



Clinical and biomedical engineering in Serbia

Perspectives & experiences

Assist. Prof. Nadica Miljković, PhD

University of Belgrade – School of Electrical Engineering, ETF

e-mail: nadica.miljkovic@etf.bg.ac.rs, URL: <https://bit.ly/2pvosx0>



IX Spring School “IoT, economic and management challenges for e-health integration in the enlarged Europe”, CEI Cooperation Activity within the Higher Education in Clinical Engineering (SSIC-HECE) Master’s Programme, University of Trieste (Italy),

<http://bioingts.units.it/spring-school-2019>.

Topics

- Biomedical engineering education in Serbia
- Clinical engineering in Serbia
- Private & public sectors: Job opportunities
- Research & biomedical engineering in Serbia
- Personal experiences and perspectives

DISCLAIMER

- This lecture reflects Author's perspectives, experiences, and opinions.
- There might be more schools, professionals, and associations (especially in private sector) practicing biomedical and clinical engineering in Serbia, but only some of them are named here.

EDUCATION

In general

- We don't have 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>, assessed on May 1, 2019).
- In most cases, we have electoral courses at both Master and Bachelor levels at Universities.
- There are accredited Master programs, but with the 5 electoral courses, students and Mentors create their own programs... aren't they?
- 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>, assessed on May 1, 2019.
- There's only one course on Clinical engineering in Serbia. And I tech it! This year is 10th anniversary since this course was introduced.
 - Recently, one course on Clinical engineering was introduced at the Faculty of Mechanical Engineering, University of Belgrade (<https://www.mas.bg.ac.rs/studije/predmeti/0820>)

More study programs and/or courses in RS

- Master studies at the Faculty of Mechanical Engineering, University of Belgrade, study module Biomedical Engineering mostly focused on nano-biomedical engineering (<https://www.mas.bg.ac.rs/studije/mas/modul-4>)
- R&D center BioIRC and the R&D at the Faculty of Mechanical Engineering, University of Kragujevac (<http://www.bioirc.ac.rs/>)
- 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.

Who works as biomedical engineer in RS?

- Well, there is a variety of backgrounds.
- Some of those engineers had some/one/none electoral course/s on biomedical engineering.
- Some of them are coming with very distant background *i.e.* energy 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, ...)
 - they LOVE their work
 - their employees in most cases don't officially acknowledge them as biomedical/clinical engineer



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

Modified photo: Tandem Job Caceres by Skydive Andes Chile;

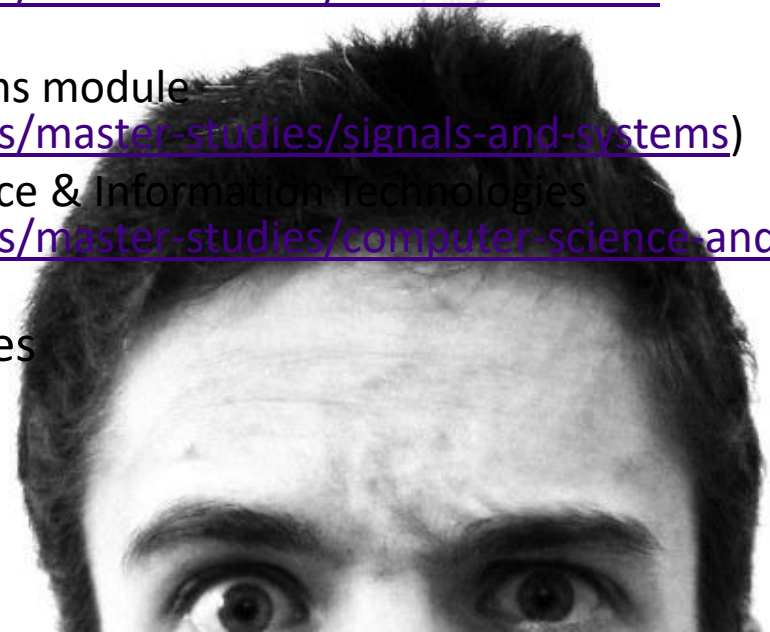
Flickr <https://www.flickr.com/photos/skydiveandes/33146152093/in/photostream/>; CC BY-ND 2.0 Generic.

What about ETF?

- Bachelor studies
 - Biomedical & Eco 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, <http://automatika.etf.rs/en/>)
- Master studies
 - Module Biomedical & Ecological Engineering (<https://www.etf.bg.ac.rs/en/studies/master-studies/biomedical-and-ecological-engineering>)
 - Electoral courses @Signals & Systems module (<https://www.etf.bg.ac.rs/en/studies/master-studies/signals-and-systems>)
 - Electoral courses @Computer Science & Information Technologies (<https://www.etf.bg.ac.rs/en/studies/master-studies/computer-science-and-information-technology>)
- PhD studies: similar as Master studies

ETF? Confusing a bit?

- Bachelor studies
 - Biomedical & Eco Engineering module @Physical Electronics Department (dedicated program, http://nobel.etf.bg.ac.rs/studiranje/osnovne_studije/bmei/)
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- Master studies
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 - Electoral courses @Signals & Systems module (<https://www.etf.bg.ac.rs/en/studies/master-studies/signals-and-systems>)
 - Electoral courses @Computer Science & Information Technologies (<https://www.etf.bg.ac.rs/en/studies/master-studies/computer-science-and-information-technology>)
- PhD studies: similar as Master studies



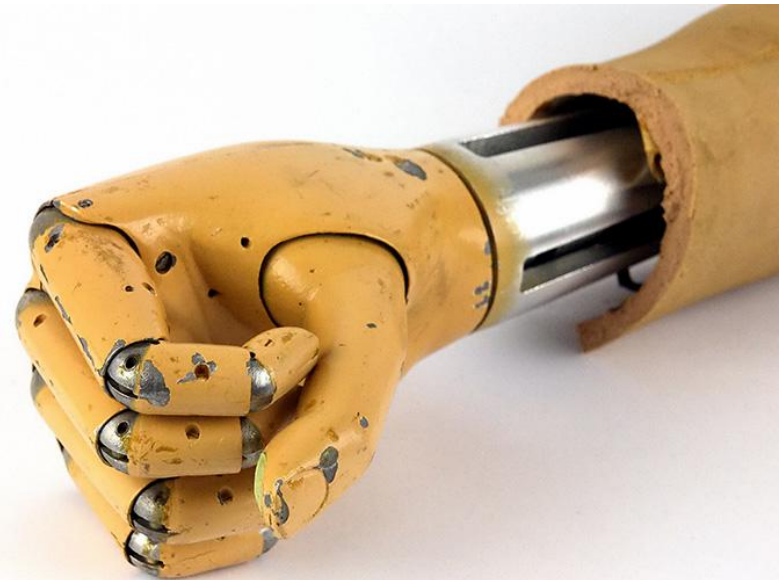
Little history

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



ETF

- The first biomedical courses were introduced in 80-ies.
- The majority of students liked them very much, 'cause they were “exotic” (with state of the art technologies about less known field in electrical engineering) and most of the courses were project oriented (a bit of novelty back then at our Faculties). [*Personal communication*]
- However, research started much earlier and it was connected to both Robotics and Biomedical Engineering – Artificial Organs (see photo of Belgrade hand from 1963).



and myself?

