XI Spring School on “IoT, economic and management challenges for e-health integration in the enlarged Europe”
Trieste, Italy, June 5-8, 2023

Clinical and biomedical engineering in Serbia: Perspectives & experiences

Assoc. Prof. Nadica Miljković
University of Belgrade – School of Electrical Engineering

I am

- Assoc. Prof. in Biomedical Engineering at the University of Belgrade – School of Electrical Engineering (ETF)
- Visiting Researcher at the Faculty of Electrical Engineering, University of Ljubljana
- Guest Assoc. Prof. at the Military Academy, University of Defence in Belgrade
- Having >6 years of industry experience in research and development of biomedical devices
- I teach courses on biomedical engineering and electrical measurements
- My research is, among others, focused on measurement and analysis of biosignals in healthy subjects and in patients
- Since 2018 I have been involved in numerous Open Science and Open Research Data Initiatives

Modified photography taken by Assist. Prof. Miodrag Tasić from University of Belgrade – School of Electrical Engineering

Content

- Biomedical Engineering & Education in Serbia
- Clinical Engineering in Serbia
- Private & Public Sectors: Career Opportunities
- Personal Experiences & Perspectives

DISCLAIMER

- This presentation reflects Author's perspectives, experiences, and opinions
- There may be more practitioners, schools, professionals, and associations (especially in a private sector) practicing biomedical and clinical engineering in Serbia, but only few are mentioned here

EDUCATION OF CLINICAL ENGINEERS

In general

- In most cases, we have electoral courses at Bachelor, Master, and PhD levels at Universities
- Bachelor studies for biomedical engineering?
  - Only recently one program was accredited at the University of Novi Sad, but with strong electrical engineering background (presentation of the program is available online: http://www.ftn.uns.ac.rs/1781008633/prezentacija-studijskog-programa, accessed on May 28, 2023)
- There is also one multidisciplinary PhD program at the University of Belgrade that I should mention – Biomedical Engineering and Technology:
  - https://webserver.rcub.bg.ac.rs/en/study-program/4507/Biomedical-engineering-and-technology, accessed on May 28, 2023

More study programs/courses in Serbia

- R&D center BioIRC and the R&D at the Faculty of Mechanical Engineering, University of Kragujevac (http://www.bioirc.ac.rs/)
  - University of Kragujevac has accredited a PhD in Bioengineering
- Faculty of sport and physical education, University of Belgrade (http://www.dif.bg.ac.rs/en/)
- Private Universities also have experts with the knowledge from biomedical engineering
- There was/is only one course on Clinical engineering in Serbia (https://automatika.etf.bg.ac.rs/sr/13e054kli). And I tech it! This year is 14th anniversary since this course was introduced.
  - One course on Clinical engineering was introduced few years ago at the Faculty of Mechanical Engineering, University of Belgrade (https://www.mas.bg.ac.rs/studije/predmeti/1283, accessed on May 28, 2023)

Who works as biomedical engineer in Serbia?

- Well, there is a variety of backgrounds
- Some of those engineers had some/one/none electoral course/s on biomedical engineering
- All biomedical engineers that I've met have three things in common:
  - they don't take continuous education for granted (they regularly go to specializations, seminars, read new materials, educate others …)
  - they LOVE their work
  - their employees, in most cases, don't officially acknowledge them as biomedical/clinical engineer
    - medical device professionals *i.e.* technical consultant for implantable pacemakers and cardio verter defibrillators

How bold or ignorant electrical engineer can you be to accept to work as biomedical engineer? It takes even bolder person to become successful in the field!

Photo by Web Donut on Unsplash

ETF

Education @ETF

- Bachelor studies
  - Biomedical & Ecological Engineering module @Physical Electronics Department (dedicated program, http://nobel.etf.bg.ac.rs/studiranje/osnovne_studije/bmei/)
  - @Signals & Systems Department (no specific study program, but electoral courses from the field of Biomedical engineering, https://automatika.etf.bg.ac.rs/en/)
- Master studies
  - Module Biomedical & Ecological Engineering (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/biomedical-and-ecological-engineering)
  - Electoral courses @Signals & Systems module (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/signals-and-systems)
  - Electoral courses @Computer Engineering and Informatics (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/computer-engineering-and-informatics)
- PhD studies: orginized similar as Master studies

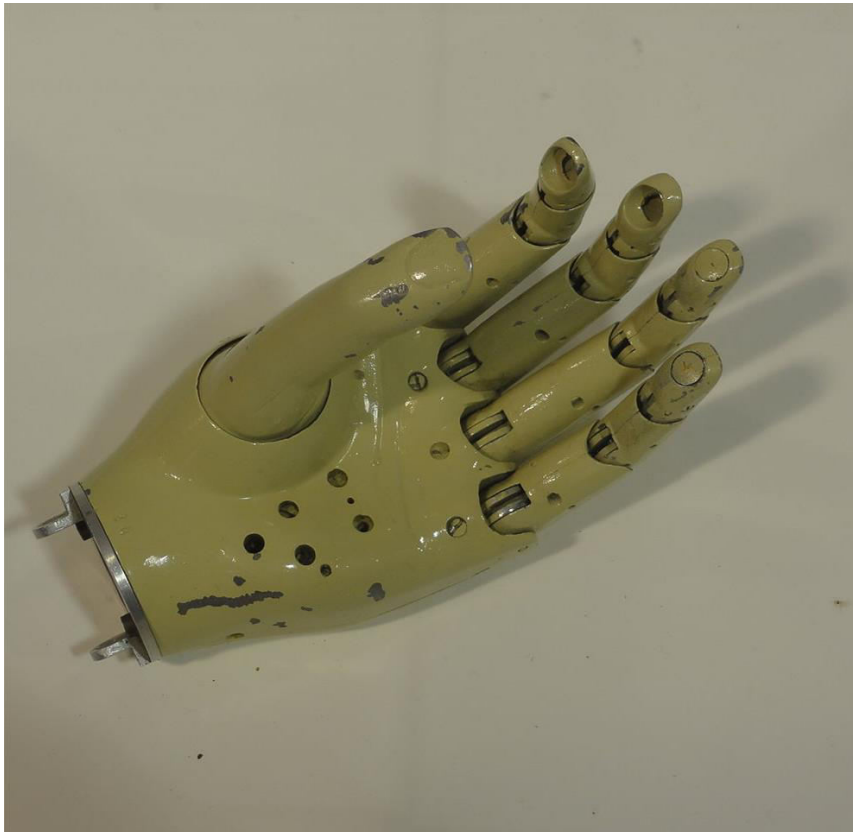
Perhaps confusing?

