Bulletin of Micro and Nanoelectrotechnologies

September 2020, vol. X, no. 1 - 2

A publication of the National Institute for Research and Development in Electrical Engineering ICPE-CA Bucharest (INCDIE ICPE-CA)

Editorial Board

ISSN 2069-1505

Manuscript submission

The Guest Editors will send the manuscripts by post or to the e-mail: mircea.ignat@icpe-ca.ro

Address:

Splaiul Unirii No. 313, sect. 3, Bucharest – 030138, Romania

Our staff will contact the Guest Editors in order to arrange future actions concerning manuscripts.

Bulletin of Micro and Nanoelectrotechnologies includes the specific research studies on:

- Microelectromechanical and nanoelectromechanical components;
- The typical micro and nanostructure of actuators, micromotors and sensors;
- The harvesting microsystems;
- The conventional and unconventional technologies on MEMS and NEMS;
- The theoretical and experimental studies on electric, magnetic or electromagnetic field with applications on micro and nano actuating and sensing effects;
- The design algorithms or procedures of MEMS and NEMS components;
- The applications of MEMS and NEMS in biology and in biomedical field;
- The new materials in MEMS and NEMS;
- The standardization and reliability preoccupations;
- The economic and financial analysis and evolutions of MEMS and NEMS specific markets.

CHRONICLE

We dedicate the 1-2/2020 number of this Bulletin of Micro and Nanoelectrotechnologies to the Conference INGIMED XXth "Biomedical Engineering at the crossroads of concepts in the world and of generations in Romania", organized by INCDIE ICPE-CA Bucharest (November 7th, 2019).

The papers represent the contributions of the participants to this event. At this conference, important personalities were present:

- *Prof. Gheorghe I. Mihalaş, MPhys, MMath – Academy of Medical Sciences Timişoara Chapter, Commission of Medical Informatics and Data Protection, Timişoara, Romania,*
- *Prof. Corneliu Zeană, MD – "Carol Davila" University of Medicine and Pharmacy & Floreasca Emergency Hospital, Bucharest, Romania,*
- *Prof. Cristina Mocanu, MD – Carpatia Group, Bucharest, Romania / Rockville Faculty of Medicine, University of Maryland, USA,*
- *Assoc. Prof. Manole Cojocaru, MD – Faculty of Medicine, "Titu Maiorescu" University, Bucharest, Romania.*

The programme of this scientific event is presented below:

Session I – Chair: Prof. Dr. Radu M. Negoescu

From multidisciplinarity to interdisciplinarity in medicine (De la multidisciplinaritate la interdisciplinaritate în medicină), *Prof. Gheorghe I. Mihalaş, MPhys, MMath – Academy of Medical Sciences Timişoara Chapter, Commission of Medical Informatics and Data Protection, Timişoara, Romania*

Session II – Chair: Dr. Mircea Ignat

Assessment of sympathetic supra-normal drive to heart via 24 h spectral RR Holter using artificial neural networks (Evaluarea controlului simpatic supranormal al miocardului prin spectrele RR derivate din Holter-24 h folosind rețele neurale artificiale), *Assoc. Prof. Şerban Dincă-Panaitescu, MEng - School of Health Policy and Management, York University, Toronto, Canada; Prof. Alin Achim, MEng - Faculty of Engineering, University of Bristol, United Kingdom; Prof. Radu M. Negoescu, MEng, MPH – Academy of Medical Sciences & National Institute of Public Health, Bucharest, Romania*

Therapeutic plasmapheresis, a solution for the patient with hypercholesterolemia (Plasmafereza terapeutică, o soluție pentru pacientul cu hipercolesterolemie), *Assoc. Prof. Corneliu Zeană, MD – "Carol Davila" University of Medicine and Pharmacy & Floreasca Emergency Hospital, Bucharest, Romania*

Determination of the rate of aging and diagnosis criteria (Evaluarea ritmului îmbătrânirii și criteriile de diagnoză), *Assoc. Prof. Vitalie Scripnic, Dr. Hab. Biol.; Assoc. Prof. Vasile Socolov, MD - International Free University; Anatol Iavorschi, MEng – The Technical University; Corneliu Scripnic, MD and Veronica Gheorghiță, MD - "Nicolae Testemițanu" State University of Medicine and Pharmacy; Kishinev, Republic of Moldova*

Flashback to founding fathers: the 150th anniversary of HW CUSHING, a key personality of world neurosurgery, a promoter of specific technologies & devices and a friend of Romania (Omagiu pentru fondatori: aniversarea 150 de ani a lui HW CUSHING, un titan al neurochirurgiei mondiale, un promotor al instrumentației și tehnologiilor specifice și un prieten al României), *Horia Mihai Berceanu, MD - Neurosurgery Section, District Hospital, Ploiești, Romania*

Aspects on the life cycle management of medical equipments (Aspecte privind gestionarea ciclului de viață al echipamentelor medicale), *Assoc. Prof. Călin Corciovă, MBioeng.; Assist. Prof. Doru Andrițoi, MBioeng.; Assist. Prof. Cătălina Luca, MBioeng. – Faculty of Medical Bioengineering, "Grigore T. Popa" University of Medicine and Pharmacy, Iassy, Romania*

Ceramic biomaterials for medical applications at ICPE-CA. Recent advances and future directions (Biomateriale ceramice pentru aplicații medicale la ICPE-CA. Rezultate recente și tendințe de dezvoltare), *Christu Țârdei, MEng; Dr. Dorinel Tălpeanu, MEng - Laboratory of Ceramic Materials, Department of Carbon-Ceramic Materials, INCDIE ICPE-CA, Bucharest, Romania*

Designing an exoskeleton for rehabilitation of the movements of the fingers (Proiectarea unui exoschelet pentru reabilitarea mișcărilor degetelor de la nivelul mâinii), *Student Cristian-Robert Zanfir – Faculty of Medical Engineering, Politehnica University of Bucharest, Romania*

We also present, different images from Conference INGIMED XXth, and the performances of the "Alexandru Proca" Center.

Editor in Chief,

Dr. Mircea Ignat

"Alexandru Proca" Centre for the Youngsters Initiation in Scientific Research (CICST) – The participation to the Conference INGIMED XXth, November 7th, 2019


From Multidisciplinarity to Interdisciplinarity in Medicine
George I.MIHALAS
ASM – Romanian Academy of Medical Sciences
Commission of Medical Informatics and Data Protection
Wilhelm KAPPEL
Radu NEGOESCU
Gheorghe MIHALAS
biomedicală


Wilhelm KAPPEL


INGIMED XX
Ingineria biomedicală

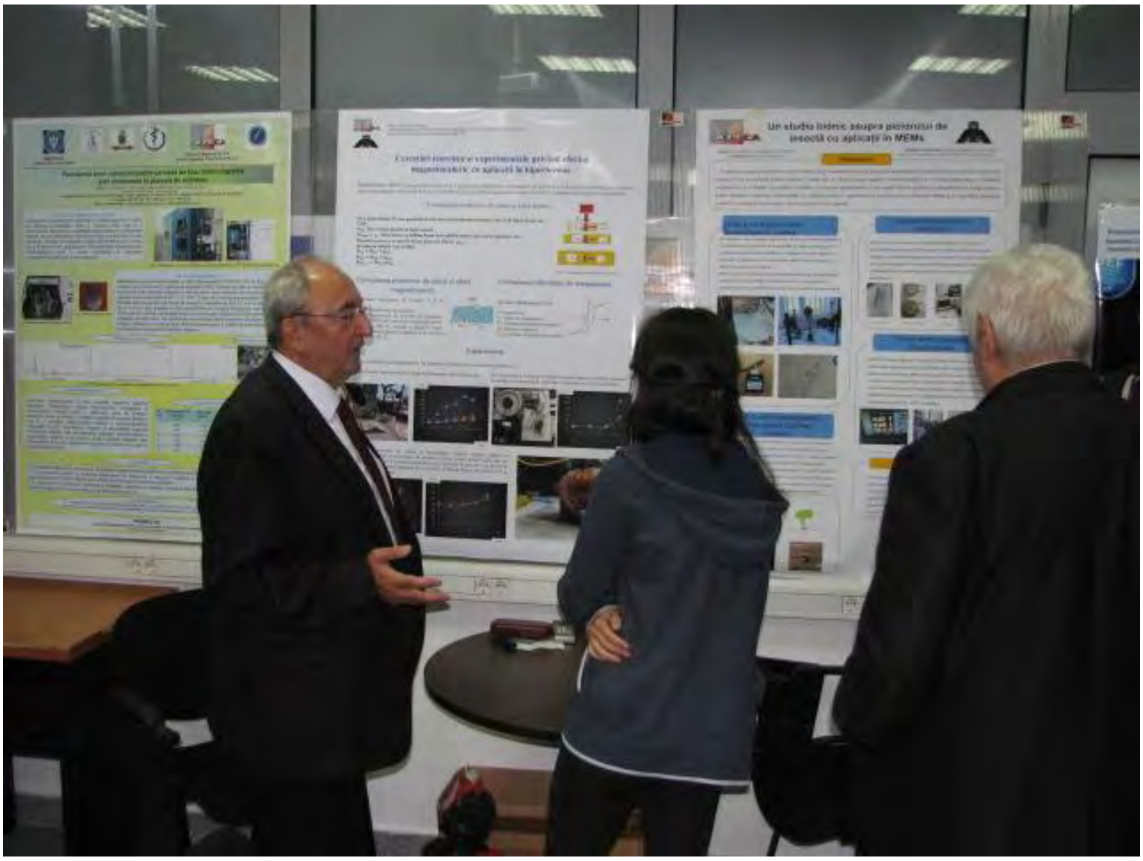

LDL PLAMSPHERESIS IN
ISCHEMIC CARDIOPATHY
WITH DISLIPIDEMIA
Corneliu Zeana,


INGIMED XX
Ingineria biomedicală
ja răscruce de concepte în lume și de


INGIMED
Ingineria biom
ja răscruce de concepte în lume și
7 noiembrie, 201
București, Ro


INGIMED XX


INGIMED XX
Ingineria biomedicală
7 noiembrie, 2019
București, România



Contents

Crossroad of BME at Present: Detaching of Bioengineering from Biomedical Engineering in Advanced Countries, and Generation Change in Organizing INGIMED Conferences in Romania

Radu M. Negoescu
Academy of Medical Sciences & National Institute of Public Health, Bucharest, Romania
nego2005radu@yahoo.fr

Abstract – Since first largely accepted definition of Harmon [1] for Biomedical Engineering (BME) in 1975 many have changed except the core: BME is the application of engineering (engng) principles and design concepts to medicine and biology for healthcare purposes, integrating Clinical Engineering that deals with practical application of the sciences of (non-living) nature in human clinic and Bioengineering, dealing with understanding of living matter by using engng concepts & tools. Nowadays (Sept. 2019), a comprehensive view on BME sub-discipline lists a large bouquet as: bioinformatics' biomechanics; biomaterials[b]; biomedical optics; tissue engineering[b]; genetic engineering[b]; molecular engineering[b]; genomics[b]; neural engineering[b]; pharmaceutical engineering[b]; medical devices including medical imaging, implants bionics[b], biomedical sensors; clinical engineering; rehabilitation engng; regulatory issues; exponent **b** marks Bioengng.

In lead-countries detaching of Bioengineering from the other BME sub-disciplines appears quite clear today, the remaining ones being generically referred to Medical Engineering. At its turn, Bioengineering is often completed to get the collocation Medical Bioengineering, to differentiate itself from biotechnologies involved in energy extraction from animal and plants residuals.

Short term perspectives of BME cannot ignore the big global challenges our planet does confront: open contempt towards Terra's resources on way to extinction as felt primarily by obvious climate change, indifference unto fellow people– often even closest ones, ―cannibalistic" attitudes and deeds versus the disfavored or weak like seniors, young girls, or children. What possibly can do the BME professionals, both medical- or bio- engineers (MErs or BIOrs), vis'a'vis of this in-progress disaster?

MErs have already conceived, designed and put on market devices to make last years of seniors life more easier in terms of self-moving and communication with health professionals, parents or caregivers able to offer them moral support and solidarity in view if the Big Passing.

Air pollution and super-heated climate bringing about excessive caloric stress at work, in traffic, or spare time spent in nature or even at home may elicit an abnormally increased sympathetic drive to myocardium visible in both increase of average heart rate (HR) and/or of low frequency fraction in spectra of ECG's RR time intervals series, simply nowadays to extracted and processed at acceptable costs from 24h high resolution Holters. Added to a vulnerable heart terrain, exacerbation of sympathetic drive to heart can lead to cardiac fatalities like sudden cardiac death; even in normal increasing the daily average HR means life shortening, in virtue of circa 2 billion heartbeats humans dispose of. Once getting aware of this truth people may find stronger reason to rally in public places than getting mixed in politician's mud: ―Radical measures to save the Planet NOW or leave the floor!". In the same vein, a two-stamp sized device placed over cordial area of a kid, can collect simply an ECG so that the brisk decrease of RR elicited by emotion be Wi-Fi–ed from a quite amenable distance by a discrete Smartphone GPS-ed application to parents or police, as a ―bioelectric alert" non-detectable by the perpetrator of a street attack, attempt of rape or hijacking. At its turn, BIOers already work shoulder-to-shoulder with biologists on periodical mutation of high fatalities viruses like Marburg, HIV or Ebola that prepare, hidden deep in the African forests, the next wave of their periodical outbursts making the CDC or WHO to shake.

Romanian BME is still searching for its identity.

The recent political move that doubles (rightly) the earnings of medical staff on para-clinical personnel's account left at a shameful level of revenue does not promise anything good for the near future. The generation who concludes its mission at this special, ―round" INGIMED XX has hopes related to youth prepared for research by ICPE-CA Proca's Center, and to generous physicians present here with them.

Index Terms - Clinical engineering, bioengineering, 2019 sub-disciplines, Terra's present challenges, Romanian BME state, generation change in Ingimed.

I. INTRODUCTION

Aloisio Luigi Galvani (1737–1798) was an Italian physician, physicist, biologist and philosopher, perceived as the first biomedical engineer.

In XIX century, BME was defined as application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. prevention, diagnosis or therapeutics) (Harmon, 1975 [1]). At that time, division of BME in Clinical Engineering, i.e. practical application of the sciences of (non-living) nature in human clinic, and Bioengineering, i.e. understanding of living matter by using engng concepts & tools was a ―soft" border traversed in both senses by people primarily educated in engineering and having received afterwards some training in basics of human biology (especially in physiology).

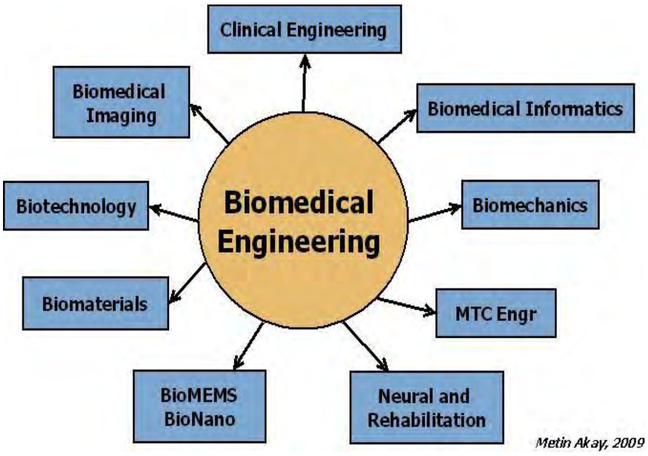


Fig. 1. A 2009 scheme of BME: MEMS are micro electro-mechanic systems, while MCT Engr is molecular, cell & tissue engineering, (cf. Akay, 2009 [2])

Nowadays (Sept. 2019) BME sub-disciplines list as follows [3]: bioinformatics[1]; biomechanics[2]; medical devices including medical imaging[11], implants[12]; biomedical optics[4]; biomedical sensors[14]; clinical engineering[15]; rehabilitation engineering[16]; regulatory issues[17]; ***biomaterials*[3]*; tissue engineering*[5]*; genetic engineering*[6]*; molecular engineering*[7]*; genomics*[8]*; neural engineering*[9]*; pharmaceutical engineering*[10]*; bionics*[13]** (#s send to the Addendum at the end).