- 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** (online only in Serbian): [Methods of Electrophysiological Signal Analysis](#) (from 2008), [Clinical Engineering](#) (from 2009), [Software Tools - Practicum](#) (from 2012), [Biomedical signal processing techniques](#) (from 2016), [Measurement Computing Devices](#) (from 2017), [Trends in Health Technologies](#) (from 2017)
- **Previous:** Electrical Measurements (2008-2016), Acquisition Systems for Electrophysiology (2009-2016), Modeling of systems and processes in organism (2009-2016), Neural Engineering (2009-2016), Systems and signals in organism (2008-2015), Practicum in Software Tools - LabVIEW (2012-2015)

WHERE DO BIOMEDICAL ENGINEERS
WORK IN RS?



@Universities: Educators & researchers

- @Faculties (@Schools)
- @Institutes
- @Centers

Photo taken by Assist. Prof. Miodrag Tasić, University of Belgrade – School of Electrical Engineering

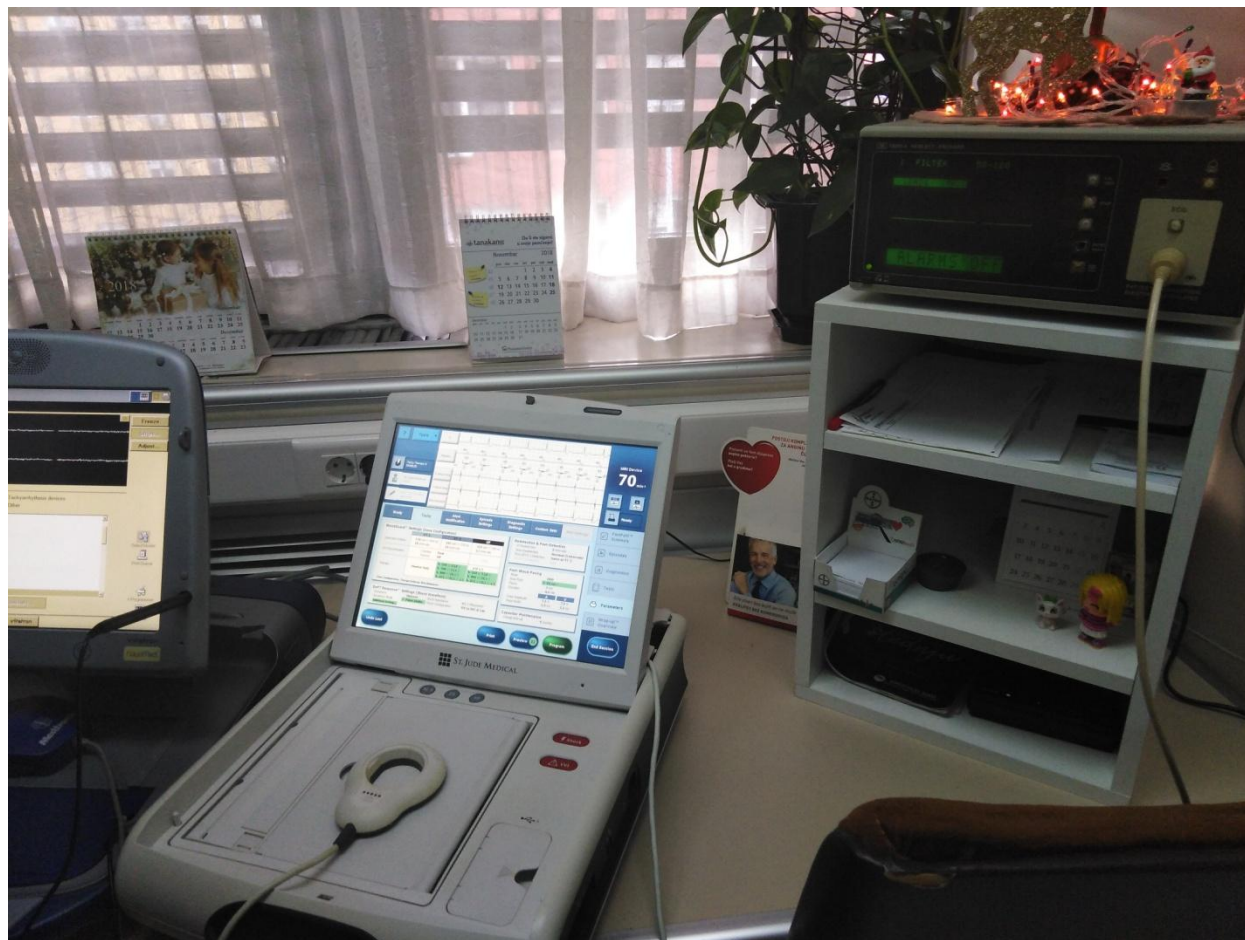


Photo taken by Assist. Prof. Miodrag Tasić, University of Belgrade – School of Electrical Engineering

Projects

- Tempus projects:
 - 2008-2012 CRHBME Curricula Reformation and Harmonization in the field of Biomedical Engineering, JP 144537-2008, <http://projects.tempus.ac.rs/en/project/757>, Project coordinator: prof. Nicolas Pallikarakis
 - 2012-2015 BioEMIS Studies in Bioengineering and Medical Informatics, 530423-2012, <http://projects.tempus.ac.rs/en/project/813>, Project coordinator: prof. Duncan Shepherd
 - 2012-2015 HUTON Assisting humans with special needs: curriculum for HUman-TOol interaction Network, 530510-2012, <http://projects.tempus.ac.rs/en/project/814>, Project coordinator: prof. Aleksandar Sedmak et al.
- Projects financed by Ministry of education, science and technological development of Republic of Serbia
- Collaboration with private companies
- EU projects, Horizon 2020 and other programs
- COST projects
- Bilateral collaborations
- Scientific national and international collaborations
- With partners from Institutes, Centers, Universities and Clinics.

Private sector in public clinics (!?)



Pacemaker center
@Clinical center
of Serbia

Medical device professionals *i.e.*
technical consultant for implantable pacemakers and cardio verter defibrillators.

Medical device professionals & ETF



BIOTRONIK



Abbott



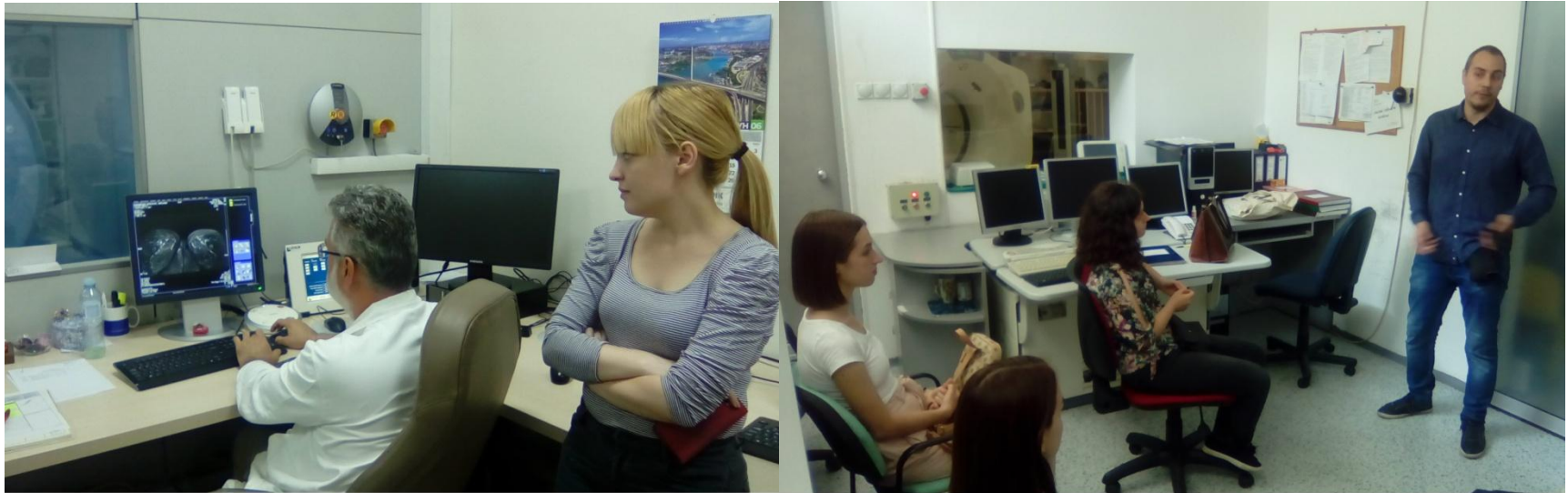
Nenad Popović, PhD student from Abbott Medical and Milan Antić, future PhD student from Biotronik are presenting their experiences to students (part of the Clinical engineering course). Presentation is available online: <http://tiny.cc/n2y75y> (in English). Photo taken at ETF, June 2018.