- Bachelor studies
  - Biomedical & Ecological Engineering module @Physical Electronics Department (dedicated program, http://nobel.etf.bg.ac.rs/studiranje/osnovne_studije/bmei/)
  - @Signals & Systems Department (no specific study program, but electoral courses from the field of Biomedical engineering, https://automatika.etf.bg.ac.rs/en/)
- Master studies
  - Module Biomedical & Ecological Engineering (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/biomedical-and-ecological-engineering)
  - Electoral courses @Signals & Systems module (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/signals-and-systems)
  - Electoral courses @Computer Engineering and Informatics (https://www.etf.bg.ac.rs/en/studies/master-academic-studies/electrical-engineering-and-computing-2019/computer-engineering-and-informatics
- PhD studies: orginized similar as Master studies

First of all, couple historical facts!

Building of Technical faculties, Belgrade, 1931., source: Historical archives of Belgrade, signature IAB-1165-A-4-0053.

Biomedical engineering @ETF



Photography of Belgrade hand from 1963, by Fæ, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=23140967

- Research started much earlier
  - It was related to both robotics and biomedical engineering – artificial organs
- The first courses in biomedical engineering were introduced in 80-ies at ETF at three modules:
  - Technical Physics
  - Signals & Systems
  - Computer Science
- Students liked them very much
  - The courses were “sensational” (with state-of-the-art technologies) and majority of the courses were project oriented, [*Personal communication*]

Biomedical engineering @ETF

- I teach only electoral courses @Signals & Systems Department to students from various modules
  - Some of them are connected directly and some of them indirectly to biomedical engineering
- Current directly related courses (dedicated websites only in Serbian):
  - Bachelor studies: Methods of Electrophysiological Signal Analysis (2008-), Bachelor studies: Clinical Engineering (2009-),
  - Master studies: Biomedical signal processing techniques (2016-)
  - PhD studies: Trends in Health Technologies (2017-), Advanced Methods of Electrophysiological Signal Analysis (2021-)
- There are other courses @Signalas & Systems Department and other two Departments with focus to biomedical signal acquisition, neural prosthesis, medical imaging, etc.

Current status @ETF

- Laboratory is shut down on Saturday September 10, 2022!
  - It operated since 1997/8
  - Apparently, due to the re-organization
  - And with the consent from the Laboratory Head?!
- Biomedical engineering is an attractive field
  - Many researchers from different scientific fields have used their expertise or developed new in the field of BE @ETF
  - They do it as we speak
- Biomedical engineering is currently not recognized as important scientific field by Signals and Systems department @ETF
  - Hopefully, this will be changed

EDUCATION OF MEDICAL PROFESSIONALS

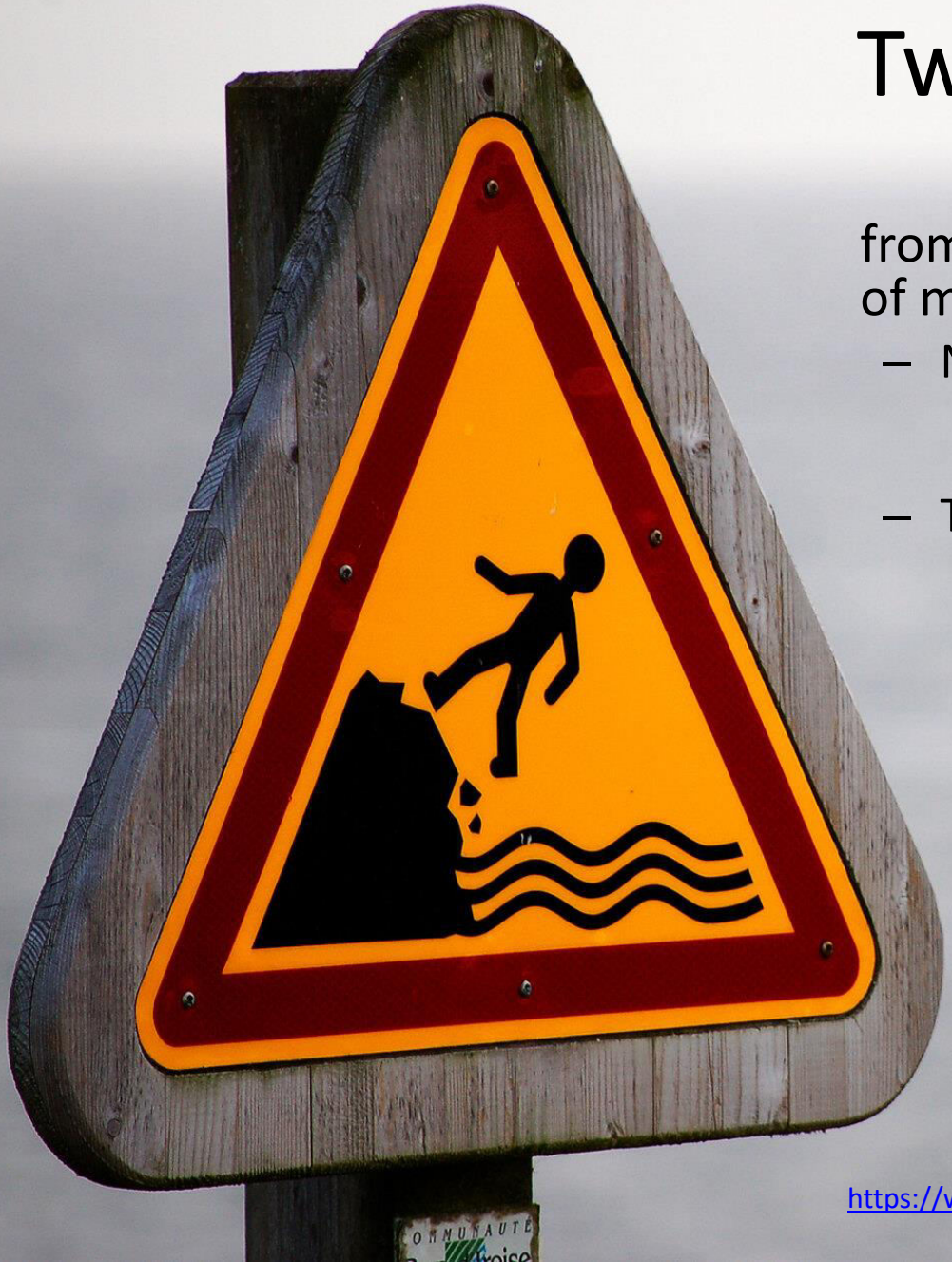
Medical faculty curriculum

- Not very popular topic. Unfortunatelly.
- Medical Faculty, University of Belgrade (http://med.bg.ac.rs/?page_id=12204&script=lat, accessed on May 28, 2023) has two courses indirectly related to biomedical engineering:
  - Radiology and nuclear medicine
  - Medical statistics and informatics (http://statistika.mfub.bg.ac.rs/)
- Courses are mostly focused on statistics and evidence-based medicine
- Important, but not enough
- Our MDs should learn about technology in general
- Why?