Subdomains put in bold are now seen as belonging to bioengineering, Italics with blue # signal relatively new domains that were in nuce or not at all in 70‘s years.

II. LEAD COUNTRIES 2019: CONCEPTS, TRAINING, CAREER, MARKET, SALARY

Detaching of Bioengineering (BIOeng) from the other BME sub-disciplines appears quite clear today, the remaining ones being generically referred as Medical Engineering (MEng).

At its turn, Bioengineering is often completed to get the collocation Medical Bioengineering (MBIOeng), to differentiate itself from biotechnologies involved in energy extraction from animal and plants residuals, or other biology & engng inter-sciences dealing with (non-human) animal and/or vegetal reigns.

The 1st training step is BS degree, some graduates evolving then towards MS or PhD; e.g. at Michigan Univ., USA, circa 30 % of graduates enroll in a further program, 50% progressing to advanced medical, dental, or veterinary degrees [4].

In 2019, the top 3 UNIV. of USA with BS degree in BME are: Georgia Inst. Technology, Atlanta; Rice U., Houston; and U. of California-Irvine, Irvine. [5].

Medical diagnostics triple in market value each year; subsequently, in the last few years, both Forbes and CNN Money have dubbed BME (lato sensu) as the best health care career.

Significantly enough, according to the US Labor Department the mean salary of a BMEer is $95,090 with the top 10% of them earning $144,350 that is more than $10,000/month [4].

III. THE OTHER FACE OF THE COIN

On this optimistic background, BME cannot ignore and confront it elf with the big challenges in the today‘s world: instead of the Society of Conscience, put forward by Draganescu & Kafatos [6] mankind seems more attracted by the ethos of the Post-Truth Society, that lets aside the Absolute Truth (named God in all religions) in order to consecrate individual‘s (possibly egoistic) truths only, and rehabilitates the deception: *"So, if you don't know what's true, you can say whatever you want and it's not a lie“*, J Holmes, 2016.

Atomizing the Absolute Truth i.e. the Fundamental Conscience of Existence (cf Draganescu) means fighting for him/her self only, contempt towards Terra‘s extinguishing resources as felt primarily by climate change, air pollution, indifference/hostility vs fellow people, ―cannibalistic” attitudes versus the disfavored or weak, like seniors, poor young girls seen as prostitution merchandise, or children.

What possibly can do the BME professionals, vis‘a‘vis of this announced disaster?

Already, MEng have already conceived, designed and put on market devices to make last years of seniors life more comfortable and easier in terms of self-moving and communication with health professionals, parents or caregivers able to offer them moral support and solidarity in view if the Big Passing [7].

Every effort from the ME community to simplify devices for spreading their usage towards needy people, with possible contributions of public authorities, health insurances and/or charities, means more dignified years to live for many people.

Super-heating climate (lesser known is that even in Romania lots of animal - like birds - or vegetal species – like pins - are already being on route for north, gradually, but clearly enough for acknowledgeable biologists!) threatens to overpass until the 2000‘s end the + 2 degrees Celsius as average annual temperature, beyond which catastrophic iceberg melting will be rising oceans‘ level so that 50 major coast cities will be submerged by 2050 (acc. to Gerhard Adrian, pres. World Meteo Org. at the COP25 UN Climate Change Conference 2-13 December 2019, Madrid, Spain).

Air pollution [8], excessive caloric stress [9] at work, in traffic, or spare time in nature (even at home, where A/C huge energy consumption spoils the environment leading to more heating a.s.o.) may elicit abnormally increased sympathetic drive to human myocardium visible in both increase of average heart rate (HR) and/or of low frequency fraction in spectra of ECG‘s RR time series, simply nowadays to be extracted and processed from 24h high resolution Holters (see Dinca-Panaitescu et al at this conference [10]).

Exacerbation of sympathetic drive to heart can lead to cardiac incidents or fatalities like sudden cardiac death [11] even in apparently healthy subjects.

By the way, increasing daily average HR means life shortening, because humans, even healthy, dispose of an inherently limited number of heart beats, of about 2 billion, irrespective of life style.

Getting aware of this effect, e.g. by comparing HR daily averages from Holter records archived a few consecutive summers, people may find one true reason to rally in public places than getting manipulated by ―political animals” (TV argot). MErs may this way substantiate the desperate cry of people: ―RADICAL STEPS TO SAVE PLANET NOW OR LEAVE THE FLOOR!” addressed to low-conscience (if any) politicians.

In the same vein, MEers know that a a two-stamp sized device ―glued” over cordial area of a kid/girl, can collect simply an ECG so that a brisk decrease of RR interval (HR high-step) elicited by a brisk emotional stress be Wi-Fi–ed from a quite amenable distance by a discrete Smartphone GPS-ed application to parents or police, as a ―bioelectric alert” non-detectable by the perpetrator of a street attack, attempt of rape or hijacking in order to enable an immediate intervention.

Here again, training of authorities and support of charities may prove indispensable, especially in the poor rural areas.

Fig. 2. Kids at soccer training (top) are surveyed and number of steps countered, using a hand watch sized. Smartphone GPS-ed application (down) collecting the radial pulse that can deliver a ―pulse pressure” alert if the HR briskly increases over a certain alarm threshold

Fig 3. A GPS module ready for use within the ―watch” shown above

At their turn, the BIOers already working shoulder-to-shoulder with biologists (many of them having earned double specializing) to disclose intricacies of human genome, may focus to a greater extent, in virtue of its huge interest, to better understanding periodical mutations of high fatalities viruses like Marburg, HIV or Ebola that prepare, hidden deep in the African forests, the next wave of their periodical outbursts making the CDC or WHO to shake (Ebola: 4,000 dead among 14,000 confirmed cases in 2014, Sierra Leone).

IV. HOW ROMANIA PRESENTS ITSELF ON THIS GLOBAL BME BACKGROUND, AS A COUNTRY SOCIETY OF CONSCIENCE WAS EMERGING FROM?

According to the WHO statistics 2010 – 2015 for its Europe Region Romania features 0,64 BMErs per 10,000 inhabitants (on a scale towered by Finland – 2,73 and Israel – 2,48), close to IRE 0.7 aver. EU [12].

Nevertheless, how much of them succeed to enter the national public health system is another item. Despite their recognition by the COR, and moderate increase BME specialization centers, MErs do not find working places in clinics, due to absence of information, bereft of reason, stupidity of managers and, of course, to barely masked financial crisis of the country these days. We remain tributary to onerous servicing contracted with producers of abroad, on patient‘s account in terms of costs & timing.

A few BIOers involved in molecular & genetic engng do a bit better, but separating of MEng vs BIOEng is only incipient at us, if any.

Keeping the story short, Romanian BME is still searching for its identity.

The recent political move that triples/doubles (rightly) the earnings of medical staff on para-clinical personnel‘s account left at a shameful level of revenue (–anyhow they are not prone to leave the country" was heard to say the former Labor Minister) does not promise anything good for the near future. The Resolution of the INGIMED XIX Centenary Conference on November 2018, tried to counteract this serious drawback, without significant echoes.

V. FINAL REMARKS

The generation who concludes its mission at this round INGIMED XX (how much we would have wished to baptize it a Jubilee!) has at least the merit of 1. voicing publicly year-by-year alerts on the state of BME –nation", 2. contributing some science & technical advances, 3. initiating and maintaining alive a professional Federation (FRIB), and 4. attracting youth‘s interest for this fascinating craft & mission as dr. Mircea Ignat does with his Center.

New, younger people, among whom generous physicians like those in this hall are invaluable, are called to take the relay, and to strongly voice, as the Saint Peter in Rome once, the Truth, for ears of blind or blinded people, for sake of their children.

VI. REFERENCES

[1] Harmon L. D., –Biomedical Engineering Education: How To Do What, with Which, and to Whom", IEEE Trans Biomed Engineering, vol. 22, no. 6, March 1975, pp. 89-94.
[2] Akay M, Biomedical engineering today. 2nd International Conference on e-Health and Bioengineering - EHB 2009, September 2009, Iasi&Constanta, Romania.
[3] https://en.wikipedia.org/wiki/Biomedical_ engineering.
[4] https://www.mtu.edu/biomedical/department /what-is.
[5] https://www.bestvalueschools.com/rankings/ biomedical-engineering-degrees/.
[6] Draganescu M., Societatea Constiintei, Raport de cercetare, Academia Romana, 2003 Bucuresti.
[7] Smart Homes for Elderly Healthcare—Recent Advances and Research Challenges Majumder S, Aghayi E, Noferesti M et al. Sensors (Basel). 2017 Nov; 17(11): 2496.
[8] Peters A, Perz S, Döring A, Stieber J, Koenig W3, Wichmann HE. Activation of the Autonomic Nervous System and Blood Coagulation in Association with an Air Pollution Episode. Inhal Toxicol. 2000 Jan;12 Suppl 2:51-61. doi: 10.1080/08958378.2000.114631999.
[9] Cozma S, Ghiciuc CM, Damian L, Pasquali V, Saponaro A, Lupusoru EC, et al. Distinct activation of the sympathetic adreno-medullar system and hypothalamus pituitary adrenal axis following the caloric vestibular test in healthy subjects. PLoS ONE, 2018, 13(3):e0193963. https://doi.org/10.1371/journal.pone. 0193963.
[10] Dincã-Panaitescu S, Achim A, Negoescu R. Assessment of Sympathetic Supra-normal Drive to Heart via 24 h Spectral RR Holter Using Artificial Neural Networks. Abstracts Book of the Ingimed XX pp 19-21, Nov 7, 2019, Bucharest.
[11] Negoescu R., Bioengineering spots heart repercussions of mental processes: sudden cardiac death corde indemno is preventable. Proc Romanian Academy, Series A, 2003, Vol. 4 (I).
[12] *** Human resources for medical devices, the role of biomedical engineers. 2017, Geneva: World Health Organization.
[13] https://bioengineering.stanford.edu/news /special-symposium-hosted-stanford-nih-biotechnology-predoctoral-training-grant-program.

VII. ADDENDUM

Addendum: [1]methods and software tools for understanding biological data; [2]study of the structure and function of the mechanical aspects of biological systems at any level; [3]any matter, surface, or construct that interacts with living system; [4]interaction of biological tissue and light; [5]creating artificial organs (via biological material) for patients that need organ transplants - a major segment of biotechnology – which overlaps significantly with BME; [6]direct manipulation of an organism's genes, unlike traditional breeding as indirect genetic manipulation; [7]design and testing of molecular properties, behavior and interactions in order to assemble better materials, s^{y}stems, and processes for specific biological functions; [8]using a combination of recombinant DNA, DNA sequencing methods, and bioinformatics to sequence, assemble, and study the structure and function of genomes; [9]using engineering techniques to understand, repair, replace, or enhance neural systems; [10]interdisciplinary science including drug; engineering, pharmaceutical technology, chemical engineering, and pharmaceutical analysis; [11]enabling clinicians to directly or indirectly "view" things not visible in plain sight utilizing ultrasound, magnetism, UV, radiology; [12]medical device made to replace and act as a missing biological structure (different from a transplant of , biomedical tissue); [13]study of the properties and function of human body systems in order to solve some pure engineering problems; [14]devices for detecting & monitoring various EM bodily properties; [15]actual implementation of medical equipment and technologies in hospitals or other clinical settings; [16]application of engineering to develop technological solutions for individuals confronted more or less temporally with disabilities (including orthotics & prosthetics that recently resort to 3-D printing of biological organs); [17]engineering safety problems brought about by using medical devices in clinic. NB: notice that in some universities items 5 to 8 are encompassed under label biotechnology [e.g. Stanford Univ. 13].

VIII. BIOGRAPHY

Professor Radu Negoescu, MEng, MPH has a background of electronics engineering with the Politehnica University of Bucharest and a doctoral/master specialization in cardiovascular bioengineering and public health. His professional itinerary includes National Institutes of Health in Bethesda, MD & Totts Gap Institute in Bangor, PA, USA, and the (National) Institute of Public Health, in Bucharest. He is an honorary member of the Academy of Medical Sciences of Romania.

Flashback to Founding Fathers: the 150th Anniversary of HW CUSHING, a Key Personality of World Neurosurgery, a Promoter of Specific Technologies & Devices and a Friend of Romania

Horia Mihai Berceanu, MD
Ploiesti County Emergency Hospital, Neurosurgery Department
horiaberceanu@yahoo.com

Abstract - Professor Harvey W. Cushing (1869 -1939), graduated from Yale University in 1891 and Harvard Medical School in 1895. He later completed his training at Massachusetts General Hospital, where he helped establish the radiology service (1895-1896). From 1896 he starts secondary surgery at Johns Hopkins Hospital in Baltimore. In 1901 he became associate professor of surgery at Johns Hopkins Hospital, and in 1913 full professor of surgery at Harvard Medical School and the head surgeon at Brigham Hospital in Boston. In 1932 he retires from surgery as a professor of neurology and director of studies in the History of Medicine. In World War I he was the director of the American Base Hospital with remarkable results. Beside neuosurgery brought important contributions in endocrinology (e.g. Cushing's syndrome). As for his contributions to medical devices and instumentations, he was involved in the use of electrical stimulation for the sensory study of the brain cortex, a collaborator of W. T. Bovie in the discovery of electrocautery, and an inventor of neurosurgical instruments; last but not least Cushing used, for the first time in the history of medicine, radiological techniques to diagnose neurological pathology. Professor Cushing contributed to training of American and European neurosurgeons, among them being - between 1927 - 1929 - Dr. Dumitru Bagdasar, whom offered his mentorship following the recommendation of Prof. Nicolae Paulescu.

Index Terms - neurosurgery founder, neurology, endocrinology, radiology & medical instuments, electrocautery, mentor of dr. D. Bagdasar, N. Paulescu.

I. INTRODUCTION

Professor Harvey William Cushing (1869 - 1939), a polyvalent personality of American medicine, was born April 8, 1869, in Cleveland. He graduated from Yale University in 1891 and Harvard Medical School in 1895. He later completed his training at Massachusetts General Hospital, where he helped establish the radiology service (1895-1896).

II. INVOLVEMENT IN NEUROIMAGING

One of Cushing's most important contributions took place in the field of neuroimaging. Although the Crooke tube, an early device for generating X-rays, would not be introduced at Massachusetts General Hospital until May 1896 (approximately 5 months after the announcement of Roentgen's discovery), Cushing foresaw its potential almost immediately. In February 1896, he wrote to his mum, ―Everyone is very excited over the new photographic discovery. Professor Roentgen may have discovered something with his cathode rays that will revolutionize medical diagnosis”. Once the Crooke tube was in hand, he wrote again in May, *“We have at last procured it* (the Crooke tube, NN), *for which I have subscribed largely and hope the conservative staff will ultimately remunerate us for it”*. However, Cushing's colleagues would not get a chance to make great use of this tube, because in October 1896, Cushing took it with him to Johns Hopkins, *“somewhat to the consternation of the staff”*. The Johns Hopkins board had approved Osler's motion to purchase an X-ray machine in April 1896 but did not act on it, so when Cushing arrived, he was able to combine his tube with the hospital's static generators and begin making pictures months before his surgical residency.