Public sector in private companies

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



Public sector



- Institute for oncology and radiology of Serbia, <https://www.ncrc.ac.rs/>.
- Practical part for the course Clinical engineering: MRI (Magnetic Resonance Imaging) and CT scan practical lessons.
- Photos: Medical radiology specialist Draško Vidojević and dipl. eng. Katarina Paunović, clinical engineer (left photo), and ETF students with M.Sc. E.E. Nenad Zrnić, clinical engineer (right photo). Photos were taken on June 6, 2018 @Institute of oncology and radiology.

WHAT ABOUT MEDICAL FACULTY

Curriculum @Medical Faculties

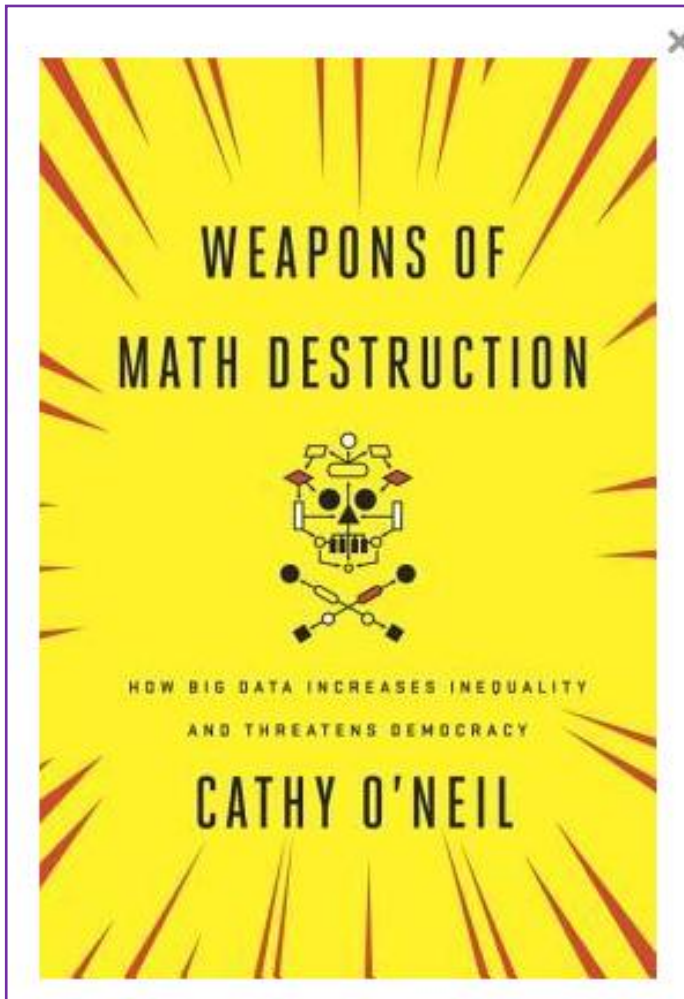
- Almost no one talks about this.
- Medical Faculty, University of Belgrade (<http://www.mfub.bg.ac.rs/dotAsset/38780.pdf>) has two courses indirectly related to biomedical engineering:
 - Radiology and nuclear medicine (more related to medical physics)
 - Medical statistics and informatics (<http://statistika.mfub.bg.ac.rs/>)
- Materials are not open, not available online. I see an issue with this, because Medical Doctors (MDs) with the degree will not be able to use these materials for their life-long education.
- Course is mostly focused on statistics and evidence-based medicine.
- Important, but not enough.
- Our MDs should learn about technology in general.
- Why?

Two potential dangers

- are coming from technological unawareness of medical stuff, especially decision makers:
 - **Not trusting technology at all!**
Buying useless equipment ...
 - **Too much trust in technology!**
Thinking that AI literally exists.
Employing potentially dangerous technologies that they don't understand.