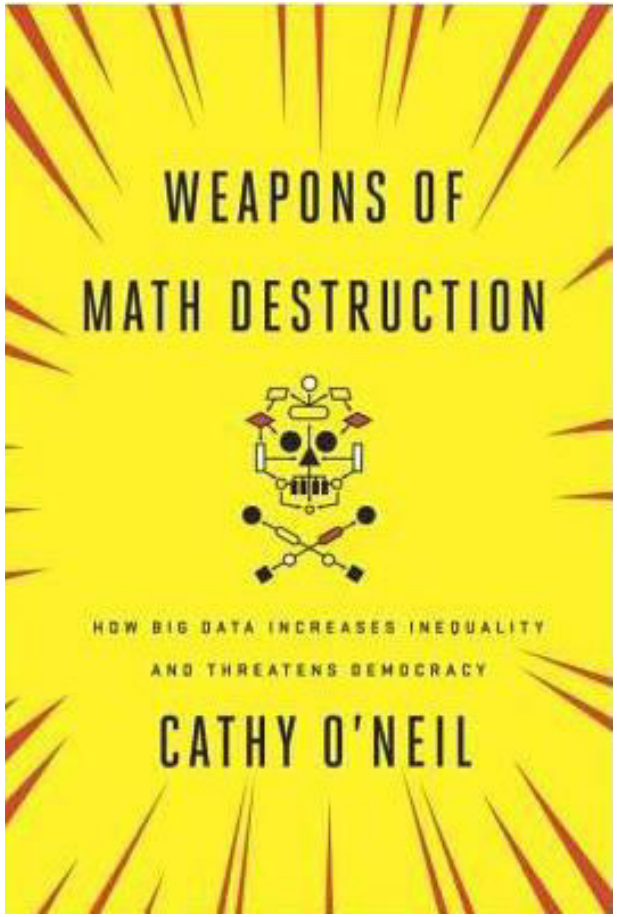
Two potential traps

from technological unawareness of medical stuff:

- Not trusting technology at all!
  - Buying useless equipment or not buying required equipment …
- Too much trust in technology!
  - Thinking that Artificial Intelligence (AI) literally exists. Employing potentially dangerous and unknown technologies ...



AI & health: Promise & prejudice



- AI can be used for enhanced diagnostics and prediction in health and it is very promising especially when dealing with large set(s) of data
- However, one should always be careful about possible AI abuses
- "*The era of blind faith in big data must end*" Cathy O'Neil:
  - Talk @TED: https://youtu.be/_2u_eHHzRto
  - Talk @Google: https://youtu.be/TQHs8SA1qpk

Book: Cathy O'Neil "Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy", Crown, 2016, https://www.goodreads.com/book/show/28186015-weapons-of-math-destruction.

MDs' education

- We need formal as well as informal educational resources
- Curricula of Medical Faculties should include biomedical engineering
- Good practices are:
  - Medical Faculty at University of Novi Sad, study program Biomedical engineering.
  - University of Defence in Belgrade, Medical Faculty of the Military Medical Academy has accredited specialist academic study program on Bioengineering and Medical Informatics,
  - Theory or practice?
- Clinical engineers should keep up with state-of-the-art technological advancements, but the same applies to MDs

Why MDs' education?

Editorial | Open Access | Published: 07 February 2023

Together we are strong! Collaboration between clinicians and engineers as an enabler for better diagnosis and therapy of atrial arrhythmias

Axel Loewe, Armin Luik, Roberto Sassi & Pablo Laguna

Medical & Biological Engineering & Computing **61**, 875–877 (2023) | Cite this article

1048 Accesses | Metrics

The first electrocardiogram showing atrial fibrillation was published by Willem Einthoven already in 1906; also electrograms recorded within the atrial cavities in humans were described more than 70 years ago [1]. Since then, the marked improvements of early and

Loewe, A., Luik, A., Sassi, R., & Laguna, P. (2023). Together we are strong! Collaboration between clinicians and engineers as an enabler for better diagnosis and therapy of atrial arrhythmias. *Medical & Biological Engineering & Computing*, *61*(4), 875-877. https://doi.org/10.1007/s11517-023-02788-0

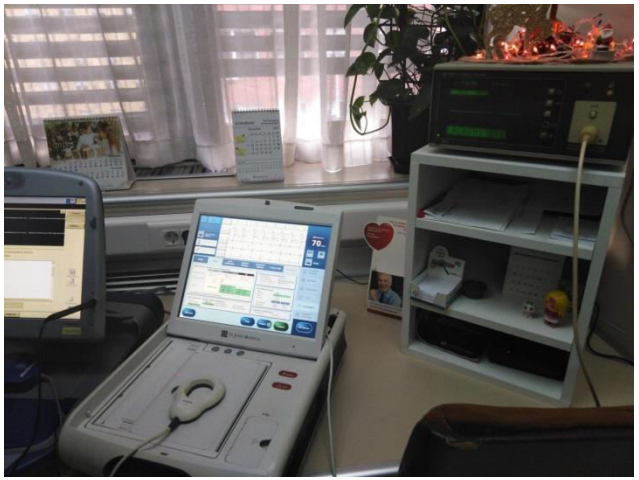
From Spring School in 2019, visit to University clinic in Trieste
https://bioingts.units.it/spring-school-2019

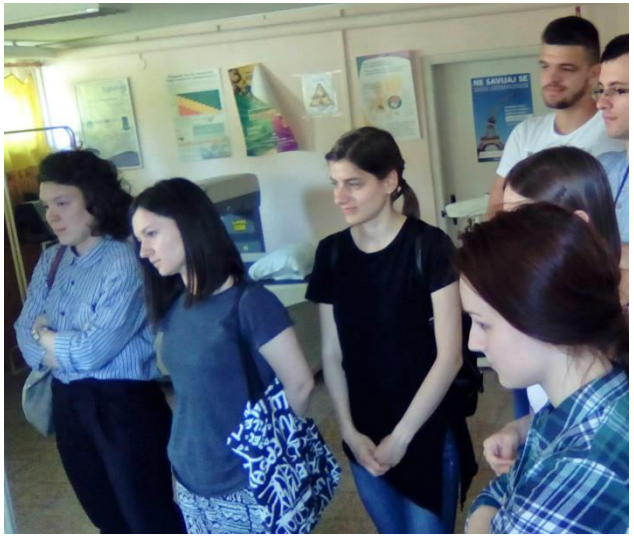
CAREER PATHS

Briefly

- Mostly in Academia
  - @universities: educators & researchers
  - @institutes
  - @centers
  - @hospitals
  - etc.
- Partly in industry
  - @R&D
  - @foreign companies
  - @startups (!!!)
  - etc.
- Alternate career paths:
  - management @hospitals, @medical suppliers
  - data analytics
  - embedded technologies
  - jobs related to artificial intelligence
  - etc.