In November 1896, Cushing recorded the first specifically neurologic application of the new X-ray machine. A woman had developed a Brown-Séquard syndrome (essentially, a hemiparaplegia, after a partial destruction of the cervical spine) following a gunshot wound inflicted by her husband. Cushing recalled the case in detail many years afterwards, at the 25th Annual Meeting of the American Roentgen Ray Society [2].

From 1896 he starts secondary surgery at Johns Hopkins Hospital in Baltimore, being monitored by William Stewart Halsted, the father of American surgery and William Osler, the father of American internal medicine. In 1901 he became associate professor of surgery at Johns Hopkins Hospital, and in 1913 full professor of surgery at Harvard Medical and the head of the Surgery Clinic at Peter Bent Brigham Hospital in Boston, where he worked until 1932, ending his work after retiring from surgery, as a professor of neurology at the School of Medicine and as director of studies in the History of Medicine [1].

In World War I he was the director of the American Base Hospital, attached to the British Expeditionary Force in France and a consultant neurosurgeon to the American Expeditionary Force from Europe.

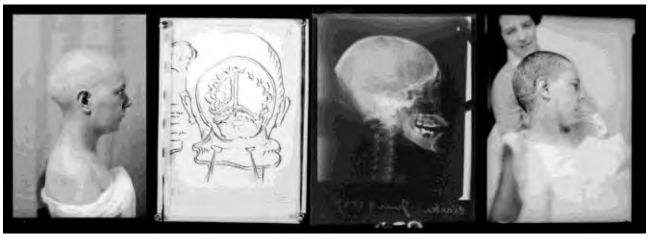


Fig. 1. An early application of X-ray in neurosurgery by Cushing: resection of a tumour; (from R to L): irradiation set-up, the radiography with partly missing occipital bone to access tumour, the intervention scheme, the final photo

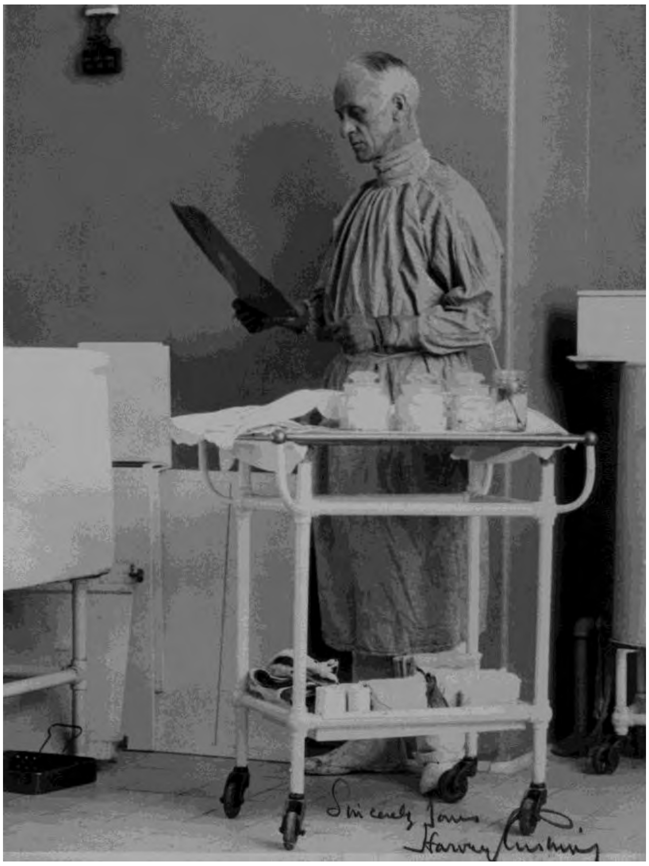


Fig. 2. HW Cushing examining an X-ray film

Multiple neurosurgical contributions were recorded: reduction of operative mortality from over 50%, when it entered the specialty, to below 10% by its painless techniques, paying attention to haemostasis and rigorous pre- and postoperative care; the trans-sphenoidal operative approach, which managed to lower the post-operative mortality to 5.2%. Important contributions in surgical endocrinology were also noticed: e.g. tumours of the pituitary gland (see Fig 3) and Cushing's syndrome; the latter is caused by either excessive cortisol-like medication such as prednisone or a pituitary tumour that results in the production of excessive cortisol by the adrenal glands. Cases due to pituitary adenoma (about 80% out of Cushing's syndromes) are known as Cushing's disease (see Fig 4) [3], [4].

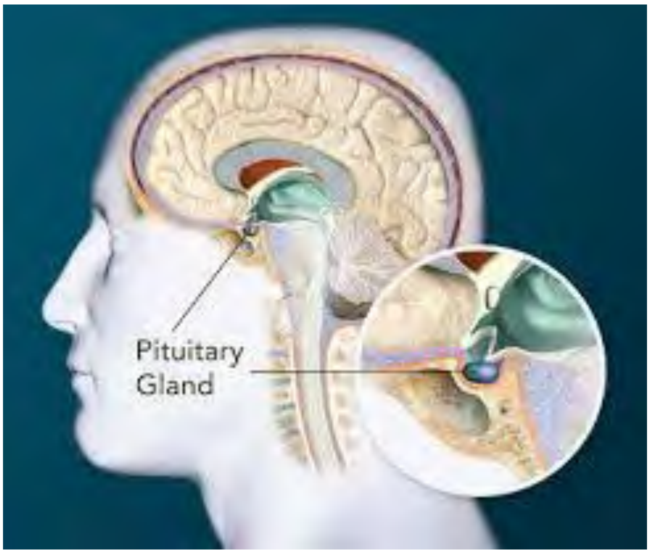


Fig. 3. Pituitary gland

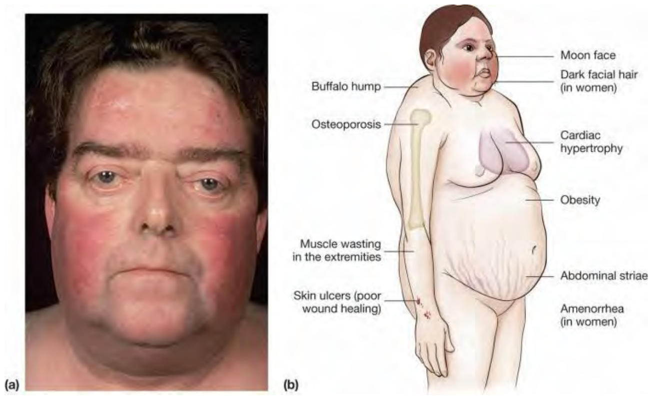


Fig. 4. Signs of the Cushing disease

III. CONTRIBUTIONS TO MEDICAL TECHNOLOGY

As for his contributions to medical devices and instrumentations, he was involved in the use of electrical stimulation for the sensory study of the brain cortex. He was also a collaborator of W. T. Bovie (1882 – 1948) in the discovery of electrocautery and a promoter of electrocoagulation in neurosurgery. Interesting and very unfortunate enough, 100 years after this epochal discovery some surgeons of XXI century (at us but not only) are not fully aware of sensitivities of this technique!

He also was an inventor of many neurosurgical instruments: neuro-forceps, the surgical magnet, the sphygmomanometer (see e. g. Fig 5). As earlier mentioned, Cushing used, for the first time in the neurosurgery, radiological techniques to diagnose neurological pathology (Brown - Séquard syndrome) [5], [6].

Fig. 5. A toolbox of neurosurgical instruments invented or improved by Cushing

Let us stop a bit on the electrocautery principle. In 1926, W. T. Bovie, a physicist at Harvard, created an instrument which revolutionised surgery – the unipolar electro cautery device. This device could make surgical incisions and provide haemostasis as well [7].

A large variety of controlled destructive effects is made available to the surgeon by modulation of high frequency oscillating currents passing between a tip electrode (the scalpel) and a flat conductive gum electrode placed under patient‘s back. The character of the effect produced is less determined by the frequency of the oscillations, but on the character of the oscillatory wave trains utilized. When a surgeon desires to destroy tissue en masse by heating, a train of damped oscillations is customarily used; but to obtain cutting effects, a train of undammed waves is used as a rule [8].

On October 1, 1926 at Peter Bent Brigham Hospital in Boston, Massachusetts, Harvey Cushing performed an operation—removal of a tumour mass from a patient‘s head -- using the first commercial electrosurgical generator developed by Bovie, the specialist we could name nowadays a clinical engineer. As shown, the Bovie tool passed high frequency alternating current into the body, allowing the current to cut and/or coagulate. The device drastically reduced the complications of bleeding during intracranial operations, further reducing the mortality rates during brain surgery. After more than 90 years this basic device remains a fundamental tool in the practice of surgery [9], [10].

When Cushing began his surgical career in the early 1900s, brain tumours were considered to be inoperable. At that time the mortality rate for a surgical procedure involving the opening of the skull was around 90%. Cushing dramatically reduced the mortality rate for neurosurgery to less than 10%, and by the time of his retirement from the Peter Bent Brigham Hospital in 1932, he had successfully removed more than 2,000 tumours. – see Fig 6 [11].

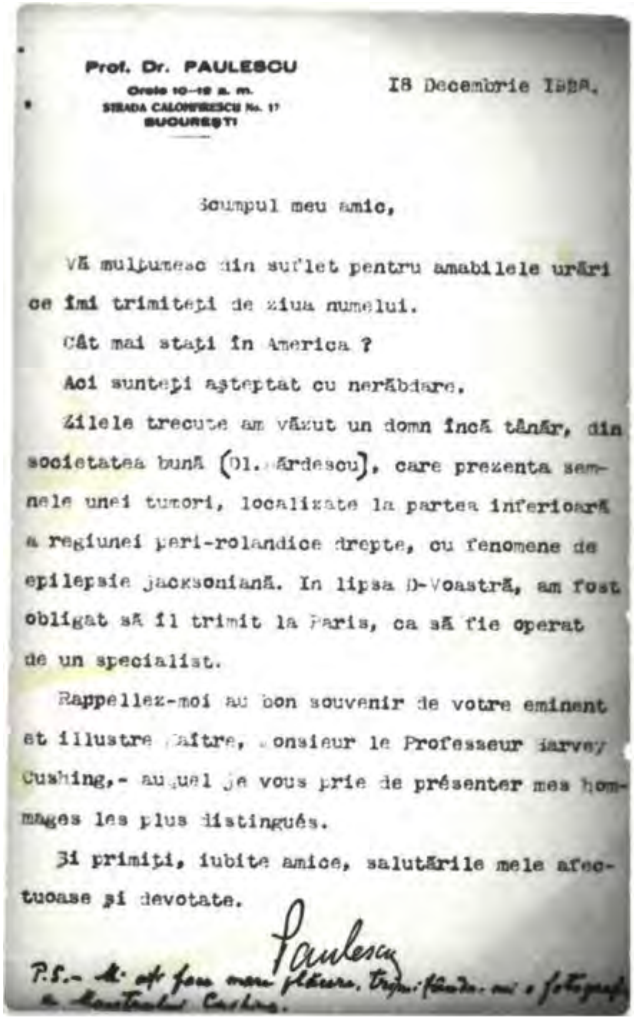
Fig. 6. Cushing at work (1st al left) on removal of a brain tumour

IV. CUSHING A AS A MENTOR OF DR DUMITRU BAGDASAR

Professor Cushing put his mark on the training of many American and European neurosurgeons, among them being - between 1927 - 1929 - Dr. Dumitru Bagdasar, whom offered his mentorship following the recommendation of Prof. Nicolae Paulescu

Between the years 1927-1929 the Doctor Dumitru Bagdasar specialized in neurosurgery at Professor Cushing‘s Clinic (Peter Bent Brigham Hospital, Boston). Cushing gave him all his professional attention, following to letter of recommendation signed by his good Romanian friend Professor Nicolae Paulescu. With all efforts of the two great professors and scientists, born in the same year - Cushing and Paulescu - to meet, this project could not be materialized.

A letter of Professor Paulescu from December 18, 1928 (see Fig 7) is eloquent on his generous desire to maintain relations of closeness to Dr Bagdasar he directed for the completion of neurosurgical specialization at the most illustrious neurosurgeon of the moment, HW Cushing, to whom Paulescu was sending his most distinguished respects [12], [13], [14].



Prof. Dr. PAULESCU
Orele 10–12 a. m.
STRADA CALOMFIRESCU No. 17
BUCUREŞTI

18 Decembrie 1928.

Scumpul meu amic,

Vă mulţumesc din suflet pentru amabilele urări ce îmi trimiteţi de ziua numelui.

Cât mai staţi în America ?

Aci sunteţi aşteptat cu nerăbdare.

Zilele trecute am văzut un domn încă tânăr, din societatea bună (Dl. Ardescu), care prezenta semnele unei tumori, localizate la partea inferioară a regiunei peri-rolandice drepte, cu fenomene de epilepsie jacksoniană. In lipsa D-voastră, am fost obligat să îl trimit la Paris, ca să fie operat de un specialist.

Rappellez-moi au bon souvenir de votre éminent et illustre Maître, Monsieur le Professeur Harvey Cushing,- auquel je vous prie de présenter mes hommages les plus distingués.

Şi primiţi, iubite amice, salutările mele afectuoase şi devotate.

Paulescu

P.S.- [illegible]

Fig 7. Letter sent in 1928 by Prof Nicolae Paulescu to Dr Dumitru Bagdasar who later became a great authority in Romanian neurosurgery

V. ACKNOWLEDGMENTS

At the end of this work, the thoughts of gratitude are headed to my long-date friend, Prof Radu Negoescu, a cardiovascular bioengineer, whom I met half a century ago at the beginning of our professional destinies, and to Mr. Radu Retezeanu, a computer engineer who offered desktop editing help as well.

VI. REFERENCES

[1] Fulton JF. „Harvey Cushing - a Biography”, p. 754. Oxford: Blackwell, 1946.
[2] Gunderman RB and Seymour ZA. „Harvey Cushing”. American Journal of Roentgenology, 2010;194: 296-298. 10.2214/AJR.09.3356.
[3] https://www.pituitarysociety.org/patient-education/pituitary-gland-function.
[4] https://www.dictio.id/t/apa-yang-dimaksud-dengan-sindrom-cushing-cushing-s-syndrome/6344.
[5] https://neurophilosophy.wordpress.com/
[6] Bovie WT, Cushing HW. "Electrosurgery as an aid to the removal of intracranial tumors with a preliminary note on a new surgical-current generator". Surg Gynecol Obstet 47: 751–84, 1928.
[7] Barrett SL, Vella JM, Dellon AL. —Historical Development of Bipolar Coagulation”. Microsurgery, 2010 Sept.
[8] Mclean AJ. —The Bovie‘s Electrosurgical Current Generator: Some Underlying Principles and Results”. Arch Surg. 1929; 18(4):1863-1873.
[9] https://library.medicine.yale.edu/blog/electrosurgical-operating-room.
[10] Bliss M, Cushing HW. A Life in Surgery. University of Toronto Press; p 407, 2005.
[11] http://doc1.med.yale.edu/historical/cushing/
[12] Iftimovici R. —Istoria Universală a medicinei și farmaciei”, Ediția a 2-a revăzută și adăugită, Secolul XX și debutul secolului XXI. Ed. Academiei Române, București, pp. 802 – 804, 2015.
[13] Iftimovici R. „Osmoza ideatică Paulescu – Cushing”, Viața Medicală, nr. 42, 14 octombrie 2016.
[14] Nicolae Paulescu, Scrisoarea către Dumitru Bagdasar din 18 decembrie 1928 (document made availale from the Național Institute of Public Health, History of Medicine Library, by courtesy of Dr Sanda Hondor - the custodian).

More readings on electrocautery technique

A. https://www.whonamedit.com/doctor.cfm/980.html.
B. https://www.albertahealthservices.ca.
C. https://www.contemporaryobgyn.net/modern-medicine-feature-articles/electrosurgery-newest-energy-based-devices.
D. https://www.uptodate.com/contents/overview-of-electrosurgery.
E. http://blogs.shu.edu/ihsl/author/hicknean.