AI & Health: Promise & Prejudice

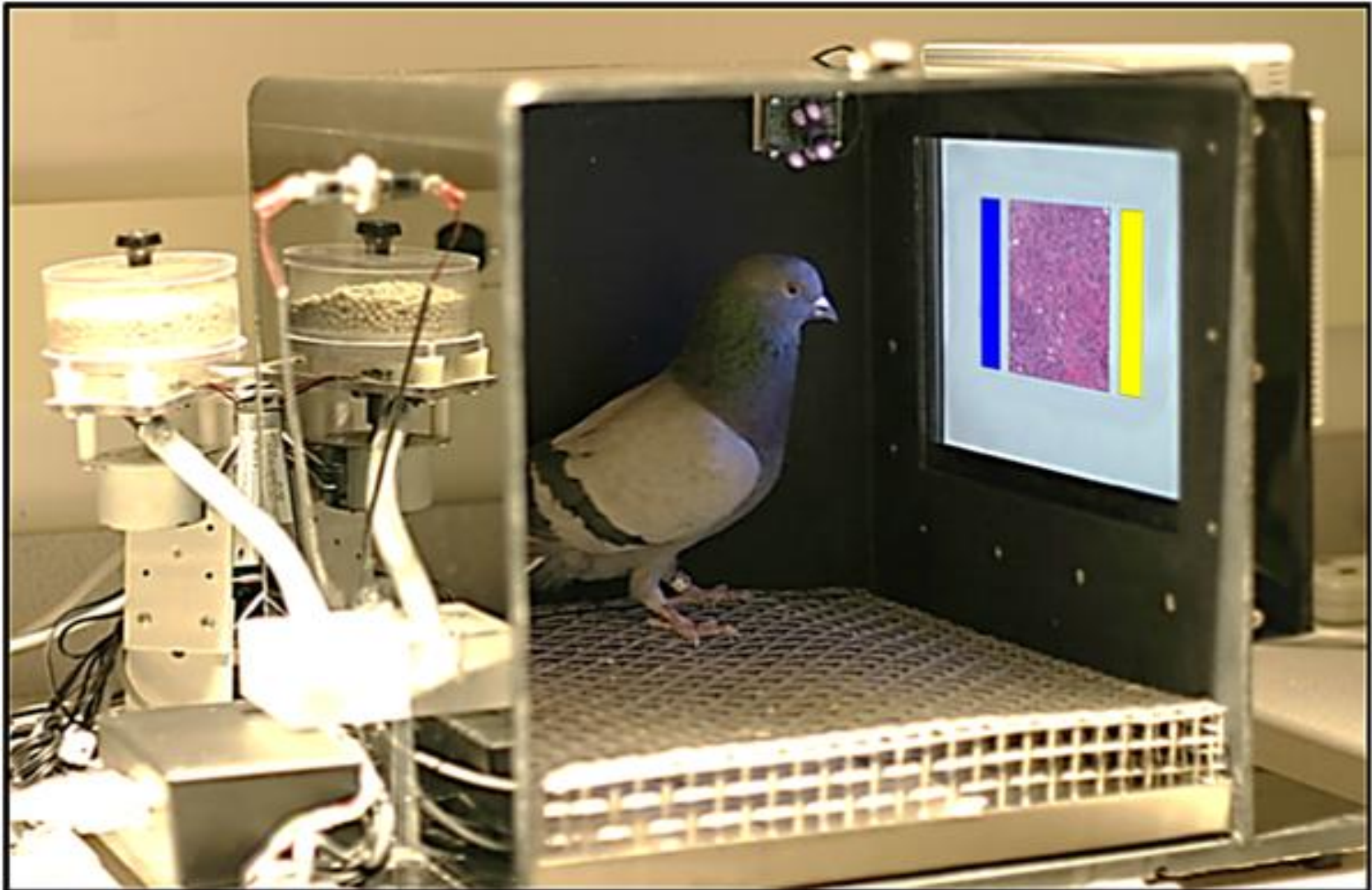


- AI can be used for enhanced diagnostics and prediction in health and it is very promising especially when dealing with large set(s) of data.
- However, one should always be careful about possible AI abuses.
- “The era of blind faith in big data must end” Cathy O’Neil. More at:
 - Talk @TED:
https://youtu.be/_2u_eHHzRto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

EXPECT UNEXPECTED

Fig 1. The pigeons' training environment.



Levenson RM, Krupinski EA, Navarro VM, Wasserman EA (2015) Pigeons (*Columba livia*) as Trainable Observers of Pathology and Radiology Breast Cancer Images. PLOS ONE 10(11): e0141357. <https://doi.org/10.1371/journal.pone.0141357>
<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0141357>

Be reminded of specificity and sensitivity.

Photo: Standing out by photographerpandora; Flickr:
<https://www.flickr.com/photos/photographerpandora/4550643487/in/photostream/>; CC BY-ND 2.0 Generic.



More materials

- Check study: Levenson R.M., Krupinski E.A., Navarro V.M., Wasserman E.A. Pigeons (*Columba livia*) as trainable observers of pathology and radiology breast cancer images. PLoS One. 18;10(11):e0141357, 2015, DOI: <https://doi.org/10.1371/journal.pone.0141357>.
- And article: How a common street bird could coach doctors against a bad diagnosis By Andrew Han, published on March 21, 2019, <https://www.audubon.org/news/how-common-street-bird-could-coach-doctors-against-bad-diagnosis> , Assessed on May 19, 2019.
- An idea what to do with pigeons in Italia?
- Amazed?
- Let's get back to MDs.

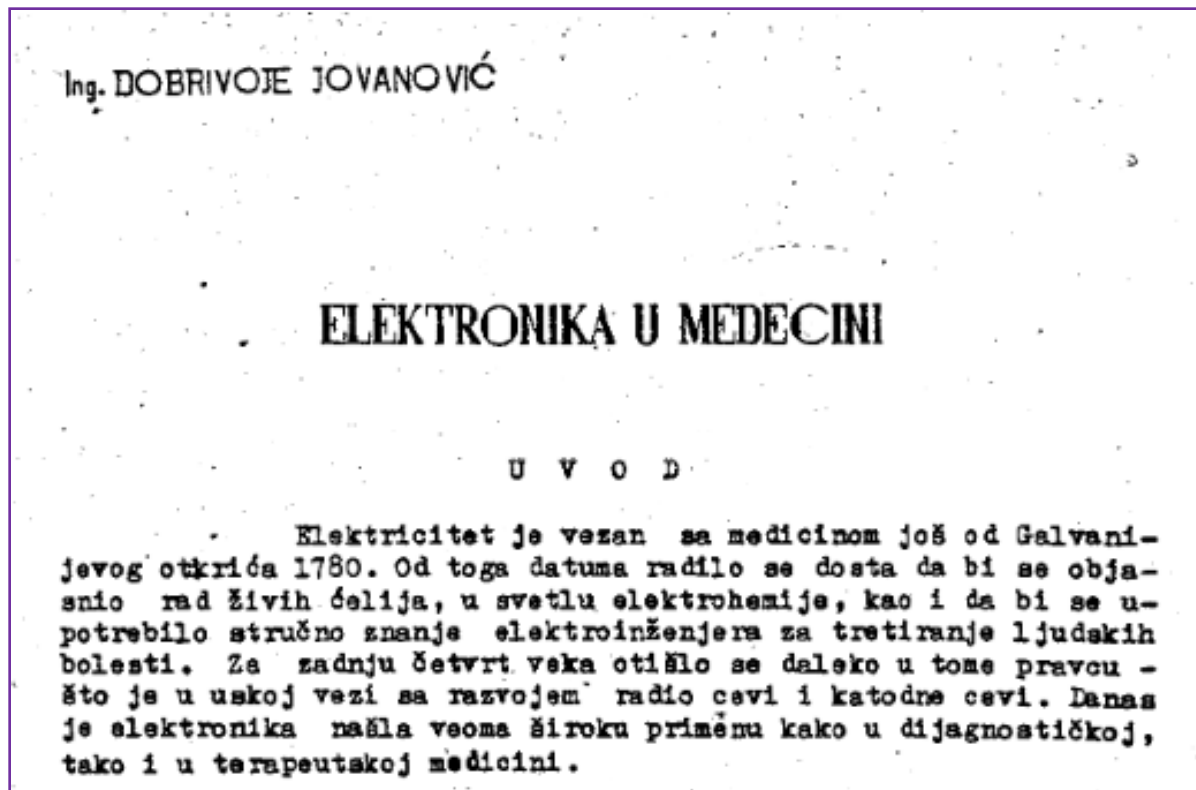
Educate MDs!

- Technology is rapidly growing.
- We need formal as well as informal educational resources.
- Clinical engineers should keep up with this trend as well as MDs.
- Curricula of Medical Faculties should include biomedical engineering.
- Medical professionals would benefit from that knowledge and better understanding between these professions would lead to new solutions and efficient diagnostics/therapies/management in clinics.
- Good practices are:
 - Medical Faculty at University of Novi Sad, PhD study program Biomedical engineering,
http://www.mf.uns.ac.rs/userfiles/file/Doktorske%20studije/Plan%20i%20program%202014_2015/Tabela%20BIOMEDICINSKI%205.2.pdf.
 - University of Defense in Belgrade, Medical Faculty of the Military Medical Academy has accredited specialist academic study program on Bioengineering and Medical Informatics,
(http://www.mfvma.mod.gov.rs/sadrzaj.php?id_sadrzaja=4978)
 - Theory or practice?