Public & private sectors @public clinics



- Practical part for the course Clinical engineering
- Institute for oncology and radiology of Serbia
- Rehabilitation clinic “Dr Miroslav Zotović”, Belgrade
- Pacemaker center @Clinical center of Serbia

Public sector in private companies

Photo by Jair Lázaro on Unsplash

- Consultancy & Collaboration
- R&D of novel diagnostics and therapeutic modalities
- Some traits:
  - Health technologies acceleration!
  - From the idea to realization to clinical study to market!
- Inter-disciplinary and multi-disciplinary teams!

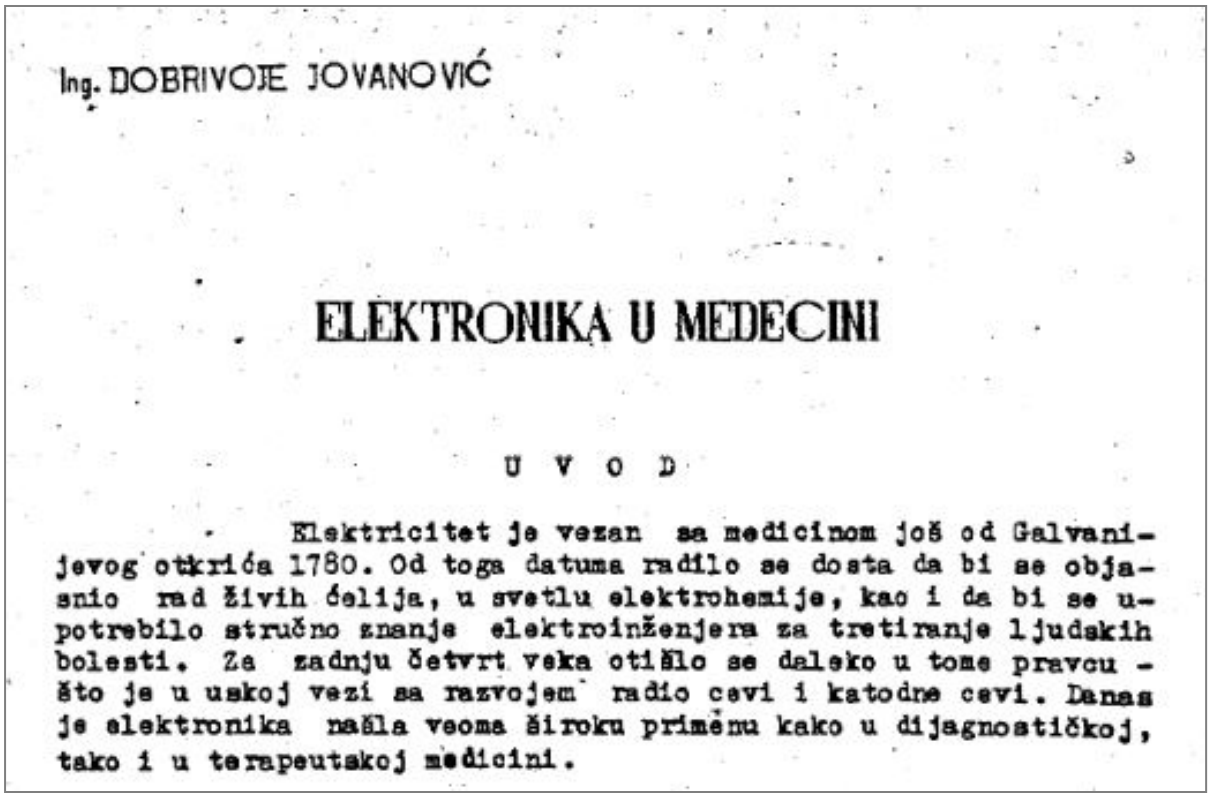
We need

- Increased visibility of biomedical/clinical engineers in
  - public sector and
  - private sector
- Increased organization
- Increased collaboration
- Mind set re-assessment won't hurt
- Modern concepts are complimenting traditional approaches, they are not threatening them!
- Please, note that this slide is the same as the slide from 2019!
- But, the things are really getting better
- Technology is rapid and MDs have to (and want to) follow them

CONFERENCES & LIFELONG LEARNING & COLLABORATION

The beginnings in Yugoslavia

- 1955 Jovanović Dobrivoje, "ELEKTRONIKA U MEDICINI", 1. Industrijska elektronika, Beograd, IE, 1, 83-89, eTRAN\01.ETAN.1955\Jovanovic.D.ETAN1955.pdf .
  - More info in paper from 2006 Popović B. Dejan, “STRUČNA SEKCIJA ZA BIOMEDICINSKU TEHNIKU ETRAN-A: PRVIH 50 GODINA” https://www.etran.rs/common/archive/ETRAN_1955-2006/ET(R)AN_1955-2006/eTRAN/50.ETRAN.2006.3/ME/Popovic%20istorijat%20ME.ETRAN2006.pdf.



Ing. DOBRIVOJE JOVANOVIĆ

ELEKTRONIKA U MEDECINI

U V O D

Elektricitet je vezan sa medicinom još od Galvanijevog otkrića 1780. Od toga datuma radilo se dosta da bi se objasnio rad živih ćelija, u svetlu elektrohemije, kao i da bi se upotrebilo stručno znanje elektroinženjera za tretiranje ljudskih bolesti. Za zadnju četvrt veka otišlo se daleko u tome pravcu - što je u uskoj vezi sa razvojem radio cevi i katodne cevi. Danas je elektronika našla veoma široku primenu kako u dijagnostičkoj, tako i u terapeutskoj medicini.