IX. BIOGRAPHY

Horia Mihai Berceanu, graduated the University of Medicine & Pharmacy „Carol Davila” of Bucharest Medical School, and the University of Bucharest Special Psycho-Pedagogy Dept., holding 3 medical specializations: family medicine, medical rehabilitation and neurosurgery, and a competence in sports medicine as well.

He was a lecturer at the University of Physical Education and Sports (UNEFS) Kinesiotherapy Dept. and a physician attached to national paralympic teams in many international competitions.

He also provided the medical support for junior football teams of the Children Palace of Bucharest over more than 2 decades and was the physician of national boxing team of Romania along 1998 - 2002.

In neurosurgery he was with —Bagdasar-Arseni” & —Elias” Emergency Hospitals from Bucharest, and Emergency Clinical Hospital of Constanta County. Nowadays is collaborating with Ploiesti County Emergency Hospital, Neurosurgery Department.

Assessment of Sympathetic Supra-normal Drive to Heart via 24 h Spectral RR Holter Using Artificial Neural Networks

Șerban Dincã-Panaitescu[1], Alin Achim[2], Radu Negoescu[3]
[1]School of Health Policy and Management, York University, Toronto, Canada
[2]Faculty of Engineering, University of Bristol, United Kingdom
[3]Academy of Medical Sciences and National Institute of Public Health, Bucharest, Romania
[3]nego2005radu@yahoo.fr

Abstract - During last 2 decades Holter records did begin to be used in cardiac/arrhythmology departments for more than highlighting abnormalities in known cardiac patients‘ ECG traces, by addressing epochs of prolonged normal RR series to explore sympathetic-vagal control interplay to heart by spectral methods. Since a few decades, research has shown that frequency spectra of short term (3 to 5 minutes) quasi-stationary time series of RR intervals may disclose sympathetic drive to ventricles (SDV) by power increase in the low frequency range (0.05-0.15 Hz) even if other heart rate (HR) trends (subject to both sympathetic – HR up – and vagal - HR down - influences) remain irrelevant. Exacerbated SDV- currently associated with chronic psycho-social stress, but also with work under caloric stress and/or air pollution - when protracted during years shortens lives by cardiac diseases including arrhythmic troubles, and, on an already ―mined” myocardium to sudden cardiac death. A factor seriously opposing to clinical acceptance of the spectral RR-variability hints is the undifferentiated consideration of spectra irrespective of their specific psycho-physiological profile underlying the state of the subject/patient during the RR data segment under scrutiny. ANYS, a step 1 aiming at state-recognition of ECG-derived RR spectra was processing 24 hours RR files derived from Holter tapes by selecting every 3-4 minute RR episode complying with quasi-stationarity, followed by a conventional Fourier transform. We considered 7 reference neuro-physiological states with well delineated spectral marks: Sitting relaxed; Standing relaxed; Focused attention sitting; Emotional stress; Exercise; Slow sleep; Rapid (REM) sleep. An expert system-like was set to classify in terms of probability the underlying state of a spectrum using a grid of spectral parameters as follows: RR mean and variance, ratio of THM (0.05-0.15 Hz) and RESP (0.2-0.4 Hz) spectral powers (POW), central THM frequency, THM clustering score, central respiratory frequency. For each neuro-physiological state we created a reference matrix which reflects the probability of occurrence of the spectral parameters in every of four magnitude ranges. Calculating the probability of a current/income spectrum to belong to a reference state was done to multiplying the reference state matrix by the matrix of current spectrum. Final probability that a current spectrum corresponds to a reference state is the ratio between current score and the maximum score of that state, always 6. As a step 2, spectral parameters were input to a three level back propagation neural network, featured by 7 hidden neurons, outputting probabilities of each of the 7 reference states assigned to an incoming spectrum. After being trained using parameters of seven best distinguished spectra assigned by ANYS to each reference state, the neural network proved to be more effective than the ANYS itself in assigning towering probabilities to the rest of spectra. The final step 3 is to make up a robot-picture of the patient suspected of autonomic control deregulations, made up of representative spectra (or average of homonym spectra) for each of the 7 reference states to be compared with normal, age adjusted specimens. The differences are to be then next interpreted in terms of normal/supra-normal sympathetic drive to heart.

Index Terms - Holter ECG, RR time series, spectral analysis, sympathetic drive to ventricles, expert systems, artificial neural networks.

I. INTRODUCTION

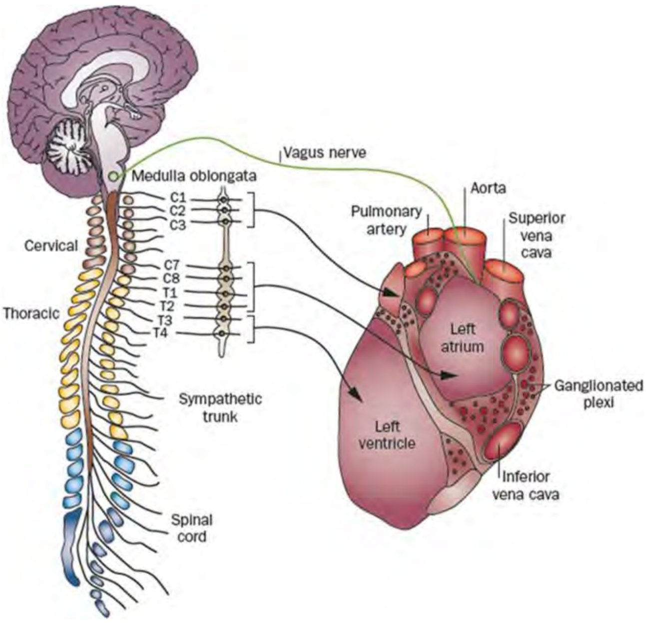
In normal humans the nervous autonomic control of the heart is done:

- via cranial parasympathetic (or vagal) branch originating in brain stem and extended mainly to atria for down-regulating heart rate (HR) by the sinus node in right atrium, and
- via the sympathetic branch derived mostly from cervical and thoracic spinal cord – targeting mainly the ventricles to control the force of heart contraction, but up-regulating HR through a few atrial neurites too.

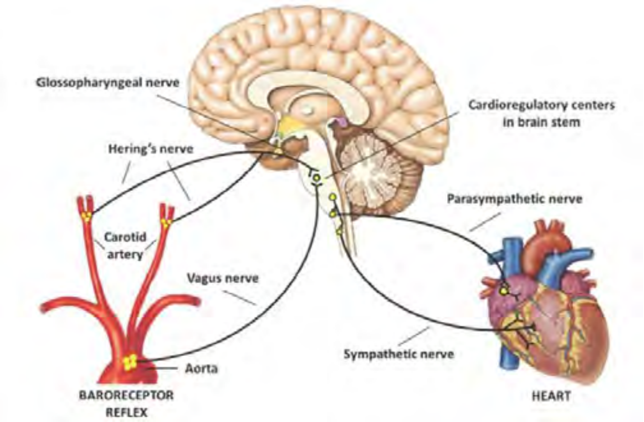
It is widely accepted that exacerbated (or supra-normal) sympathetic drive to ventricles (SDH) - when protracted through chronic psycho-social stress, but also by caloric stress or air pollution – leads to:

- an abnormally higher average HR (humans have to live no more than 2 billion heart beats, possibly encompassing 60, 70, or 80 years!)
- shortening lives by ventricular diseases including arrhythmic troubles and, on a mined myocardial terrain, to sudden cardiac death.

Sometimes a normally increased vagal tone (by exercising e.g.) mitigates the HR going-up masking the real extent of SDV.



Figs. 1 & 2. Cardiac innervation scheme
(view from the rear -1 up, and from the front – 2 down);
CV centers in brainstem integrate inputs from carotid arteries and aorta root (as well from suprajacent respiratory neurons modulating vagus) to control HR and force of contraction.



Research conducted during last decades in both US and Romania has shown that the differential diagnosis could be made using the Fourier spectra of short term (3 to 5 minutes) quasi-stationary time series of RR intervals as derived from high resolution (1-2 ms) ECG traces.

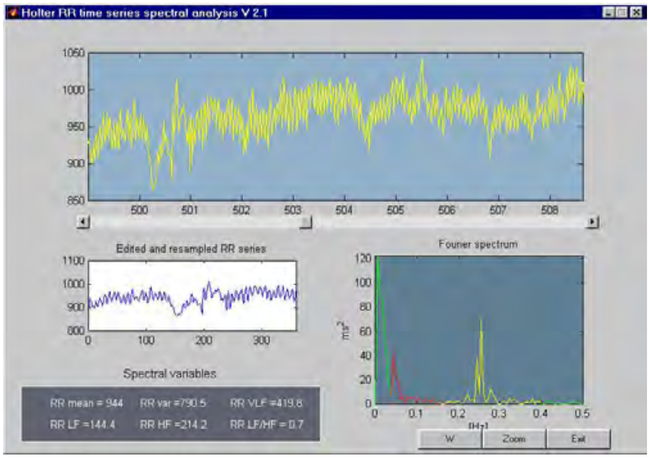


Fig 3. A 30 min long RR graph (top), a short term (5 min) RR time series (left down) and its spectrum at right (red: LF/THM --> SDV; yellow: respiratory HF peak).

An abnormal increase of low frequency power (LF: 0.05-0.15 Hz, known also as Traube-Hering-Mayer, THM band) may disclose sympathetic ”pressure” on heart irrespective of HR response, and may offer reasons to institute prevention steps, if the case presents [1].

II. THE HOLTER TEST

During last 2 decades Holter records did begin to be used in cardiac/arrhythmology departments for more than highlighting ECG abnormalities in known cardiac patients‘, namely by addressing epochs of prolonged normal ECG traces to extract RR time series for exploring sympathetic-vagal interplay by time or spectral methods.

In Romania, even if in some more advanced ECG or Holter equipments time/spectral RR analysis is available, information derived from longer normal ECG segments is rarely appealed to.

In its pioneering epoch, interpretation of spectra suffered from applying conventional or fast Fourier transform over excessively nonstationary RR data segments [2].

Very recently more sophisticated spectral approaches seem to overcome this obstacle in both short (a few minutes) or long (24h Holters [2,3]) RR time series.

A factor seriously opposing to clinical acceptance of insight brought by short-term spectral RR-variability in Holter records is the undifferentiated consideration of spectra irrespective of their specific psycho-physiological or patho-physiological substratum, i. e. the state of the subject/patient during the RR data segment under scrutiny.

Or, RR spectrum's alteration in the same individual induced by brainstem "re-wiring" when posture, mental loading status, or sleep stage changes often competes or overpasses inter-individual differences referred to the same state.

III. STEP 1: ANYS

A first phase aiming at recognition of the state behind RR spectra has used Turbo C software written in the-latter-includes-the-former style to process 24 hours RR time series derived from Holter.

First, the program searched every 3-4 minute RR episode complying with quasi-stationarity needed by spectrography, that was then Fourier transformed.

Spectral parameters able to identify a neural-physiologic state and their variation ranges were set empirically by Negoescu et al, based on studies conducted on normal subjects, done in Romania & Cardiol. Dept. of the Nat'l Heart, Lung & Blood Inst. of NIH, Bethesda, US [4].

We considered 7 neural-physiological references states that have most clearly separated spectral outlines:

Relaxed sitting;
Relaxed standing;
Focused attention while sitting;
Emotional stress;
Exercise;
Slow sleep;
Rapid (REM) sleep.

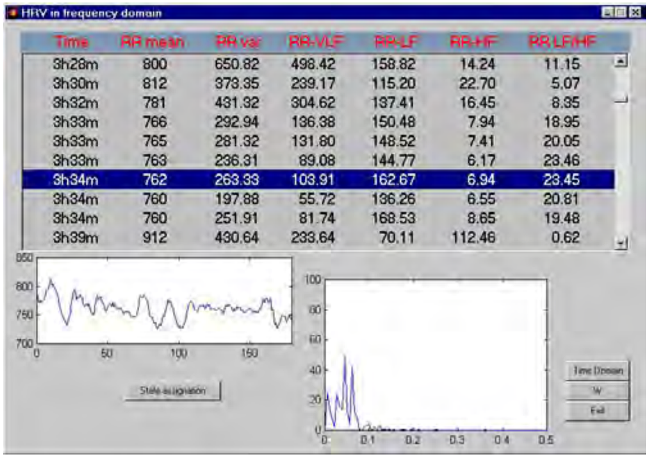


Fig. 4. A typical spectrum during RELAXED STANDING; 3 min long RR time series since time landmark 3h34min; in lower, left hand corner: the RR time series resampled at 500 ms; lower right hand corner: the spectrum, dominated by low frequency component (LF: 0.05-0.15 Hz); the respiratory, HF component (about 0.2 Hy) is almost annihilated. Mathlab screen.

We added then an expert system-like module (ANYS) to classify the states underlying spectra in terms of probability, and once a validation examination having passed - to assign to a current/incoming spectrum a reference state.

Classification used a grid of 6 spectral parameters as follows:

RR mean,
RR variance,
Ratio of THM (0.05-0.15 Hz) vs RESP/HF (0.2-0.4 Hz) spectral powers (POW),
Central THM frequency,
THM clustering score,
Central respiratory frequency in spectrum.

	LOW	MILD	MODERATE	HIGH
HR [bpm]	50 - 70	70 - 85	85 - 100	>= 100
RR_{VAR} [ms2]	< 100	100 - 200	200 - 400	> 400
P_{LF}/P_{HF}	< 1	1 - 4	4 - 16	> 10
f_{LF} [Hz]	<0.07	0.07 - 0.1	0.1 - 0.13	> 0.13
c_{LF} [%]	25	25 - 32	32 - 40	> 40
f_{HF} [Hz]	<0.22	0.22 - 0.27	0.27 - 0.33	> 0.33

Fig. 5. The 4 magnitude ranges empirically chosen for the 6 spectral parameters

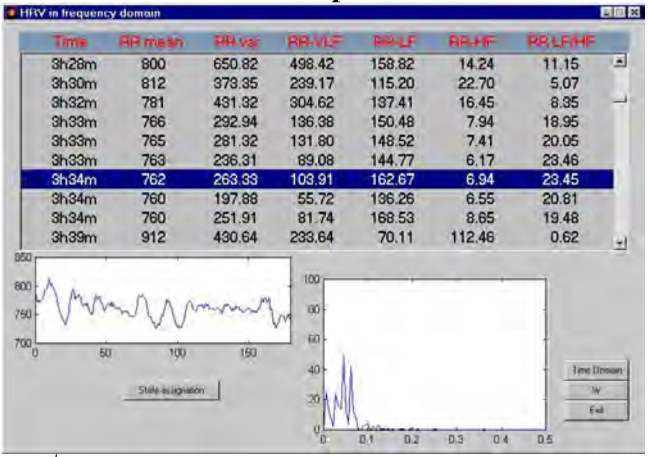
The reference matrix for relaxed standing

	LOW	MILD	MODERATE	HIGH
HR [bpm]	0	3/5	2/5	0
RR_{VAR} [ms2]	0	1/5	4/5	0
P_{LF}/P_{HF}	0	0	0	1
f_{LF} [Hz]	3/5	2/5	0	0
c_{LF} [%]	0	0	0	1
f_{HF} [Hz]	1/5	3/5	1/5	0

Fig 6. For each reference neural-physiological state we created a state matrix which reflects the probability of occurrence of the spectral parameters in the four magnitude ranges as shown. The reference state matrices are determined through experiments when the state of the subject is known. e.g., below is the reference matrix for **relaxed standing** (such an episode is shown in Fig 4).

