druga manj zalita. Po drugi strani pa je ročno zalivanje manj optimalno glede na dejansko vlažnost zemlje, kot če je avtomatsko. Vendar smo tudi s temi rezultati bili zadovoljni, saj so nam sporočali, da sistem dobro deluje tudi, če nas samo opozarja, kdaj moramo zalivati rastline.
- skupina C; Razvile so se vse štiri rastline, vendar precej različno. Ena rastlina je na robu preživetja, dve rasteta počasi. Le ena od štirih rastlin je dokaj primerne rasti. Samo dve od štirih rastlin izgledata zdravi. Tretja ima rumene listke, četrta je izrazito zakrnela. Vzrok izraziti raznolikosti v izgledu rastlin je verjetno le močno nihanje namočenosti zemlje, ki se je lahko v treh dneh popolnoma izsušila ali pa je bila še vlažna, ko je bil čas ponovnega zalivanja. Torej rastline v bistvu nikoli niso bile primerno zalite. Ta test nam je nazorno pokazal, da

avtomatično časovno namakanje slabo zadosti potrebam rastline po vodi.

- skupina D; V tej testni skupini sta od posajenih petih rastlin dve propadli. Preostale tri so se v višino razvile različno. Preostale rastline izgledajo zdrave, vendar so v povprečju precej nižje kot v testih A in B. Le ena od rastlin je dosegla podobno velikost kot v prvih dveh skupinah. Vzrokov za takšen rezultat je več - neenakomerno zalivanje, različni časovni intervali, včasih je oseba na rastline pozabila, včasih pa jih je premočno zalila. S tem testom smo dobro ponazorili običajno zalivanje rastlin. Tudi rezultati so temu primerni.

Na sliki 4 so prikazani lončki po dveh mesecih rasti.



Slika 4: Lončki po dveh mesecih

7. ZAKLJUČEK

V našem projektu smo si zadali nalogo izdelati sistem, ki bi omogočal digitalizacijo in avtomatizacijo vrtnih površin. Sistem deluje na principu glavnega modula, ki sprejema podatke oddaljenih modulov. Oddaljeni moduli so postavljeni po vrtovih, iz katerih želimo pridobivati podatke, pomembne za zdravo rast in razvoj rastlin. Sistem omogoča tudi avtomatično zalivanje vrtov. Zalivanje se prilagaja trenutnim razmeram na vrtu in dejanski potrebi rastlin po vodi, s principom logike čakanja pa se voda enakomerno razporedi po zemlji pred ponovnim namakanjem. Sistem uporabniku nudi tudi spletno stran, preko katere lahko spremlja svoje vrtove, prav tako omogoča obveščanje preko spletne pošte v primeru, da se zemlja na vrtu preveč izsuši.

V splošnem pa smo z delovanjem projekta zadovoljni. Sistem deluje podobno, kot smo si ga že na začetku zamislili. Najbolj nas je prepričalo testiranje našega sistema, ki smo ga implementirali v razvoj sadik čilija. Rezultati so zanesljivo govorili v prid našega projekta, saj so tako občutljive rastline, zalivane z našim sistemom zalivanja, zrasle najvišje in bile med najbolj zdravimi sadikami.

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Matjaž Gams, Aleš Tavčar