Meetings

- Two types of meetings: **narrow specialization and broad specialization (usually with specialized sessions/tracks).**
- Do we need narrow-themed conferences on national level at all? I don't have the right answer to this question.
  - Past (honorable mention): Human-Machine Interface from Student-to-Student Interface @ETF (http://bmit.etf.bg.ac.rs/en/home/).
  - Current (with long tradition, but old-fashioned): IcETRAN (https://www.etran.rs/2019/IcETRAN/About_Conference/)
- Conferences (where I published my papers, in case you are interested):
  - In Serbia: NEUREL, IcETRAN, ETRAN, YU INFO, OTEH, Memorial Symposium "PetarArežina", Kongres fizijatara Srbije sa međunarodnim učešćem, HMI from SSI, MIT, ZINC, Telfor, PSSOH, NEUROCARD, BelBi, satRday, SICAAI INFOTEH Jahorina, etc.
  - Abroad: IFESS Conference, ICABB, IFMBE, EMBC, ICNR, ICFDA, ISEK, ESPRM, ICOM, ISEK, EFIC Congress, BaSS ICIST, DSC, etc.

Associations

- There are active associations. Some of them, though old (dating from 50ies and 60ies) stopped or slowed their work. Reasons: many.
  - To name one: poor management *i.e.*, one person operation. Or they are directed towards students and operated by them (see the problem? – students come and go). We should have more sustainable solutions.
- Couple of them are active.
- All past and current efforts toward associations should be acknowledged!
- However, more work needs to be done!
- My personal observation (if you care): **currently some of these associations (not all) are interested dominantly in resources and less in people. This should be reversed!**
- I am not part of them
- No ideological background
- Simply, no one called me
- And, I had no specific interest of mine to join them

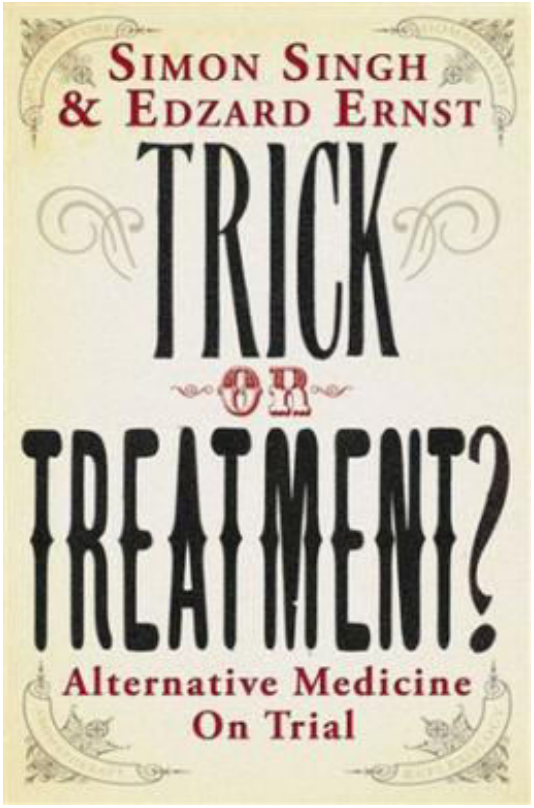
PERSONAL EXPERIENCES AND VIEWS

Clinical engineering course @ETF

- I wanted to change course name and scope (http://automatika.etf.rs/sr/13e054kli)
- Then, I changed my mind
- Clinical engineers helped me change my mind
- Clinical engineering is important
- I believe in that!

Predmet 13E054KLIN	Status	Broj časova (P+V+L)	Krediti
Plan nastave	Izborni	3+1+1	6
Predavanja - dr Nadica Miljković, vanredni profesor, kabinet 68			
Vežbe - dr Nadica Miljković, vanredni profesor, kabinet 68			
Laboratorijske vežbe - dipl. inž. Marta Mirkov			

What did I change?



- Incorporated more my own clinical research and experiences
- Included Ethics and procedures for performing clinical research, privacy issues, etc.
- Legal requirements for obtaining CE marks and FDA approvals
- Added more information on evidence-based medicine
- Asked clinical engineers to share their experiences and career paths with students
- Asked MDs to share their views and experiences
- Etc.

By http://www.randomhouse.com/catalog/display.pperl?isbn=9780593059043 specifically http://www.randomhouse.com/catalog/winfit.pperl?pic_url=%2fcatalog%2fcovers_450%2f9780593059043.jpg, Fair use, https://en.wikipedia.org/w/index.php?curid=21193143

Medical device professionals @ETF

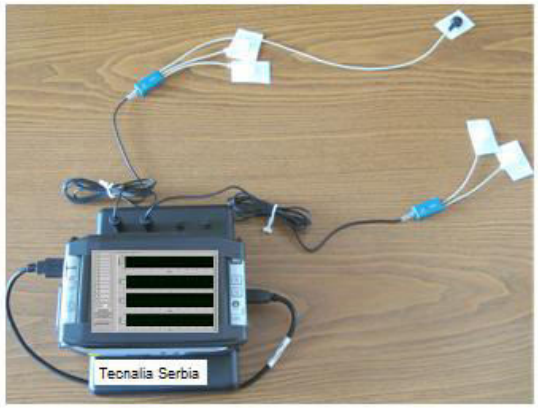
- Nenad Popović, PhD and Milan Antić, MSc from Abbott Medical (Milan was affiliated with Biotronik in 2018) presenting their experiences to students (part of the Clinical engineering course)
- Presentation is available online (in English)
- Photography is taken @ETF, June 2018