To calculate the probability of a current spectrum (subject of classification) to belong to a reference state, we had previously to make up the current matrix signaling by 1 the magnitude corresponding to a given spectral parameter pertaining to that current spectrum.

Current spectrum



√

HR = 78,7 b/min;
RR_{VAR} = 263.33 ms^2;
P_{LF}/P_{HF} = 23.45;
f_{LF} = 0.083 Hz;
c_{LF} = 48.8%;
f_{HF} = 0.208 Hz

√

Current matrix

	LOW	MILD	MOD.	HIGH
HR [bpm]	0	1	0	0
$RR_{VAR}[ms^2]$	0	0	1	0
P_{LF}/P_{HF}	0	0	0	1
f_{LF} [Hz]	0	1	0	0
c_{LF} [%]	0	0	0	1
f_{HF} [Hz]	1	0	0	0

Current conformity score for a current spectrum to comply to a reference state if got by multiplying the above matrices. Final probability that the current spectrum corresponds to a reference state is the ratio between the current score and the maximum score of that reference state (always 6). This case, current spectrum is 4/6 = **66% RELAXED STANDING.**

$$I_{stare} \otimes M_{curent\breve{a}} = \begin{pmatrix} 0 & \frac{3}{5} & \frac{2}{5} & 0 \\ 0 & \frac{1}{5} & \frac{4}{5} & 0 \\ 0 & 0 & 0 & 1 \\ \frac{3}{5} & \frac{2}{5} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{1}{5} & \frac{3}{5} & \frac{1}{5} & 0 \end{pmatrix} \otimes \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & \frac{3}{5} & 0 & 0 \\ 0 & 0 & \frac{4}{5} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{2}{5} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{1}{5} & 0 & 0 & 0 \end{pmatrix}$$

Current score = 3/5 + 4/5 + 1 + 2/5 + 1 +1/5 = 4

Criteria for validating the reference state assigned to a current/incoming spectrum:

1. Probability that the current spectrum corresponds to a reference state be > 50%.
2. Defining parameters for the current spectrum should be within the ideal intervals quoted in literature for at least 2 out of the 6 spectral parameters of the reference state.

For example, 2 ideal parameters for relaxed sitting are: POW LF/POW HF < 3; RRVAR ≥ 500 ms^2.

Notice that the criterion #2 functions when probability criterion #1 is low enough. For higher probabilities (e.g. > 90%) the #2 becomes perhaps superfluous, explaining our step 2 approach.

IV. STEP 2: NEURAL NETWORK

To advance automation of state classification, the 6 spectral parameters were input to a three level back propagation neural network, featured by 7 hidden neurons, outputting probabilities assigned to an incoming spectrum to correspond to each of the reference states

The neural network written in C used an activation function of sigmoid type: $f(x) = 1/(1+ e^{-x})$ and was trained with a spectral values set according to ANYS classification. The training parameters were: η= 0.75, (step of weight change per iteration) α=0.85 (momentum, inertia); maximum number of iterations was 500 while error threshold was set to 0.06.

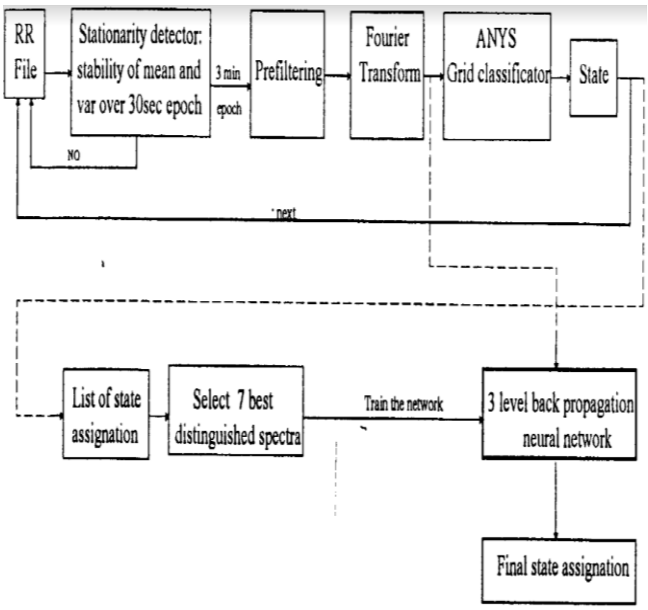


Fig 7. The outline of the combined expert-like system & neural network

After being trained using parameters of the seven best classified spectra according to ANYS, the neural network proved to be more effective than the ANYS itself in assigning towering probabilities to the rest of spectra. The cost paid is the initial training using the knowledge-data base stored into the grid classifier [5].

V. STEP 3: THE FINAL ONE

That is to make up a robot-picture of a patient suspected for autonomic control deregulations, made up of representative spectra (or average spectra) for each of the 7 main references states bearing the print of heart control through vagal-sympathetic interactions.

This peculiar portrait is to be compared with specimens from a healthy mid-aged (or young/old, respectively) subject, referring to the homonym state. The differences are to be interpreted in terms of normal/supra-normal sympathetic drive to heart.

VI. CONCLUSION

The major application of Holter spectral RR series approach in terms of underlying psychic-physiologic substrata is detection and limitation of risk for malignant cardiac arrhythmias entailed by chronic sympathetic supra-drive, in both cardiac patients and apparently healthy subjects with sporadic arrhythmic complaints on a quasi-normal clinical/ para-clinical background, who are not dealt with by conventional cardiology.

VII. REFERENCES

[1] Negoescu R., Bioengineering spots heart repercussions of mental processes: sudden cardiac death corde indemno is preventable. Proc of the Romanian Academy, Series A, Vol. 4 (I), 2003.

[2] Pinna GD, Maestri R, Di Cesare A, Colombo R, Minuco G. The accuracy of power-spectrum analysis of heart-rate variability from annotated RR lists generated by Holter systems. Physiol. Meas. 1994 May; 15(2):163-79. Abs: https://www.ncbi.nlm.nih.gov/pubmed/8081194.

[3] Li K, Rüdiger H and Ziemssen T. Spectral Analysis of Heart Rate Variability: Time Window Matters. Front. Neurol., 29 May 2019. https://www.frontiersin.org/articles/10.3389/fneur.2019.00545/full.

[4] Negoescu R. An expert system module for recognizing psycho-physiological settings underlying RR spectra, Internal report, NHLBI Dept. Cardiology – NIH, Bethesda, MD, 1992.

[5] Dincã-Panaitescu S, Bozocea G, Negoescu R: Neural network expert-module for state-recognition of RR spectra, Papers Natl Conf. Med. Inf., p. 63-68, Bucharest, 1995.

VIII. BIOGRAPHIES

Associate Professor Serban Dinca-Panaitescu, MEng was born in Bucharest on February 23, 1970. He graduated from Electrical Engineering in 1994 and he received PhD degree in industrial engineering from Bucharest Polytechnic University in 2001.

His employment experience included the Institute of Public Health in Bucharest, Romania and School of Health Policy and Management, York University, Toronto, Canada, where he is now teaching as an associate professor.

Dr. Dinca-Panaitescu has worked for many years in the area of medical informatics focusing on computer processing of physiological signals. His major research contributions address the field of cardiovascular disease prevention by developing decision support tools aiming at detecting the cardiovascular dysfunction in the subclinical phase. He has published numerous articles and one book in this field. Dr. Dinca-Panaitescu‘s research is also employing statistical modeling techniques to untangle the complex relationship between socio-economic factors and different diseases such as diabetes. Other research interests include medical equipment, health information systems and e-health.

Professor Alin Achim, MEng graduated from Electrical Engineering from Bucharest Polytechnic University in 1994 and received PhD degree from University of Patras, Greece. He teaches biomedical signal processing, in particular artificial neural networks and wavelet methods at Faculty of Engineering, University of Bristol, United Kingdom.

Professor Radu Negoescu, MEng, MPH has a background of electronics engineering with the Bucharest Polytechnic and a doctoral/master specialization in cardiovascular bioengineering and public health. His professional itinerary includes National Institutes of Health in Bethesda, MD & Totts Gap Institute in Bangor, PA, USA, and the (National) Institute of Public Health, in Bucharest. He is an honorary member of the Academy of Medical Sciences of Romania.

Research Thesis: Applications of Microwires and Nanowires in Engineering and Biomedical Regenerative Treatments

Ioana Iordan
―Alexandru Proca" Centre for the Youngsters Initiation in Scientific Research (CITCS), INCDIE ICPE-CA, Splaiul Unirii, No. 313, District 3, 030138, Bucharest, Romania
―Spiru Haret" National High School
ioana.iordan259@gmail.com

Abstract - The Centre‗s researcher proposes a theoretical and experimental study of micro- and nanowires, including their mechanical, thermal and electrical properties which determine their prospective technical implementation in engineering and medicine.
Their perpetual study research of micro- and nanowires revealed a chemical procedure and multiple remarkable uses in the augmentation of efficiency of industrial processes and medical treatments.
Throughout the development of the thesis, experiments pertaining to inductance, capacitance, as well as mechanical and electrical resistance were performed in order to develop application models and demonstrate the inherent benefits of their implementation.

Index Terms – microwires, nanowires, biomedical, microtechnology, glass-stripping, hydrofluoric acid, microsensors, neural networks, electromagnetic shielding

I. INTRODUCTION

- ❖ Research in the micro- and nanowires may yield applicability in engineering and medicine given their vast advantages. Such models could be revolutionary in industries and biomedical treatments solutions.
- ❖ Microwires & nanowires are materials infinitesimal compared even to human hair. The domains of quadric-cylindrical geometry include:
  - internal microconductors, with electromagnetic properties (~1 - 50 μm);
  - exterior glass insulations (~1- 20 μm thick).

II. TECHNOLOGICAL CONTRIBUTIONS

A. Chemical glass-stripping procedure

In order to interconnect and use microwires in electric a process through which the exterior, insulating glass coating is stripped from the wire at its ends, thus allowing electric currents to pass through the micro-conductor subdomain.

The current glass-stripping method is mechanical in nature, implying manual glass removal. It leads damage to internal microconductors (counterintuitive effect in microtechnology development) and unfit glass removal.

Therefore, this process and the damage caused to the metallic core encourage the development of a chemical glass-stripping procedure which doesn‗t affect the wire‗s integrity. => a reagent dissolving the insulating glass without attacking metal compounds is necessary.

Hydrofluoric acid (HF) is an average-strength acid found as an aqueous, colourless solution with a characteristic odour. HF is not highly reactive with metals/metallic alloys, but strongly attacks silicon dioxide (SiO2, main component of glass, amorphous solid with and many industrial uses) => it is the ***ideal chemical compound*** for a glass-stripping procedure.

Process: In initial contact with HF, glass surfaces become matte, the amorphous structure decomposing eventually under the acid‗s influence and leaving only the metallic interior, intact. The internal micro-conductor remains unaltered from a physical-chemical standpoint.

Impact: Comparing microscopies of microwires mechanically and chemically stripped, one may observe the efficient & nonresidual.

$$SiO_2+4HF=SiF_4+2H_2$$

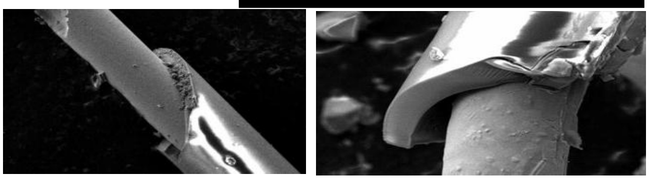


Fig. 1. Comparison between microscopies of a mechanically stripped microwire (left) and a chemically-stripped microwire (right)

Experiment: The chemical procedure was attempted at the Institute. It entailed a fixed microwire (e. g. on a plexiglass surface) and administering HF to its ends using a syringe/inserting the ends into a beaker with HF and analysing the effects. The catalytic dissolution of glass noticeably thins the wire, leaving only the metallic interior – effect confirmed post a microscopic analysis. Multiple glass-stripping trials with HF highlighted the efficacy of processing groups of 4-7 microwires rather than individually, without affecting process quality wise.

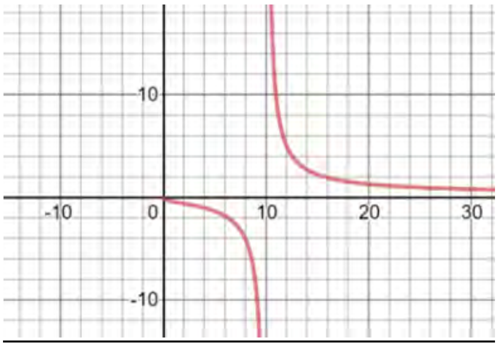


Fig. 2. Graph of capacitance of microcapacitor (Oy) depending on the distance between its conductors (Ox)

B. Integration in electric circuits

Due to microwires' lacking manoeuvrability, developing microtechnology models is difficult. Integrating a single microwire into circuits is cumbersome given fragility and size. Traditional connectors aren't efficient as they damage wires' insulation and internal micro-conductors.

As such, the Centre's researcher proposes an innovative connector. Based on symmetrically distributing magnetic interactions, structural integrity is ensured. The connector is made by superposing 3 magnetic surfaces, fixing a normal wire and a microwire between them.

Such connectors can be placed in any concerning circuit branch.

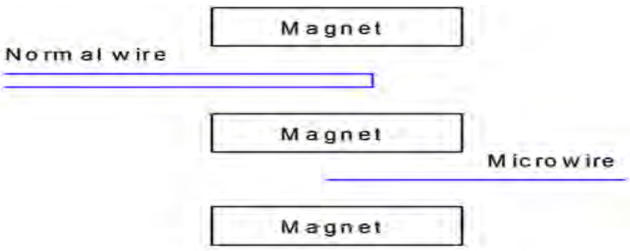


Fig. 3. Theoretical illustration of a magnetic connector

III. APPLICATIONS IN MEDICINE AND ENGINEERING

*A. Microsensors *(edited for length & detail)*

*A1. Capacitive polymerization microsensors**

Polymerisation technologies are omnipresent in industries, thus leading to a common problem, accurate identification of polymerisation duration. Manufacturers aim to minimise costs & energy spent fuelling a component's polymerisation. Therefore, inserting a microsensor (microwire capacitor) capable of measuring its duration alongside the impregnated component is economically effective.

A capacitive microsensor can be made using 2 parallel microwires with stable geometry can be made with metallic conductive plates made of a rotor/stator or a micro-coil Provided capacitance is known, it can measure the permittivity of a substance or indicate the drying of polymerisation varnish.

Considering the capacitance equation of a microcapacitor with spherical conductors (Eq. (1)) one notices that if the distance remains constant, the relative permittivity varies proportionally to the impregnation process, stabilising itself once the polymerisation concludes and stabilises.

$$C \approx \frac{\pi l \varepsilon}{ln\frac{a}{r}} \ (1) \qquad C = \frac{q}{U} = \frac{\pi l \varepsilon}{ln\frac{a-r}{r}} \qquad C = \frac{0.646 \times 10^{-10}}{ln\left(\frac{x}{5} \times 10^{6}\right)} \ (2)$$

$$\varepsilon = \varepsilon_\circ \times \varepsilon_r \ (3) \quad \varepsilon = \frac{1}{4\pi 910^{9}} \times \varepsilon_r \times \frac{c}{V} \times m = 6,86 \times 10^{-12}\frac{\varepsilon_r C m}{V}$$

$$f(x) = \frac{\pi l \varepsilon}{ln\frac{x}{r}}$$

*A2. Capacitive microsensors measuring mechanical/thermal expansion of a medium**

Straining a medium Ω with a force F, then distance between microconductors will become $a \pm \Delta a$ (where a is initial distance) resulting in the modification of capacitance.

A medium's variation in permittivity determines a proportional variation in capacitance C.