CONFERENCES & ASSOCIATIONS

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](https://www.etrans.rs/common/archive/ETAN_1955-2006/ET(R)AN_1955-2006/eTRAN/50.ETRAN.2006.3/ME/Popovic%20istorijat%20ME.ETRAN2006.pdf).
 - More info in paper from 2006 Popović B. Dejan, "STRUČNA SEKCIJA ZA BIOMEDICINSKU TEHNIKU ETRAN-A: PRVIH 50 GODINA" [https://www.etrans.rs/common/archive/ETAN_1955-2006/ET\(R\)AN_1955-2006/eTRAN/50.ETRAN.2006.3/ME/Popovic%20istorijat%20ME.ETRAN2006.pdf](https://www.etrans.rs/common/archive/ETAN_1955-2006/ET(R)AN_1955-2006/eTRAN/50.ETRAN.2006.3/ME/Popovic%20istorijat%20ME.ETRAN2006.pdf).



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 (wo)man operation. We should have more sustainable solutions.
- Couple of them are active. Some links:
 - <http://akis.rs/strana/onama>
 - http://2016.ifmbe.org/members/members_directory/wpbdp_tag/serbia/
 - <https://sites.google.com/view/srneurosociety/>
 - <http://www.unms.rs/>
- 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.

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.etrans.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 "Petar Arežina", [Kongres fizijatara Srbije sa međunarodnim učešćem](#), HMI from SSI, [MIT](#), [ZINC](#), [ICIST](#), [PSSOH](#), [NEUROCARD](#), [BelBi](#), [satRday](#)
 - **Abroad:** [IFESS Conference](#), [ICABB](#), [IFMBE](#), [EMBC](#), [ICNR](#), [ICFDA](#), [ISEK](#), [ESPRM](#), [ICOM](#), [EFIC Congress](#), [BaSS](#)

Spare slide with full names #1

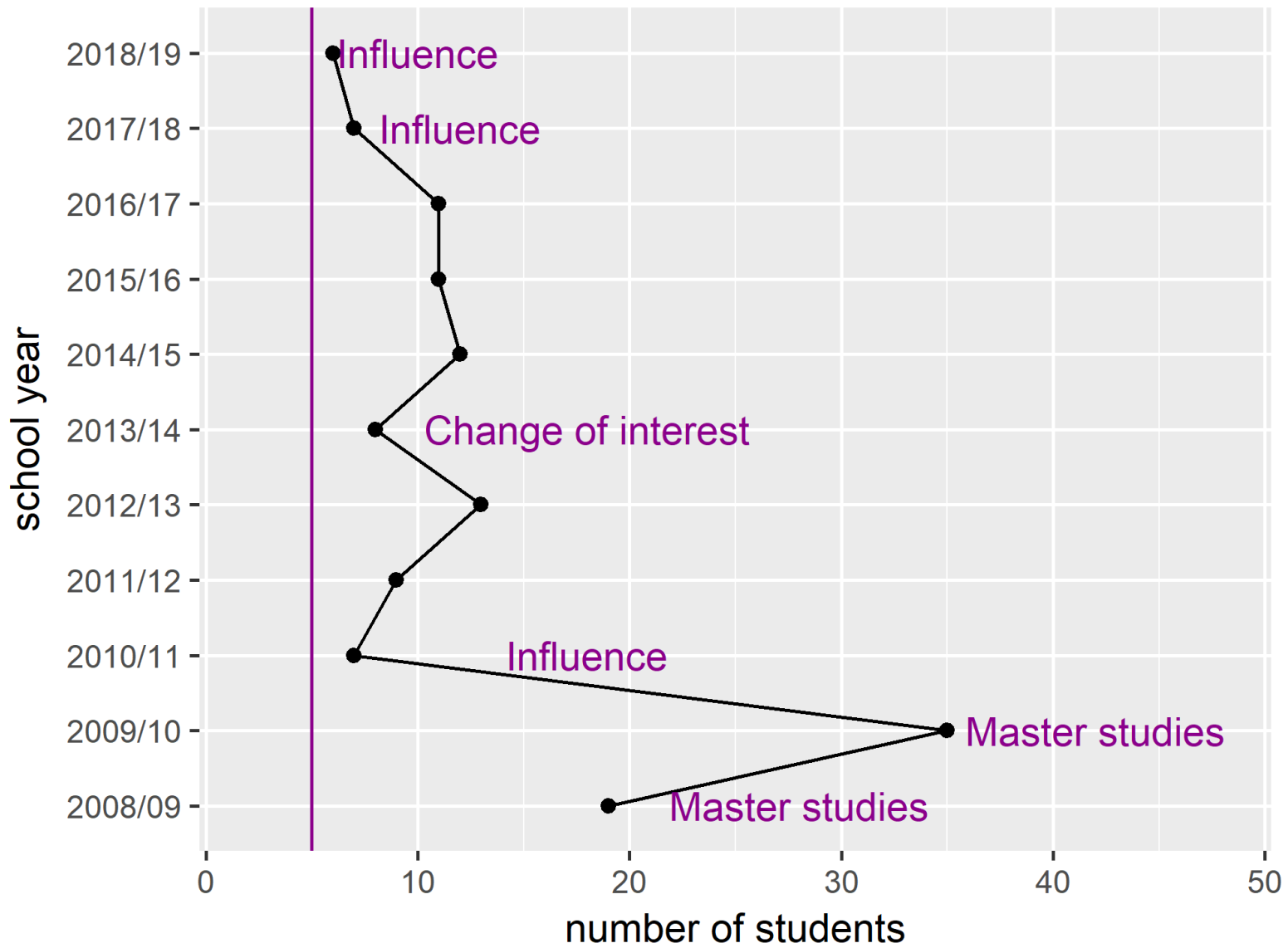
- **In Serbia:** [NEUREL](#) (Symposium on Neural Network Applications in Electrical Engineering), [TELFOR](#) (Telecommunication Forum), [IcETRAN](#) (International Conference on Electrical, Electronic and Computing Engineering), [ETRAN](#) (Meeting of the Society for Electronics, Telecommunications, Computing, Automatics and Nuclear engineering), [YU INFO](#), [OTEH](#) (International Scientific Conference on Defensive Technologies), Memorial Symposium “Petar Arežina” by [Serbian Association of Physical and Rehabilitation Medicine](#), [Kongres fizijatara Srbije sa međunarodnim učešćem](#), HMI from SSI (Human-Machine Interface from Student-to-Student Interface) organized by the [Laboratory for Biomedical Instrumentation and Technologies](#) @ETF, [MIT](#) (Konferencija Merno-informacione tehnologije, Measuring-Information Technologies Conference), [ZINC](#) (Zooming Innovation in Consumer Electronics International Conference), [ICIST](#) (International Conference on Information Society and Technology), [PSSOH](#) (Primena slobodnog softvera i otvorenog hardvera, Application of Free Software and Open Hardware), [NEUROCARD](#) (International Symposium on Neurocardiology), [BelBi](#) (Belgrade Bioinformatics Conference), [satRday](#) Conference in Belgrade

Spare slide with full names #2

- **Abroad:** [IFESS Conference](#) (International Functional Electrical Stimulation Society), [ICABB](#) (International Conference on Applied Bionics and Biomechanics), [IFMBE](#) (European Conference of the International Federation for Medical and Biological Engineering), [EMBC](#) (International Conference of the IEEE Engineering in Medicine & Biology Society), [ICNR](#) (International Conference on Neurorehabilitation), [ICFDA](#) (International Conference on Fractional Differentiation and its Applications), [ISEK](#) (Congress of the International Society of Electrophysiology and Kinesiology), [ESPRM](#) (European Congress of Physical & Rehabilitation Medicine), [ICOM](#) (International Conference on the Physics of Optical Materials and Devices), [EFIC Congress](#) (European Pain Federation Congress), [BaSS](#) (Congress of the Balkan Stomatological Society)

MY EXPERIENCES & ADVICES

Course on Clinical Engineering



Clinical engineering course @ETF

- I wanted to change course name (<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!