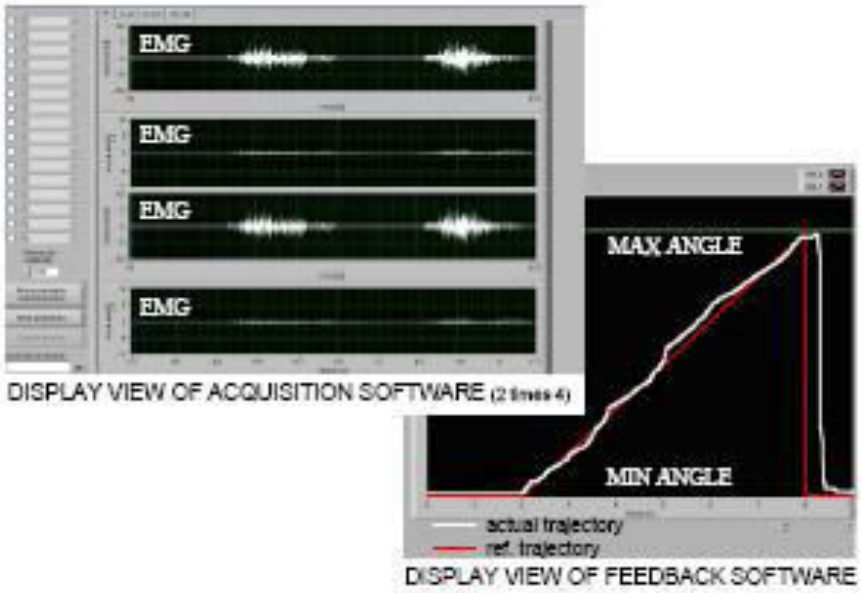
Clinical research

- Incorporated in the course
- Include studies @Rehabilitation clinic “Dr Miroslav Zotović” in Belgrade related to brain traumas (cerebro-vascular insult, CVI) and low back pain assessment by algometry, electromyography, and ultrasound imaging
- Selected journal papers:
  - J. Kojović, N. Miljković, M. M. Janković, D. B. Popović, Recovery of motor function after stroke: a polymyography-based analysis, *Journal of Neuroscience Methods, 194(2):321-328, 2011.* https://doi.org/10.1016/j.jneumeth.2010.10.006
  - N. Miljković, I. Milovanović, A. Dragin, Lj. Konstantinović, D. B. Popović. Muscle synergies with Walkaround® postural support vs. "cane/therapist" assistance, *Neurorehabilitation, 33(3):491-501, 2013.* https://doi.org/10.3233/NRE-130982
  - O. Djordjevic, Lj. Konstantinović, N. Miljković, G. Bijelić. Relationship between electromyographic signal amplitude and thickness change of the trunk muscles in patients with and without low back pain, *Clinical Journal of Pain, 31(10):893-902, 2015.* https://doi.org/10.1097/AJP.0000000000000179
  - O. Djordjevic, Lj. Konstantinović, N. Miljković. Difference between subjects in early chronic phase of low back pain with and without neuropathic component –observational cross sectional study, *European Journal of Physical and Rehabilitation Medicine, 64(2): 177-185, 2018.* https://doi.org/10.23736/s1973-9087.18.05226-7

КЛИНИКА
ЗА РЕХАБИЛИТАЦИЈУ
“ДР МИРОСЛАВ ЗОТОВИЋ”

Electromyography (EMG)