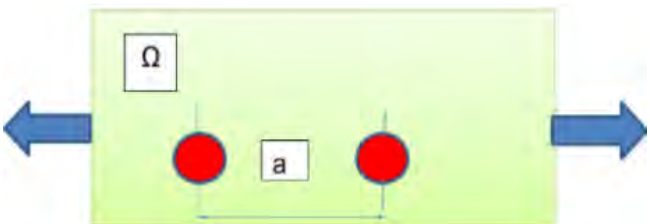


Fig. 4. Theoretical illustration of microsensor

*A3. Microsensors made using microconductors**

If stress (such as a force F) is applied to the end of a microwire of length l, section area, and resistance $R = \rho\frac{l}{S}$. By modifying l or S, the resulting variation in R transforms a microconductor into a microsensor.

A4. Resistive microsensors for mechanical tensions/forces

Parameters of microwires such as electrical resistance & inductance of microwires facilitate the fabrication of resistive microsensors that can determine the integrity of structures or measure values of mechanical stress. The structure of a contact microsensor is considered a planar conductor, so that the electrical resistance of an electric contact depends on an exterior force R=R(F).

*A5. Contact microsensors for boundary layers**

Through Prandtl‘s *boundary layer* notion it‘s established that a flow domain may be separated into subdomains, each defined by motion equations.

Should a solid object in a fluid flow with uniform speed, then due to surface adherence, the area in its immediate vicinity is characterized by a strong speed gradient (derivative of tangential speed) and friction forces, which tend to nullify at greater distances from the aforementioned solid object. A *boundary layer* is the domain in the object‘s vicinity where speed varies from 0 (on object surface) to the speed value measured on its normal‘s direction. Outside that domain, friction efforts may be neglected and the fluid considered ideal (no shear stress & viscosity).

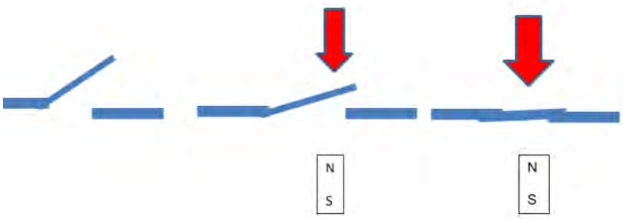
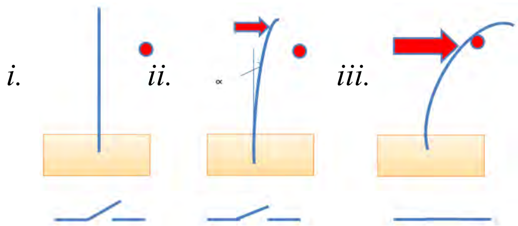


Fig. 1. Theoretical scheme of the contact



i. *Microsensors in an unstrained state (equilibrium contact)*
ii. Microsensor in a quasi-strained state (open contact)
iii. Microsensor in a critical strained state (closed contact)

Fig. 2. Theoretical scheme of interaction between contact microsensors and magnetic fields

A6. Microsensors detecting temperatures in controlled environments & A.7. Humidity-detecting microsystems**

Microwires may be used in the fabrication of temperature-detecting microsensors with low cooling times for materials under the action of a controlled heat source. They can also be placed in various organic/ inorganic mediums with humidity-detecting role.

*A8. Resistive-capacitive microsensors for investigations in cranial & abdominal cavities**

The proposed microsensor can be used in medicine, either in medical investigation or biochemical analysis, as its reduced dimension facilitates the measuring of pH values/internal organic parameters.

*A9. Inductive microsensors for ferromagnetic fluid/object detection**

Either in medicine or engineering, inductance-based microsensors can be used for the detection and identification of ferromagnetic objects. Their presence in fluids or various mediums may be indicated by an induced electromagnetic field.

*A10. Inductive microsensors for ferromagnetic fluid/object detection**

Also using microwires (with a core made of critical minerals) one may fabricate microsensors that can detect and/or control magnetic fields through electric charges and magnetic interactions.

Microsensors can be placed in various organic or inorganic mediums with humidity-detecting role.

Either in medicine or engineering, inductance-based microsensors can be used for the detection and identification of ferromagnetic objects. Their presence in fluids or various mediums may be indicated by an induced electromagnetic field.

B. Incorporation in neural networks

Developing micro- & nanowires alongside progress in STEM regenerative technology reveals the possibility of remaking and/or replacing deteriorated synapses (due to nervous system diseases, accidents, degenerative damage, etc.) with inorganic materials similar to organic nervous tissue. *[points **i. & ii.** apropos anatomy were cut for length]

iii. Theorization and preliminary calculations

1. Theorization:

The nervous cell and neural patterns have been a relevant interest throughout history. An influential 1952 paper by Hodkin & Huxley (later awarded the Nobel Prize (J. Physiol, 117, p.500) established elementary knowledge. It focused on membranary processes, yet not exhausting aspects concerning nervous cells and neural systems.

A second shock in the domain was the development of unconventional technologies concerning micro- and nanowires, used as replacements for biological, organic matter of neural systems (axons, dendrites, etc) and even the creation of new systems based solely on micro- and nanowires. ***As such, when projecting new neural-circuit elements, planning and calculations based on the characteristics of inorganic matter used are required.***

Therefore, the study will introduce preliminary applied mathematical modules and projection schemes. The physical-mathematical breviary entails precise values for circuit parameters (resistances, inductance, capacitances *etc.*) intervening in (partly) artificial neural networks.

Microtechnological applications relevant in biomedical treatments and bioengineering are based on the intersection between electrical engineering and nervous system (NS) physiology:

I. Electric circuit & electric engineering theory

Telegrapher's equations are used in the simulation and highlighting of inorganic parameters (formulated based on the NS, e.g. nervous signal transmission).

II. Scientific aspects regarding replacement feasibility of neural elements using microwires

Current use of microwires in medicine is experimental and rare (refined, biomedical treatment in top clinics).

Propagation of action potentials through a nervous cell, including its body, neural extensions (axons, dendrites) and synapses leads to assimilation with long field lines.

The result is a useful representation of electric signal transmission through organic and inorganic elements, respectively.

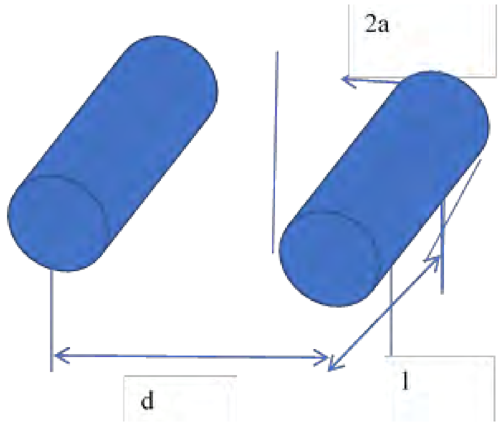


Fig. 7. Illustration of mutual inductance

This representation leads to an experimental treatment of deteriorated anatomic NS components via their facilitated replacement utilising nano- or microwires.

Physical parameters of interest are line densities such as:

Longitudinal linear resistance: $\boldsymbol{Rl}=\mathbf{lim}\Delta x-0\Delta R\Delta x$ [Ω/m]

Longitudinal linear inductivity: $\boldsymbol{Ll}=\mathbf{lim}\Delta x-0\Delta L\Delta x$ [H/m]

Transversal linear capacitance: $\boldsymbol{Cl}=\mathbf{lim}\Delta x-0\Delta C\Delta x$ [F/m]

Transversal linear conductance: $\boldsymbol{Gl}=\mathbf{lim}\Delta x-0\Delta G\Delta x$ [S/m]

Elementary tension falls on resistance: $\boldsymbol{duf}=\boldsymbol{Rl2idx}$

Elementary magnetic flux of scheme of length dx: $\boldsymbol{d\Phi}=\boldsymbol{Llidx}$

Elementary electrical charge on conductor surface: $\mathbf{dq}=\boldsymbol{Clidx}$

2. Preliminary calculations:

- The resistance of copper microwires (1 meter long) of 8 different diameters is calculated using equation $R = \rho\frac{l}{S}[\Omega]$, provided resistivity constant ρ = 0,017 Ωm.

TABLE I.

d	S [m²]	R[ohms]
10 nm	$78,5 \cdot 10^{-12}$	$2,16 \cdot 10^{8}$
20 nm	$314 \cdot 10^{-12}$	$0,5 \cdot 10^{8}$
50 nm	$1963 \cdot 10^{-12}$	$8,662 \cdot 10^{5}$
100 nm	$7850 \cdot 10^{-12}$	$2,1 \cdot 10^{6}$
5 microns	$19,625 \cdot 10^{-6}$	$8,662 \cdot 10^{2}$
10 microns	$78,5 \cdot 10^{-6}$	$2,16 \cdot 10^{2}$
50 microns	$1962,5 \cdot 10^{-6}$	8,66
100 microns	$7850 \cdot 10^{-6}$	2.16

- Preliminary values of microwires' inductances and inductivity:

a. Bifilar inductance

$$L_b = \frac{\mu_0 l}{2\pi}\left[\frac{1}{2} + 2ln\frac{d}{a}\right] \qquad (2)$$

b. Mutual inductance between 2 parallel wires (bifilar)

$$M \cong \frac{\mu_0 l}{2\pi}\left[ln\frac{2l}{d} - 1\right] \quad (3)$$

Let l = 1 m, and $\mu_0 = 4\pi 10^{-7}$ [Hm] (void permittivity), and d = 50 nm, 100 nm, 1 µm, 10 µm, 100 µm, 1 mm, and 10 mm. (Table II)

According to the geometry presented in Fig. 7, the relation between wires and their diameter is not constantly proportional. Therefore, Table I will show compatible circuitry parameters, positive values for inductance depending on the wires‘ dimensions.

To conclude, neural networks can be made or enhanced using microwaves at a 50nm distance with the following diameters: 10 nm, 20 nm, 50 nm, 100 nm.

TABLE II.

d=50 nm	d=100 nm	d=1 µm	d=10 µm	d=100 µm	d=1 mm	d=10 mm
10 nm	10 nm	10 nm	10 nm	10 nm	10 nm	10 nm
20 nm	20 nm	20 nm	20 nm	20 nm	20 nm	20 nm
50 nm	50 nm	50 nm	50 nm	50 nm	50 nm	50 nm
100 nm	100 nm	100 nm	100 nm	100 nm	100 nm	100 nm
			5 µm	5 µm	5 µm	5 µm
			10 µm	10 µm	10 µm	10 µm
				50 µm	50 µm	50 µm
				100 µm	100 µm	100 µm

On lines where inductance appears, condition: $R > \omega L$ (1), must be respected, where $f < R2\pi L$ (2).

iv. Inorganic simulation of axons. Synaptic study application*

As basis for representing and modelling the aforementioned physical parameters and aspects, the following equivalent scheme is used:

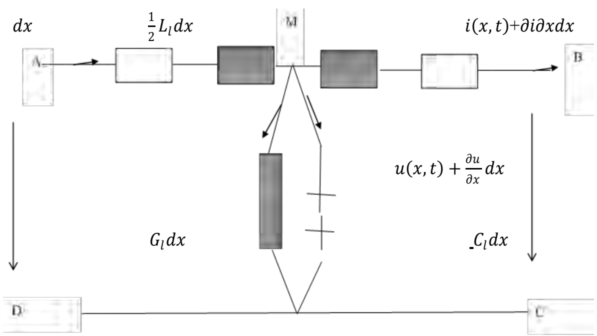


Fig. 8. Equivalent scheme of linear parameters

Using the elementary scheme in a series circuit, an axon may be modelled, utilising a nano- or microwire inorganic replacement.

In the scheme, by neglecting transversal conductance and capacitance inside circuit AMBCD, the following expression is written, as per Kirchhoff‘s 2nd Law:

$$\frac{i}{2}R_l dx + \frac{1}{2}L_l dx\frac{\partial i}{\partial t} + \frac{1}{2}L_l dx\frac{\partial i}{\partial t} + \frac{i}{2}R_l dx + u + \partial u/\partial x - u = 0$$

which becomes, after term reductions:

$$-\frac{\partial u}{\partial x} = R_l i + L_l\frac{\partial i}{\partial t}.$$

<u>Biophysical interpretation of equations and schemes:</u>

The subtracted tension u per unit length of axon line is equal to the sum of resistive tension fall and inductance, both varying on axon unit length.

Similarly, an equation for electrical currents is written:

$$-\frac{\partial i}{\partial x} = G_l u + C_l\frac{\partial u}{\partial t} \quad (3)$$

Equations (2) & (3) represent a system of first order partial derivatives in terms of voltage and current.

If instead of distance x measured from an axon‘s point of entry in a circuit, the distance: $x/=l-x$ measured from the axon‘s end is used, the equations then become:

$$\frac{\partial u}{\partial x/} = R_l i + L_l\frac{\partial i}{\partial t} \quad (4)$$

$$\frac{\partial i}{\partial x/} = G_l u + C_l\frac{\partial u}{\partial t} \quad (5)$$

Removing a variable from equations (4) & (5), *u(x, t)* or *i(x, t)* and deriving the resulting expression in respect of x, yields the telegraphers‘ equations:

- for voltage (U)

$$\frac{\partial^2 u}{\partial x^2} = R_l G_l u + (R_l C_l + L_l G_l)\frac{\partial u}{\partial t} + L_l C_l\frac{\partial^2 u}{\partial t^2}$$

- for intensity (I)

$$\frac{\partial^2 i}{\partial x^2} = R_l G_l i + (R_l C_l + L_l G_l)\frac{\partial i}{\partial t} + L_l C_l\frac{\partial^2 i}{\partial t^2}$$

The equations represent the theoretical transmission of electric currents and biophysical parameters alongside the organic course of axons.

Axons' myelinic shells complicate renderings:

Simulation of axo-dendritic myelinated circuit

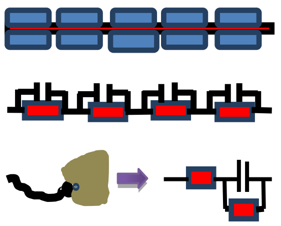


Fig. 9. Axon rendering

Fig. 10. The main scheme is conductive, where myelinic segments equal capacitances

Fig. 11. A representation of dendrites is imposed

Final circuit illustration and biophysical interpretation:

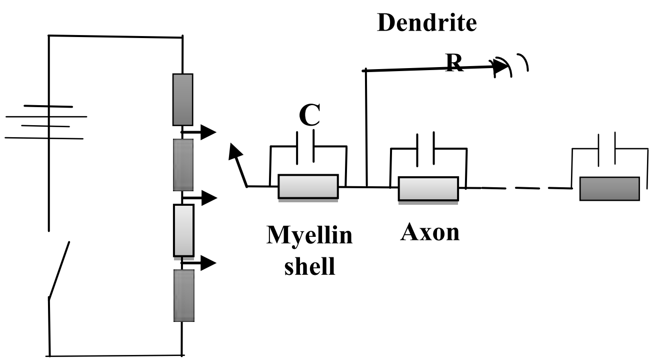


Fig. 12. Final circuit illustration

The equations simulate the theoretical transmission of electrical currents and biophysical parameters along the organic course of an axo-dendritic synapse of the human organism, where myelinic segments are equivalent to capacitance and dendrites to resistances.

The equations simplify if a linear parameter is null.

$$\text{Let } L_l = 0 \Rightarrow \begin{cases} \dfrac{\partial^2 u}{\partial x^2} = R_l G_l u + (R_l C_l)\dfrac{\partial u}{\partial t} \\ \dfrac{\partial^2 i}{\partial x^2} = R_l G_l i + (R_l C_l)\dfrac{\partial i}{\partial t} \end{cases}$$

*C. Electrodes *(edited for length & detail)*

Developing neurostimulant microtechnologies using microwires induces possible advances in electrotherapy, implicitly the stimulation of atrophied muscles, organs or tissues. Therefore, microwires may be used in the fabrication of microelectrodes and microtechnologies for the rehabilitation, improving, or regaining of muscular activity/sanguine circulation *etc*.