Signali i sistemi – Katedra i Odsek

Signals & Systems Department

traži...

Početna

Predmeti

Nastavnici

JAC

Projekti

Diplomski i Master radovi

Monografija

Obaveštenja

Partneri katedre

Kliničko inženjerstvo



Predmet	Status	Broj časova (P+V+L)	Krediti
Plan nastave	Izborni	3+2+0	6
Predavanja - Nadica Miljković , kabinet 68, lab. 69			
Vežbe - Nadica Miljković , kabinet 68, lab. 69			

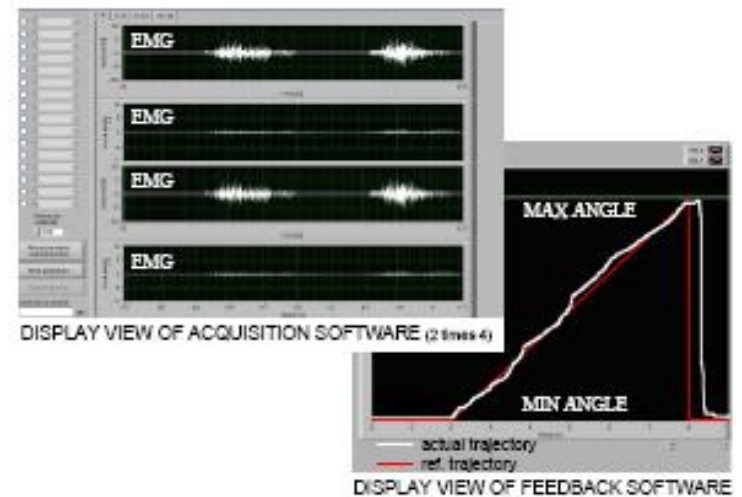
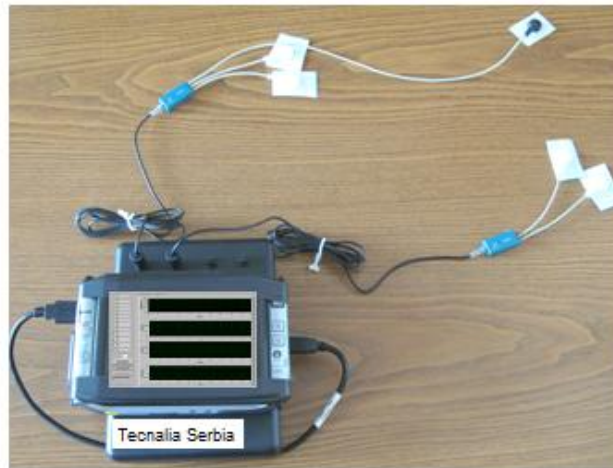
My clinical experiences

- 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.
- Published 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.
 - 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.
 - 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.
 - 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.

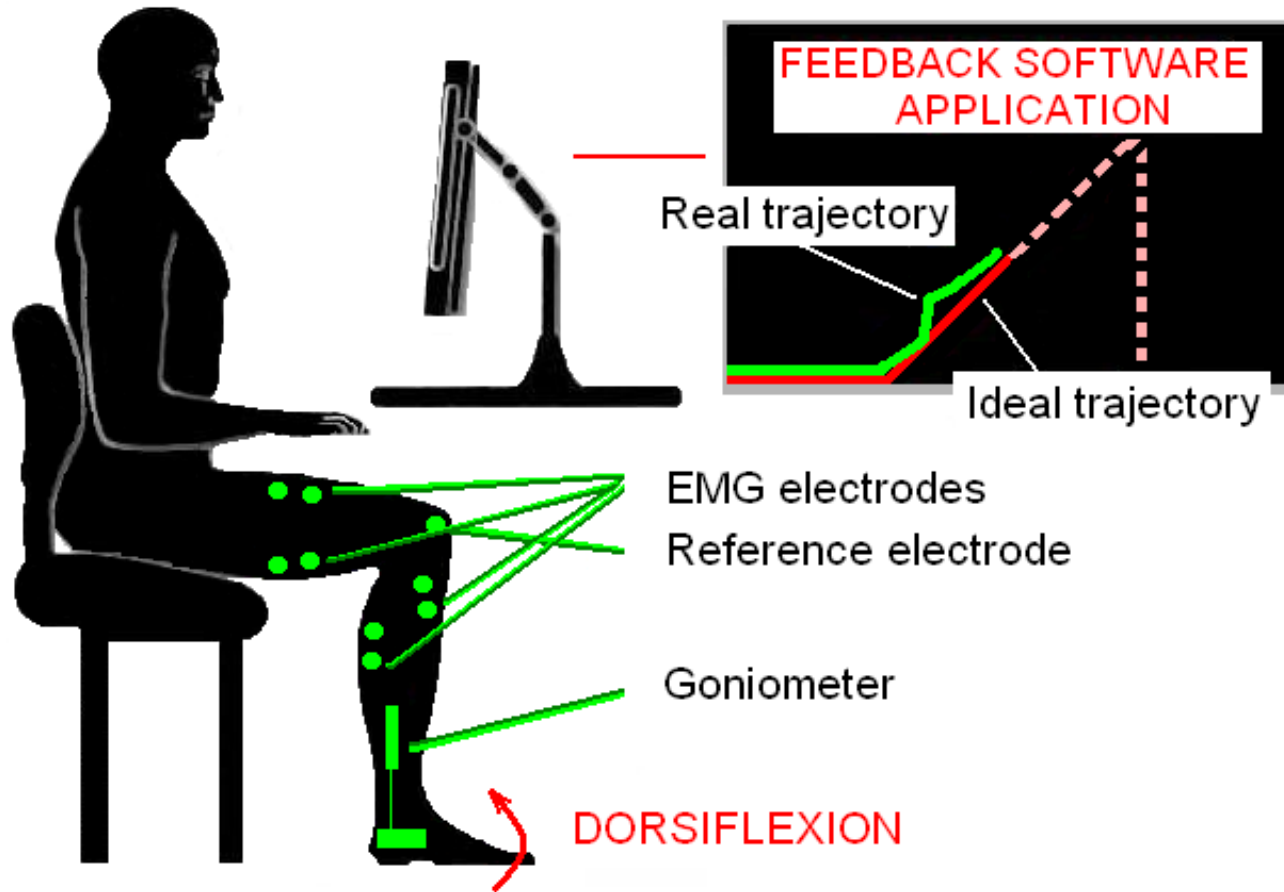
Voluntary muscle contraction



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: prof. Dejan B. Popović, ETF, pp. 1-55, 2009.



Muscle 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.