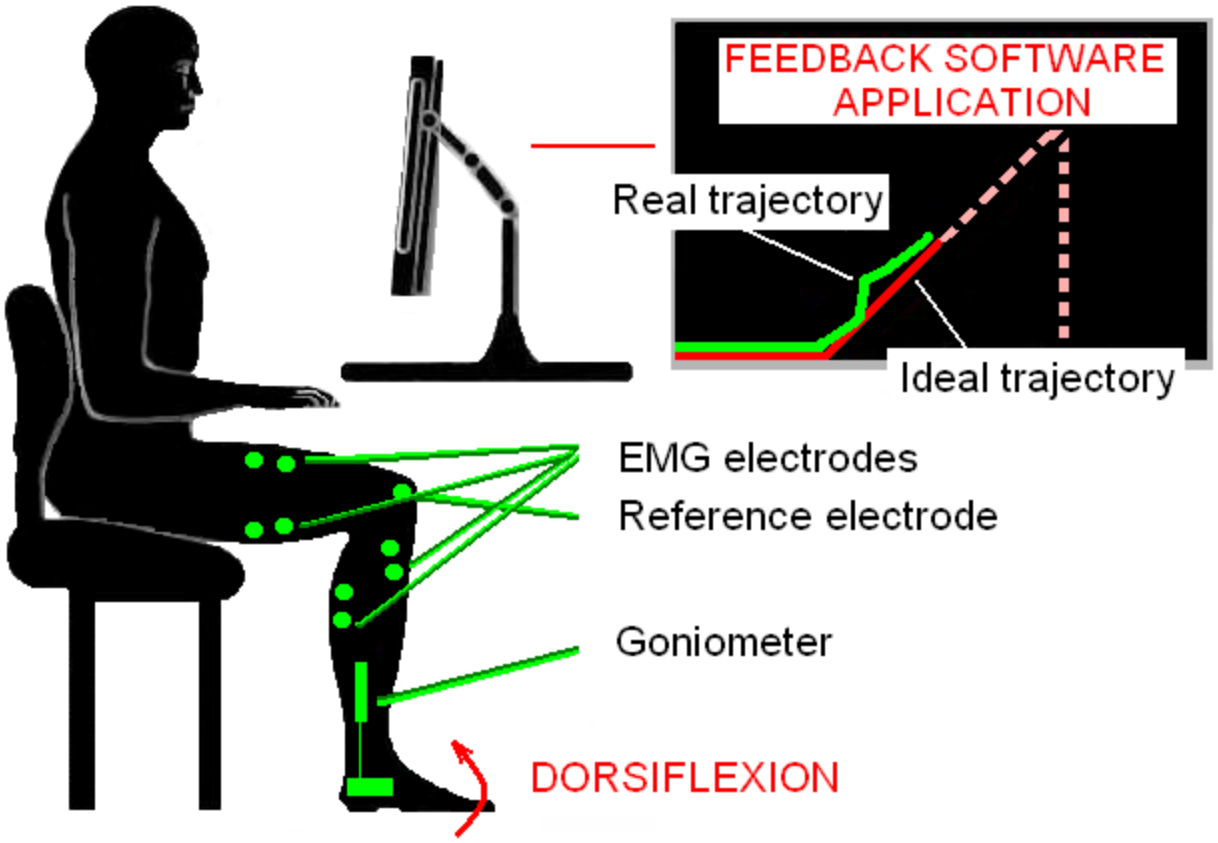


DISPLAY VIEW OF ACQUISITION SOFTWARE

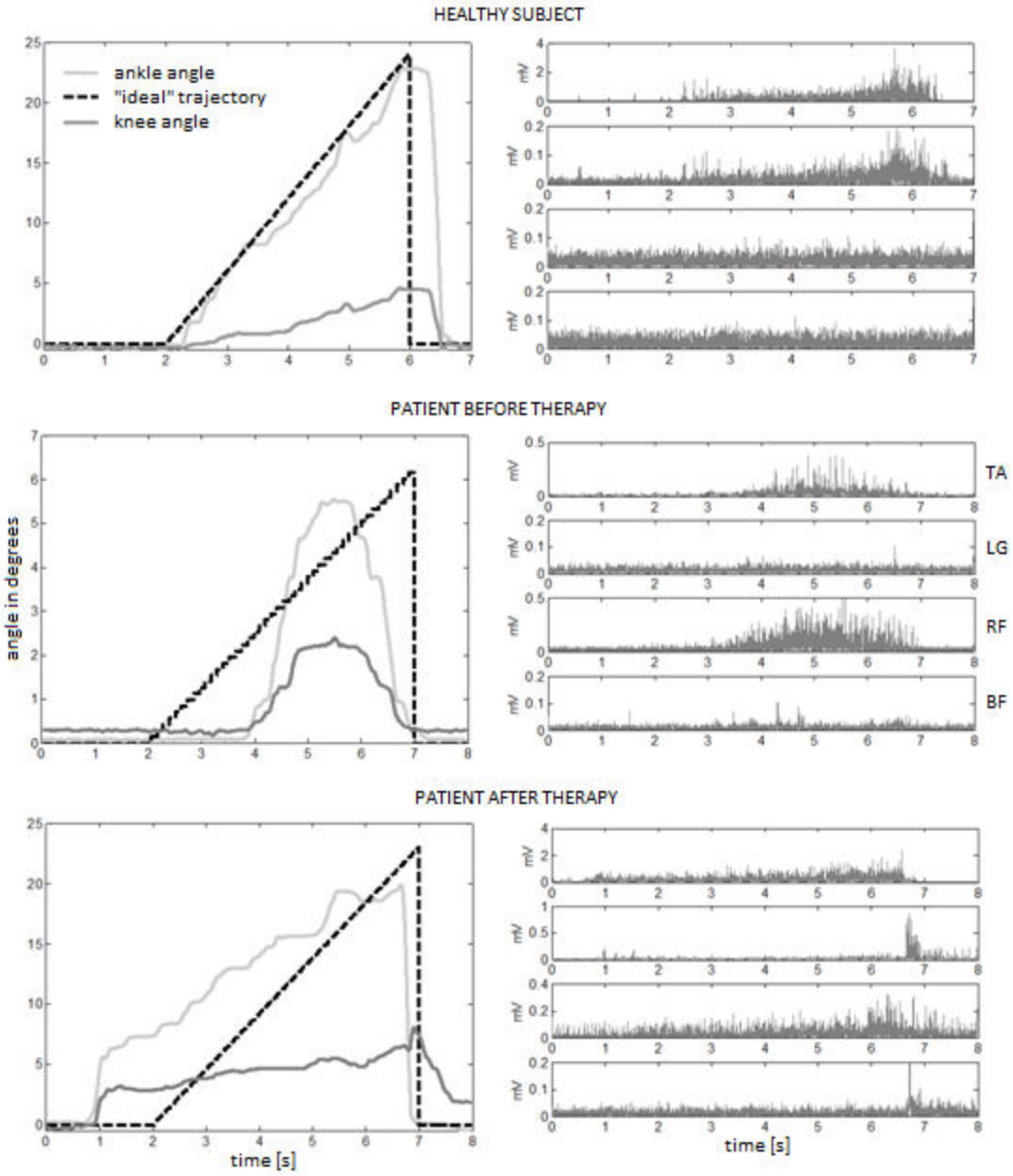
DISPLAY VIEW OF FEEDBACK SOFTWARE

- AceLAB device (Tecnalia Serbia Ltd., Belgrade, Serbia and ETF) with LabVIEW (National Instruments Inc.) software. URL: https://www.youtube.com/watch?v=-IMdSpkT7ZY
- N. Miljković. Multi-channel EMG for analysis of recovery function after central nervous system injuries, Master thesis, mentor: Academician Prof. Dejan B. Popović, ETF, pp. 1-55, 2009.

Muscle co-contraction assessment



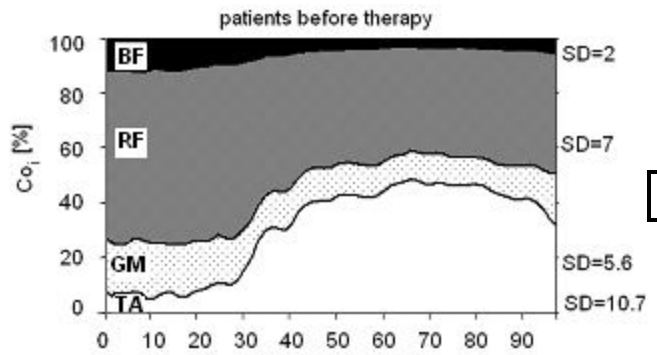
N. Miljković, M. M. Janković, D. B. Popović. Clustering technique for quantitative assessment of motor function in stroke patients, *IFMBE EMBEC Conference Proceedings, Budapest, Hungary, 2011.* https://doi.org/10.1007/978-3-642-23508-5_196



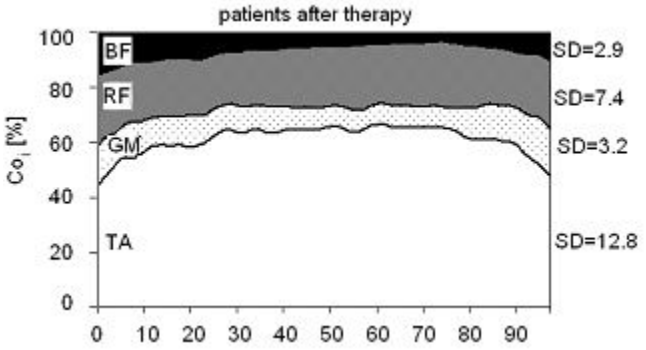
Dorsiflexion

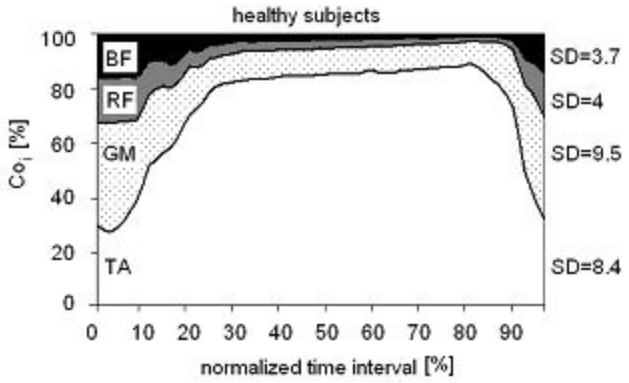
- 10 healthy volunteers
- 10 “control” patients
- 10 patients before/after FET
  - FET – Functional Electrical Therapy
- Figure is adapted from doctoral dissertation: N. Miljković. Methods and instrumentation in assessment of motor function by the means of EMG), Mentor: Academician Prof. Dejan B. Popović, ETF, 2013.