*D. Microanalysis devices**

Microanalysis devices can be devised using microwires as components. In medicine, they may be used to detect high glycemia levels in sweat, once introduced in clothing items. Their sparse dimensions allow them to be woven in textiles or medical micro-devices/machinery. Therefore, microwires can be used in developing symptomatic and preventive medical treatments.

*E. Security and authentication applications**

E.1. Antitheft

Alarms can be developed out of microwire, which could discreetly be introduced in item tags or /luxury items.

E.2. Authentication and control

As security is crucial in most institutions and industries, microwires are useful in developing innovative, subtle, yet counterfeit-proof identification techniques that can ensure the integrity of valuable information, technology, prototypes etc. Ferrous microwire systems, once inserted in access key cards/document seals can be authenticated utilising the aforementioned ferromagnetic microsensors.

E.3. Monetary authenticity

A standard microstructure made of woven microwire patterns (similar to previous concept) may be introduced into monetary printing presses, thus preventing fraud.

*F. Electromagnetic shielding**

Electromagnetic shielding is the practice of reducing an electromagnetic field surrounding an object by blocking it with metallic barriers, commonly metal sheets forming gaskets or Faraday cages made using copper wire mesh.

Shielding is typically applied to enclosures to isolate electrical devices/cables from their surroundings.

Electromagnetic shielding that blocks radio frequency (RF) electromagnetic radiation is known as RF shielding. RF entails coupled electric and magnetic fields, the previous exercising force on a conductor's electrons. As such, an electric current determining the flow of electric charges, cancels out the applied field. The end result is reflexion on the conductor's surface. The advantageous dimensions, flexibility, and inductance of microwires determine their versatile technological applications, including their usefulness as components in electromagnetic shielding (Faraday micro-cages).

*G. Electrical microcomponents fabrication**

The physical properties of microwires determine their prospective use in fabricating electrical microcomponents necessary in microtechnologies and circuit elements.

*H. Plane-geometry heating microsystems**

Given their dimensions, microwires can be woven in textile materials/inserted in various structures, which, in conjunction with their strong electric-thermic effect, deems them useful in surface heating or in fabricating specialty/industrial lightweight sartorial items.

IV. CONCLUSION

As a result of the ample and varied physical properties of microwires, their applicability is vast, ranging from medicine to engineering. The Centre's researcher analyses and proposes microtechnology models accordingly, considering them future fundamental elements in improving industrial efficacity and neurostimulant biomedical treatments. Microwire-based systems are characterised by an intrinsic, cylindrical, disorganised and amorphous structure; therefore, their mass-produced use requires the furthering of current study of their properties, electric integration, and technologies. The purpose of this paper and future research efforts is the concretisation of relevant parameters in microtechnological advancements. Prototypes and experimental treatments have been introduced in this paper, industries, and further studies, yet not exhausting the ample domain of micro- and nanotechnology. The aforementioned microtechnological and regenerative contributions are viable theoretically & experimentally.

V. MAIN REFERENCES*

[1] Magnetic Nano-&Microwires, *Design, Synthesis, Properties and Applications*, Electronic & Optical Materials, Manuel Vasquez, 2015.

[2] Acheson, Elementary Fluid Dynamics, Oxford Applied Mathematics &Computing Science Series, Oxford Univ. Press, 1990.

[3] Mathematics of the Faraday Cage, S. S. Jonathan Chapman David Hewett Society for Industrial and Applied Mathematics, 2015, Oxford University Press.

[4] Course on boundary layer equations, Dr. Ing. Tudor Baracu, Polytechnic Univ. of Bucharest.

[5] Electrochemistry – Theoretical principles, Atanasiu, Facsko, Ed. Tehnică Bucharest 1958.

[6] Physiology, Prof. Dr. Doc. Petru P. Groza, Ed. Medicală 1991.

[7] Electric contact theory-Electric machinery, Hortopan, 1986.

[8] Electric Contacts - Ragnar Holm, Ed. John Wiley, 1956.

[9] Biomedical applications of glass-coated microwires, Journal of Magnetism & Magnetic Materials, Kozejova, Fecova, Klein.

[10] Bulletin of Micro- and Nanoelectrotechnologies, INCDIE ICPE-CA.

[11] Research of electromagnetic absorption properties of microwires, Avram, Dimitrachi, Kolpakovici, Balanici, Beregoi, Univ. Tehnică din Moldova.

[12] C. I. Mocanu, Electric circuit theory, ed. Didactică și pedagogică, 1979.

[13] C. I. Mocanu, Electromagnetic field theory, Editura Didactică si pedagogică, 198117.

[14] Glass isolated microwires, National Institute for research in Technical Physics – Iași.

[15] Weldon Owen, Trip inside the Human Body Ed. Arthur, Bucharest, 2009.

VI. ACKNOWLEDGMENTS

Special thanks are due to Digital Spirit for supporting Romania's delegation for the Regeneron International Science and Engineering Fair 2020. Outstanding gratitude to the National Institute for Research & Development in Electrical Engineering for guiding student research efforts.

VII. BIOGRAPHY

Ioana Iordan is a student currently in the 12th grade at the ―Spiru Haret" National High School in Bucharest, Romania, where she primarily studies Physics and Mathematics. Next year, as a college freshman, she will continue studying Physics and Astrophysics, beginning an academic career in scientific research.

Alongside her formal education, she is a member of the ―Alexandru Proca" Centre for the Youngsters Initiation in Scientific Research, division of the National Institute for Research and Development in Electrical Engineering ICPE-CA.

Scholarly achievements of hers include winning the First Place Award at the Romanian Science and Engineering Fair, as well as qualifying for the following International Science and Engineering Fair.

In her spare time, she reads literature and philosophy, debates, and fronts her school's guitar and photography groups.

The Design of an Exoskeleton for the Rehabilitation of the Finger Movements

Cristian-Robert Zanfir
University Politehnica of Bucharest, Splaiul Independenţei 313, Bucharest 060042, Romania,
cristiano_robert97@yahoo.com

Abstract - The purpose of this project is building a device especially designed for persons with certain disabilities of the fingers, in order to help them regain total or partial movement control. This study will show an exoskeleton type of model, which assists the patient for a quicker and more efficient recovery.

Index Terms - exoskeleton, rehabilitation, stroke.

I. INTRODUCTION

In the whole world, there are a lot of persons who live with some kind of disability. Among those persons, there is a big number of persons who suffer from motor disabilities. Therefore, their recovery represents a very important challenge, which means helping and improving the quality life of those patients, with the help of classic physical therapy or by using new technologies in the rehabilitation centers.

The main object of this paper is to build a device that can be used for the rehabilitation of the finger‘s mobility. The rehabilitation has the purpose of treating or amelioration of a certain condition, by using traditional technics of physical therapy or new technics of rehabilitation.

Innovations in the domain of robotics have led to significant improvements of the traditional means of rehabilitation. So, the precision, repeatability, control and accuracy of the movements of a robotized system can offer patients very detailed rehabilitation routines. Usually, those systems are the exoskeleton type, which are placed on the patient‘s joints, helping him to perform the rehabilitation routine and to supervise the processes necessary for the recovery. In a lot of countries, the disabilities and lesions of the fingers are caused by cerebrovascular accidents, neuro-muscle-skeleton diseases, such as tetraplegia, hemiplegia, tendinitis, broken bones and degenerative diseases, such as arthritis, which affects the movement of the fingers. To ameliorate these diseases, passive and active physical therapy treatments are used, in order to avoid permanent deterioration of the joints. Passive assisted recovery requires a physical therapist who will repeatedly apply moves of flexion and extension on the patient‘s fingers, while the purpose of active rehabilitation is using flexibility and stretching exercises, specific for certain lesions [1].

In this paper we will follow aspects related to building and the functionality of an exoskeleton, as well as medical aspects in order to properly understand the needs of the patient.

II. MEDICAL RESEARCH AND STUDIES

In order to understand the approach that the physical therapists use during the rehabilitation process, we must present some anatomical and physiological aspects of the hand, which hold great importance in the first steps of building the exoskeleton.

The hand is the region of the upper limb, distally situated from the radiocarpal joint.

It contains three parts:
- carpus (the region);
- metacarpus (the region);
- fingers (five fingers including the pollex).

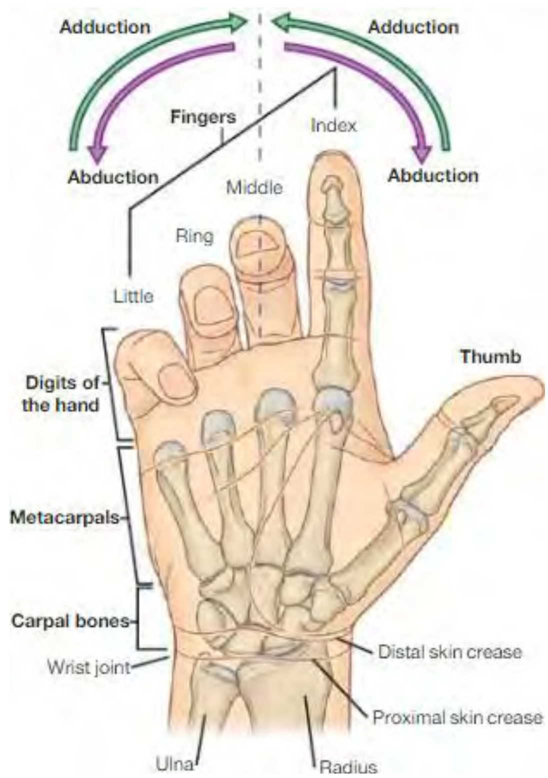


Fig. 1. The hand, in the anatomical position; the fingers are straight in adduction

The five fingers are represented by: the pollex situated on the side, and medially situated form them, the four fingers: index finger, middle finger, ring finger and little finger.

The abduction and adduction of the fingers are defined by reporting to the long axel of the middle finger. In anatomical position, the long axel of the pollex is rotated at 90^{o} from the other fingers so that the volar face of the pollex faces medial: in consequence, the pollex's movements are made in a perpendicular plan from the movements of the other fingers.

The hand has a mechanical and a sensorial role. A lot of the traits of the upper limb are destined to facilitating the positioning the hand in space.

Bones

The hand has three categories of bones:
- eight carpal bones-the bones of the wrist;
- five metacarpal bones (I-V)-the bones of the metacarpus;
- phalanges-the bones of the fingers- the thumb has two, while the others have three.

The carpus bones

The carpus bones are small and are arranged on rows, proximal and distal, each one containing four bones.

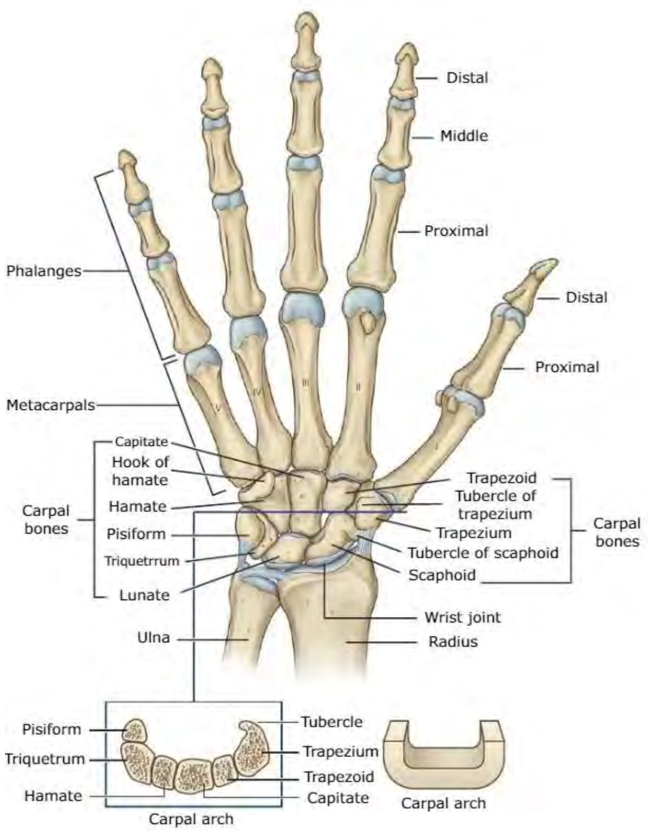


Fig. 2. The bones of the hand

Metacarpals

Each metacarpal corresponds to a finger:
- metacarpal I - corresponds to the pollex;
- metacarpal II-V correspond to the other four fingers.

Phalanges

Phalanges are the bones of the fingers:
- the pollex has two phalanges (proximal and distal);
- the other fingers have three phalanges (proximal, medium and distal).

Muscles

The intrinsic muscles are: the short palmar, the interosseous muscles, the pollex's adductor, the thenar muscles, the hypothenar and lumbar muscles. In contrast to the extrinsic muscles of the hand, which start at the forearm and insert themselves into the hand and interfere in the grabbing movements which require more force, the interosseous muscles are located strictly on the hand and interfere in the fine prehension with the fingers and the pollex [2].

III. THE MOVEMENTS OF THE FINGERS

Flexion and extension

Those movements are executed around a radioulnar axis which goes through the head of the metacarpals. In flexion, the first phalange inclines on the palm of the hand just like in the closing of the fist, and in extension it moves away from that. These movements are produced either simultaneously, or isolated in the three joints of the fingers.

The lateral tilt

Through this move, the phalange can be moved in the ulnar direction (adduction) or radial (abduction) around the dorsal-palmar axis which goes through the head of the metacarpals. This marginal tilt movement is possible only with the fingers in extension.

Circumduction

It results from the successive execution of the before described movements: flexion, ulnar tilt, extension, radial tilt or vice versa [3].

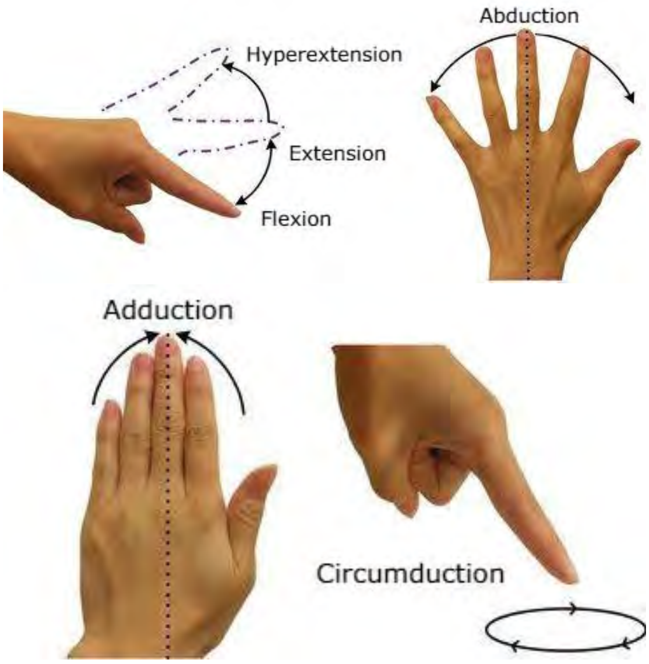


Fig. 3. Types of movements of the fingers

IV. KINEMATIC DATA

Regarding kinematics, the hand is a kinematic chain, open starting from the wrist and finishing with the joints of the fingers. Thanks to the specific structure of the human joints, only the rotation movements are possible. If you structurally analyze the hand as a biomechanism, the individual bones are considered mobile pieces, as well as their combinations as kinematical pairs of different classes. It is said that every group of science men who studied the biomechanics and kinematics of the hand, especially the simplifying of the mechanism, have reached different descriptions which vary, particularly the number of degrees of release of the model. In 2008, Sobos presented a model of the hand, containing 19 links that imitate human bones and 24 degrees of release representing the joints [4].