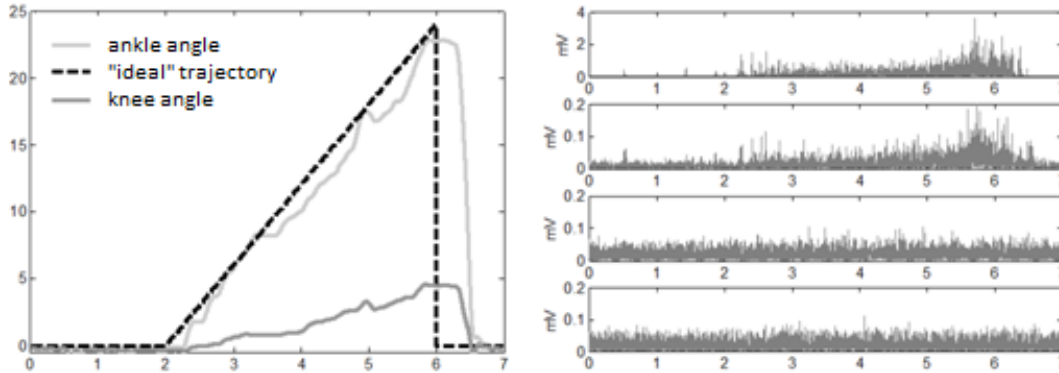
Dorsiflexion

- 10 healthy volunteers
- 10 “control” patients
- 10 patients before/after FET

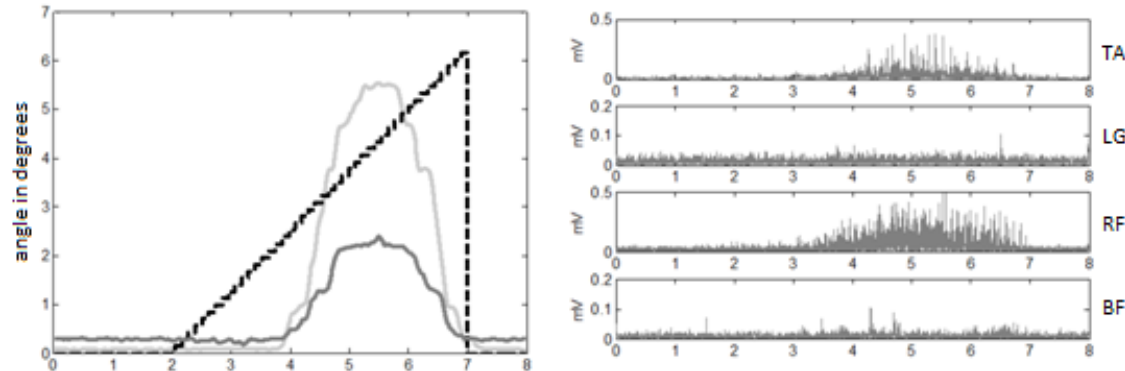
FET – Functional Electrical Therapy

Figure is adopted from doctoral dissertation: N. Miljković. Methods and instrumentation in assessment of motor function by the means of EMG), Mentor: prof. Dejan B. Popović, Academician, ETF, 2013.

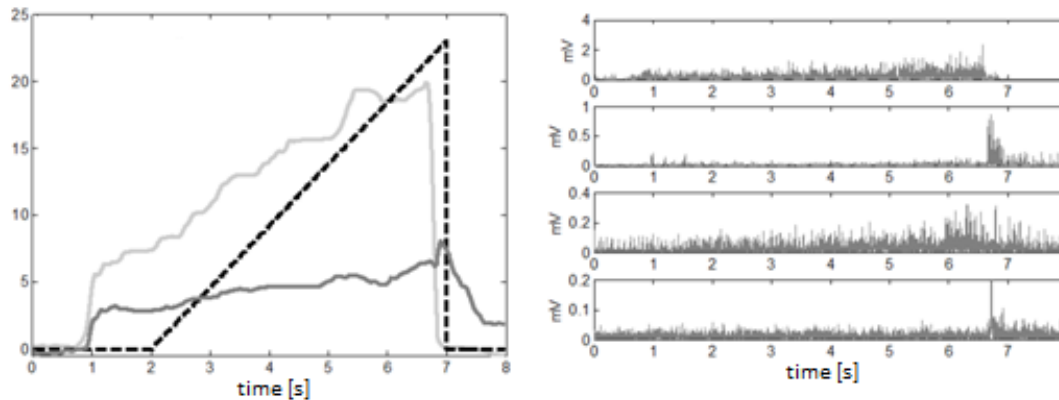
HEALTHY SUBJECT



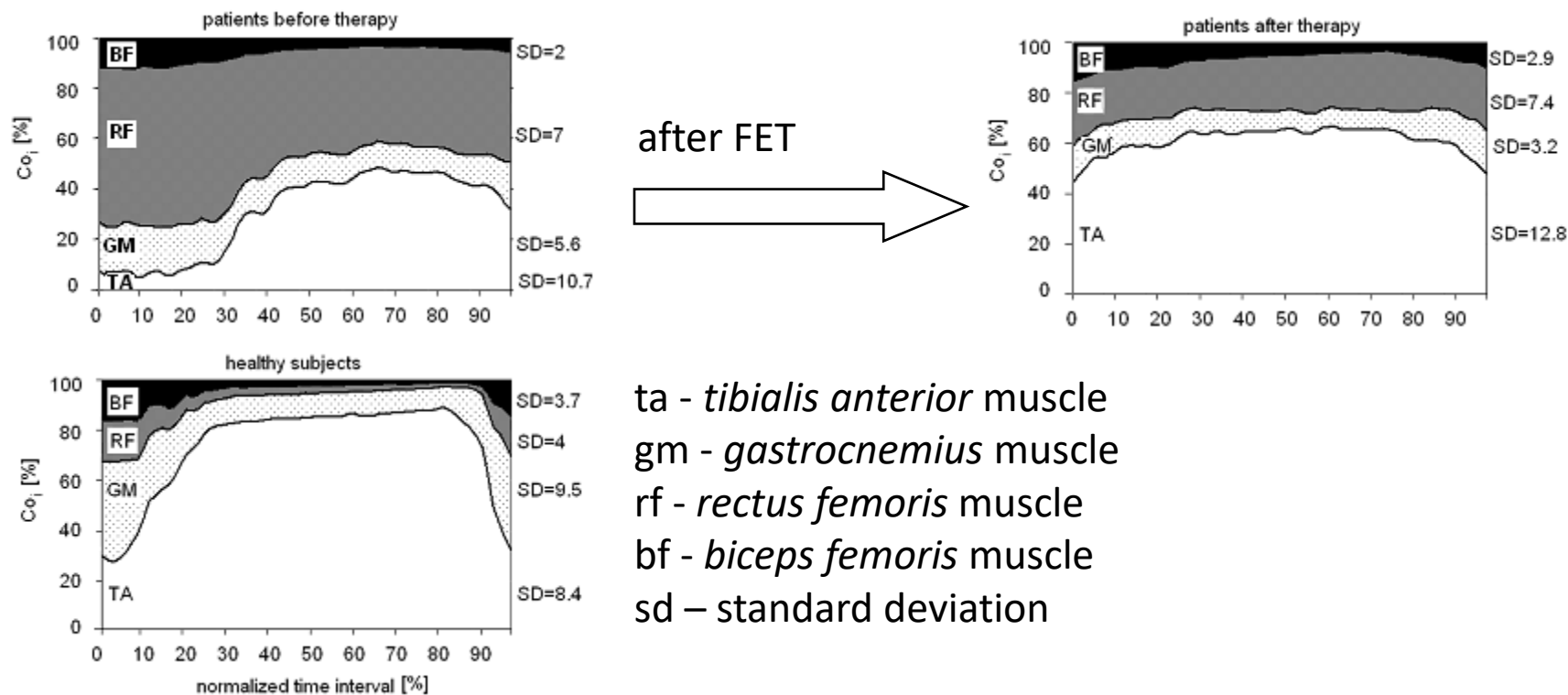
PATIENT BEFORE THERAPY



PATIENT AFTER THERAPY



Results (therapy assessment)



- Relative muscle cocontractions (C_{oi}) for healthy volunteers and patients.
- Evaluation of Functional Electrical Therapy in patients who survived cerebrovascular insult (stroke).