Therapy assessment



after FET





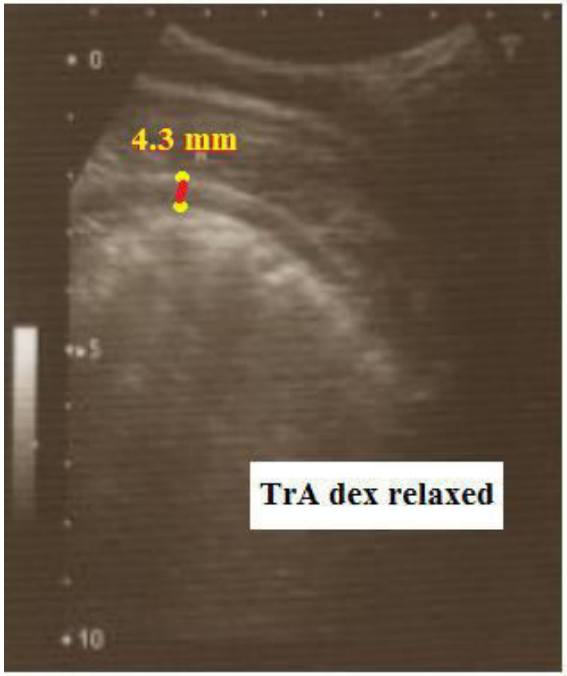
ta – *tibialis anterior muscle*
gm – *gastrocnemius muscle*
rf – *rectus femoris muscle*
bf – *biceps femoris muscle*
sd – standard deviation

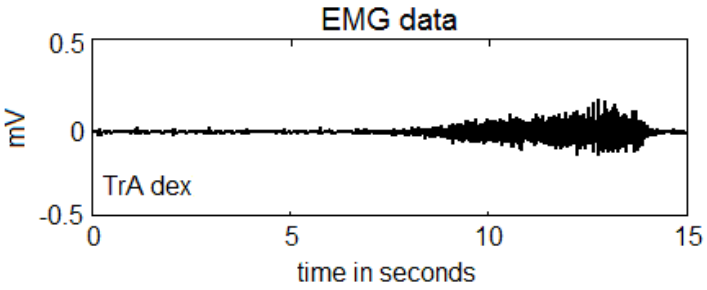
- Relative muscle co-contractions (Coi) for healthy volunteers and patients
- Evaluation of Functional Electrical Therapy in patients who survived cerebro-vascular insult (stroke)

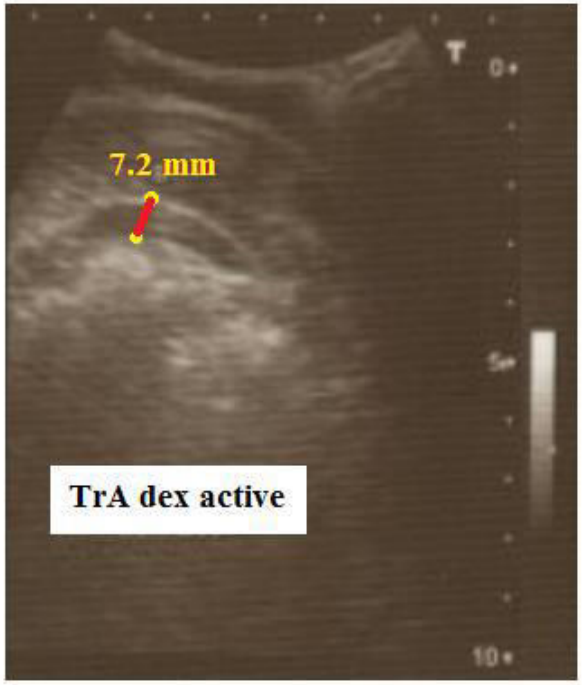
Gait assessment

N. Miljković, I. Milovanović, A. Dragin, Lj. Konstantinović, D. B. Popović. Muscle synergies with Walkaround® postural support vs. "cane/therapist" assistance, *Neurorehabilitation, 33(3):491-501, 2013.* https://doi.org/10.3233/NRE-130982

Electromyography & ultrasound







N. Miljković, O. Djordjevic, G. Bijelić, Lj. Konstantinović, L. Schwirtlich, C. Rodriguez-de-Pablo, D. B. Popović, H. Zabaleta. EMG and ultrasound imaging measurements of low back muscles, Proc. of the 18th IFESS Annual Conference, pp. 199-202, ACADEMIC MIND, University of Belgrade, Donostia – San Sebastian, Spain, 2013.

Electromyography & ultrasound

Lumbia device (by Tecnalia) for muscle assessment, https://youtu.be/vTMVGMs_crk [online, Assessed on May 7, 2019.], LUMBIA, a new (not so new currently, check the date!) prevention, assessment and therapy tool for lower back pain, published on April 22, 2013.

CURRENT RESEARCH?

Analyzing data recorded in patients

Sensing Time Effectiveness for Fitness to Drive Evaluation in Neurological Patients

Nadica Miljković[1], Jaka Sodnik[2]

1: University of Belgrade – School of Electrical Engineering, Bulevar kralja Aleksandra 73, 11000 Belgrade, Serbia

2: Faculty of Electrical Engineering, University of Ljubljana, Tržaška cesta 25, 1000 Ljubljana, Slovenia

Abstract

We present a method to automatically calculate sensing time (ST) from the eye tracker data in subjects with neurological impairment using a driving simulator. ST presents the time interval

Miljković, N., & Sodnik, J. (2022). Sensing Time Effectiveness for Fitness to Drive Evaluation in Neurological Patients. *arXiv preprint arXiv:2205.08942*. https://arxiv.org/abs/2205.08942

Analyzing data with the help of clinicians

Received: 10 September 2021 | Revised: 8 November 2021 | Accepted: 12 November 2021

DOI: 10.1111/anec.12919

ORIGINAL ARTICLE

WILEY

Relationship between electrocardiogram-based features and personality traits: Machine learning approach

Tanja Boljanić MSc[1,2] | Nadica Miljković PhD[1] | Ljiljana B. Lazarevic PhD[3] | Goran Knezevic PhD[4] | Goran Milašinović MD, PhD[5]

Boljanić, T., Miljković, N., Lazarevic, L. B., Knezevic, G., & Milašinović, G. (2022). Relationship between electrocardiogram-based features and personality traits: Machine learning approach. *Annals of Noninvasive Electrocardiology*, *27*(1), https://doi.org/10.1111/anec.12919

We received recognition for this paper as the most read paper on journal website!

It is an OA journal

A CONCLUSION?

Acknowledgements

- For their constant support and efforts in advancing the fields of biomedical & clinical engineering, I am very grateful to all my students, colleagues, MDs and technical stuff at clinics and institutes
- I’d also like to thank to Prof. Agostino Accardo, Assist. Prof. Miloš Ajčević, and Aleksandar Miladinović, PhD for inviting me and for organizing this school of Clinical engineering!

Clinical and biomedical engineering in Serbia: Perspectives & experiences

Assoc. Prof. Nadica Miljković
University of Belgrade – School of Electrical Engineering
e-mail: nadica.miljkovic@etf.bg.ac.rs
url: https://bit.ly/3yRFlV4