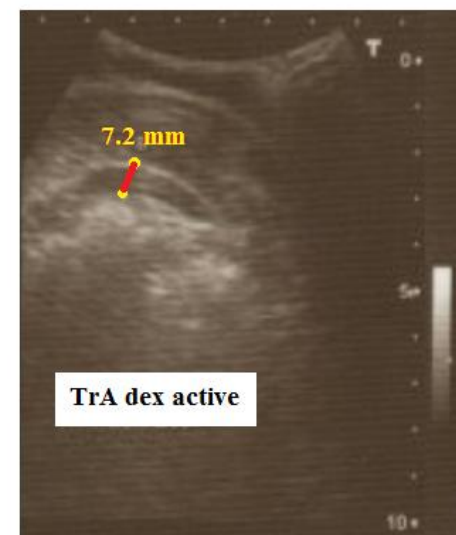
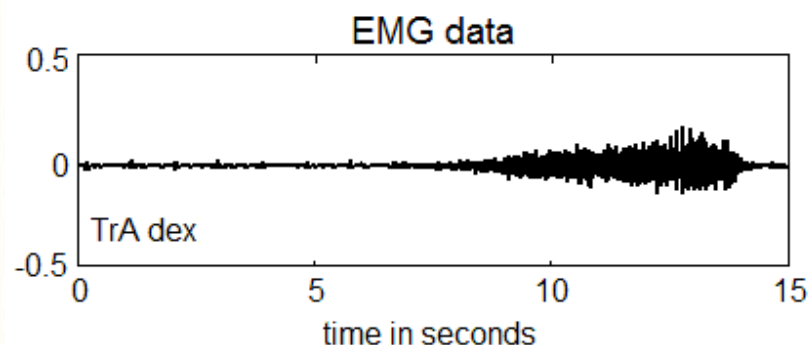
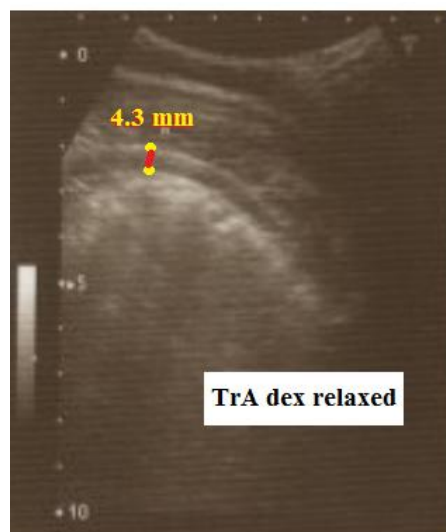
Gait assessment by Coi



Photo was recorded at the Rehabilitation clinic "Dr Miroslav Zotović" in 2010 and results were published in paper: 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.

Electromyography & ultrasound

Lumbia© (Tecnalia & BTS) device

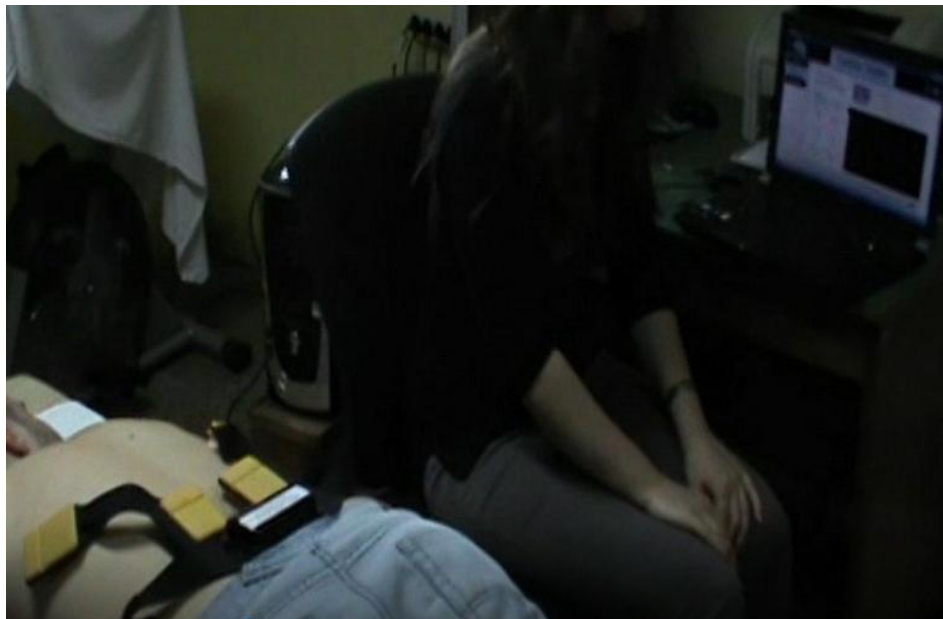


N. Miljković, O. Đorđević, G. Bijelić, Lj. Konstantinović, L. Schwirtlich, C. Rodriguez-de-Pablo, D. B. Popović, H. Zabaleta. EMG and ultrasound imaging measurements of low back muscles, Proc of the 18th IFESS Annual Conference, pp. 199-202, ACADEMIC MIND, University of Belgrade, Donostia- San Sebastian,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

Lumbia© device (by Tecnalia) for muscle assessment, https://youtu.be/vTMVGMs_crk [online, Assessed on May 7, 2019.], Lumbia©, a new prevention, assessment and therapy tool for lower back pain, published on April 22, 2013.

Electromyography & ultrasound

Lumbia© (Tecnalia & BTS) device



- Photos taken at the Rehabilitation clinic “Dr Miroslav Zotović” in 2013 presenting prototype testing of Lumbia© device (by Tecnalia).
- Results of the presented protocol are published in N. Miljković, O. Đorđević, 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.

AT THE END



Future work towards

- 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!

Acknowledgement

- For their constant support and efforts in advancing the fields of biomedical & clinical engineering, I am very grateful to
 - all my students, especially to clinical engineers Nenad B. Popović, PhD student and Milan Antić, future PhD student.
 - all my colleagues, especially to clinical engineer Nenad Zrnić, MSc EE
 - all technical staff from the Institute of oncology and radiology of Clinical center of Serbia, especially to medical radiology specialist Draško Vidojević
 - all MDs and medical staff I worked with at the Rehabilitation clinic “Dr Miroslav Zotović”, especially to Olivera Djordjevic, MD PhD
 - my colleagues from ETF
 - I’d also like to thank to Res. Miloš Ajčević, PhD, Aleksandar Miladinović, PhD student, and Prof. Agostino Accardo, PhD for inviting me and for organizing this school of Clinical engineering.
 - Special thanks to Marco for his kind help with my introductory speech in Italian!
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Clinical and biomedical engineering in Serbia Perspectives & experiences

Assist. Prof. Nadica Miljković, PhD

University of Belgrade – School of Electrical Engineering

e-mail: nadica.miljkovic@etf.bg.ac.rs, URL: <https://bit.ly/2pvosx0>