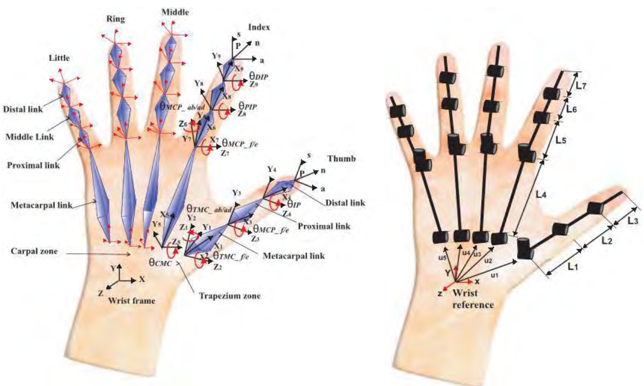


Fig. 4. Kinematic chains of the fingers

V. COMMERCIAL SOLUTIONS

WaveFlex

WaveFlex (QAL Medical) is a commercial device used for passive continuous movements for hand physical therapy. An electric motor is use for actuation. This device achieves a full range of movements of flexion and extension using a drive bar and attachments for the fingers, to assist them through a natural path to achieve a good movement. WaveFlex is portable and light, this thing allows is to be worn for long periods of time and it is also adjustable for different finger lengths, using attached finger clips. This device is also capable of measuring the interaction force. When the interaction force exceeds a certain threshold during motion, the ‗reverse-on-load‘ function controls the device to move in the reverse direction, in order to prevent overloading the user‘s fingers. The user can use this device for moving the pollex as well. However, it is not possible to move the pollex simultaneously with the other fingers [5].

Fig. 5. WaveFlex

VI. EXPERIMENTAL SOLUTIONS

HandSOME

This prototype is a passive device which has the role of giving an extension moment to the finger‘s joints so that it compensates the finger hypertonia caused by a stroke. It is designed to follow the normal kinematic trajectory of the hand during grabbing, offering a prolonged extension torque profile, which compensates the finger hypertonia. A hydraulic mechanism which contains four bars was designed for the pollex and the other fingers to coordinate with precision the natural gesture of grabbing [6].

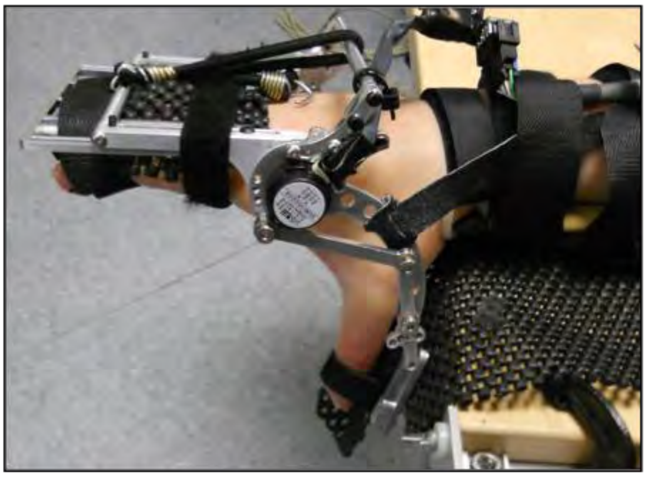


Fig. 6. HandSOME

VII. MECHANICAL SCHEMES

Depending on the specific application of the rehabilitation system (for example: rehabilitation protocols, the patient‘s pathology, object manipulation) the design must face a wide range of options, such as: the mechanism kinematics, the actuation and transmission system, the control sensors, etc. Despite the main decision, other decision show up, that entail both advantages and disadvantages which affect other aspects of the design.

From the mechanical design point of view, the main specification that must be defined refers to the mobility of the system. Indeed, based on the specific applications, the designer must choose, in the first place, how many mechanisms will the recovery system form, and how many degrees of freedom will be independently controlled. A rehabilitation system can fully control the patient‘s hand only if it has 20 active degrees of freedom (four degrees for each finger). On the other hand, the hardware components and the device control must be taken into consideration, because a very complex system might be formed. Alternative solutions can be obtained by worsening the functionality and versatility, controlling a small number of degrees of freedom, thus limiting the complexity of the system. In order to define a systematic criterion of classification, the attention can be placed on the number of degrees of freedom controlled by the mechanism, represented on the index, offering 5 groups of different rehabilitation systems, from 0 (for the passive devices) to 4 degrees of freedom, in figure 7 there are presented the schemes which illustrate the different exoskeleton mechanisms, sketch 1 has 1 to 3 controllable degrees of freedom (symbolizing the activation of the wrist) [7].

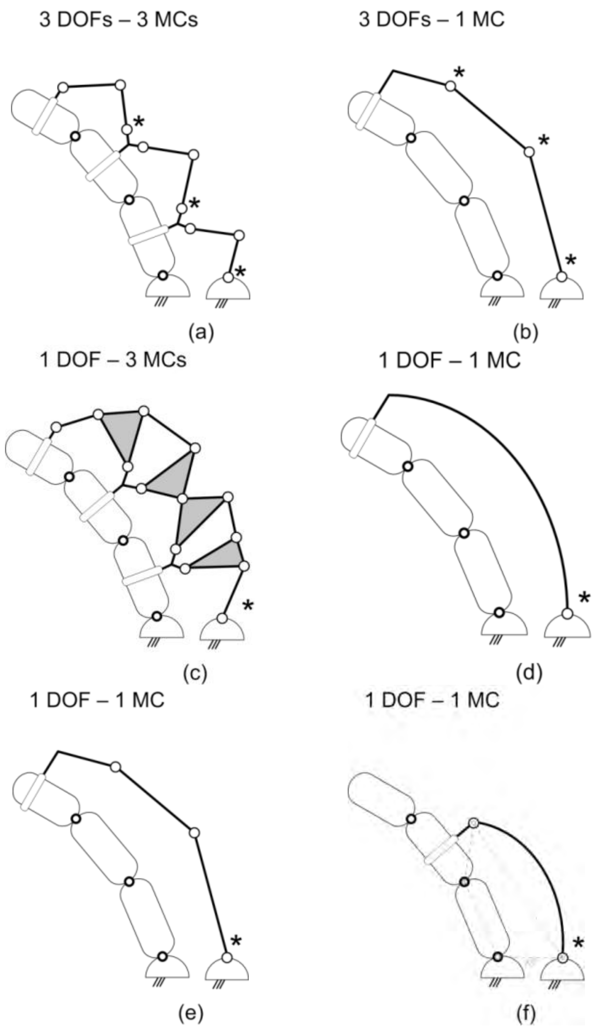


Fig. 7. Scheme of common mechanisms with 1 or 3 degree of mobility (DOFs) and 1 or 3 mechanical connections (MC). Star symbols indicate joint actuation. (a) external/integrated; (b) External/Stand-Alone; (c) external/integrated; (d) External/Stand-Alone; (e) external/integrated; (f) external/integrated

VIII. THE EXOSKELETON

Examining the previously described mechanisms and the commercial devices, the building of a prototype was achieved, which has the purpose of rehabilitating the finger‘s movements, or, in the case of paralyzed persons (at finger level), to help in grabbing objects. The exoskeleton built in this paper has the following components: a system of mechanical connections which allow 3 degrees of mobility and is especially designed for the patient‘s fingers, a motor that will help the movements of the fingers, an Arduino type of board for programming the motor to execute certain moves, and a potentiometer that will help vary the motor‘s rotations for actioning the mechanical connections system.

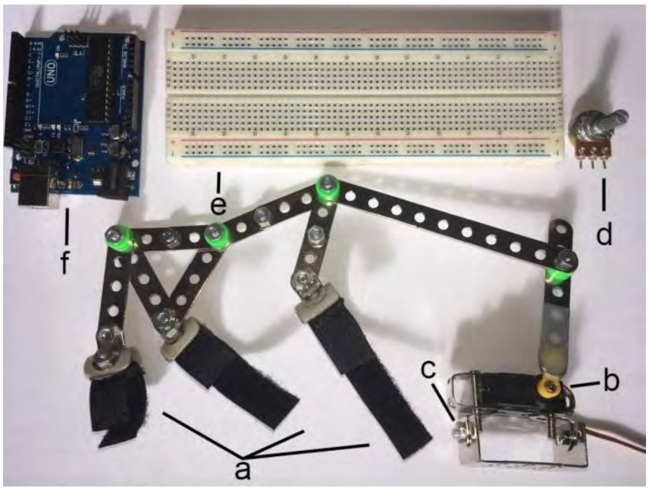


Fig. 8. The main components of the prototype, where: a) the system of mechanical connections; b) Motor; c) engine holder; d) potentiometer; e) Breadboard; f) Arduino Uno R3

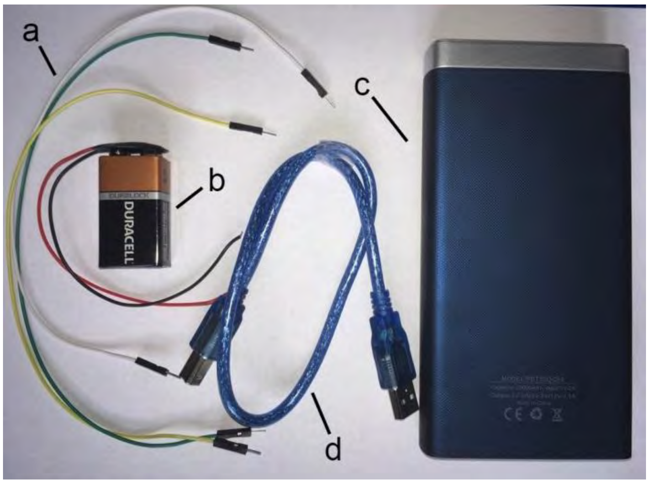


Fig. 9. The secondary components of the prototype, where: a) wires; b) 9V battery; c) power cord; d) External Battery

The main purpose of this exoskeleton is to assist the patient during the rehabilitation process of the fingers. During the process of building the prototype, the main diseases that were taken into consideration were strokes, broken bones or muscles and paralysis. So, one of the main problems in rehabilitation at this level was the personnel which will make sure that the patient learns the procedures, the device having the purpose of reducing the number of physical therapists and the time of execution of a rehabilitation program. Being an easy to use device, the physical therapist should not spend the whole time with the patient, and he would only come at the end of the session to see the made improvements, and the execution time of the procedure would be smaller for the patient.

Another important criterion that was taken into consideration is the size and weight of the device. So, it having relatively small dimensions and a small weight, it shouldn‘t cause any discomfort to the patient.

This prototype was also built to be used by patients at home or in other places, so going to the hospital or admitting the patient is no longer necessary, leading to smaller costs for rehabilitating patient with these conditions.

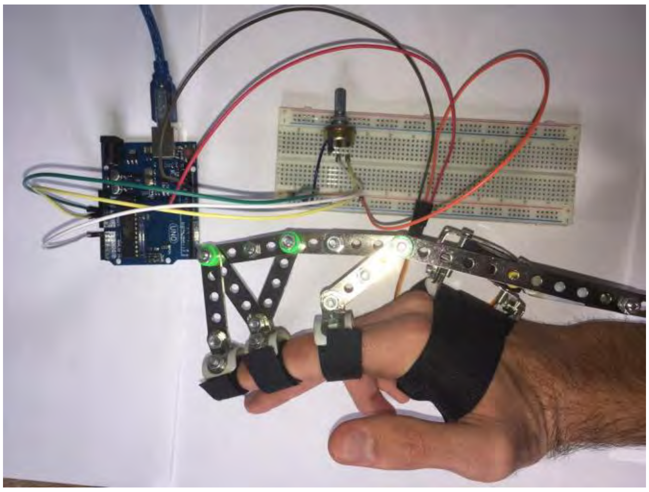
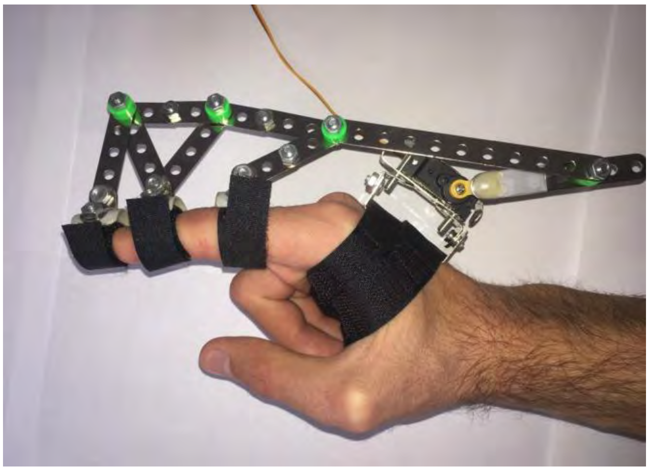
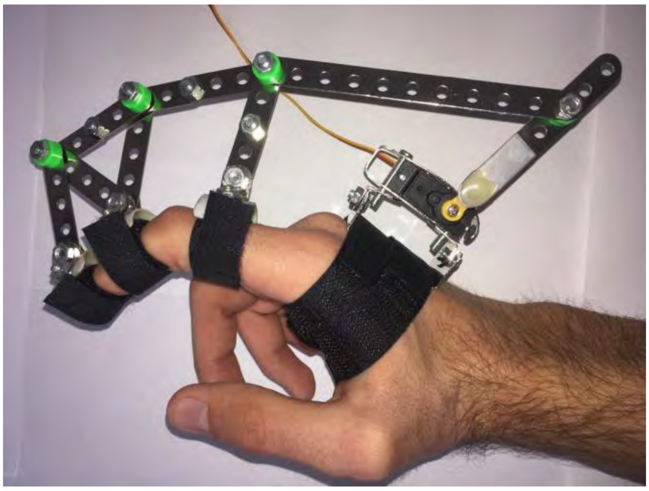


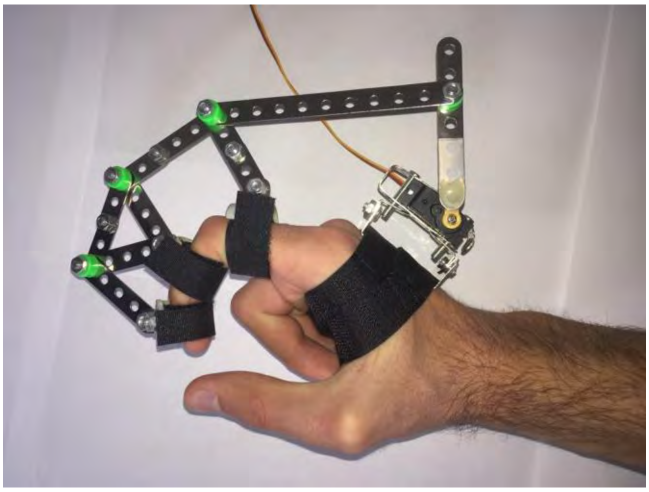
Fig. 10. The final prototype

Through its specific design, this exoskeleton can exercise a force strong enough to hold small sized objects with relatively bigger weights. It is built as a module, meaning it can be used on the all the fingers, except the pollex, because the pollex requires a reconfiguration in order for the exoskeleton to only have two degrees of freedom. It can be easily controlled, having only the possibility to vary a potentiometer that will rotate the motor, which has a 180-degree limit angle, and the possibility to block the exoskeleton when we don‘t vary the resistance of the potentiometer. The alimentation is realized using an external battery or one of 9 V.

Figure 11 shows all the positions that the exoskeleton can perform, showing the high possibility of executing the flexion and extension of the finger, with the aid of the exoskeleton‘s motor, which can be locked in a certain position in order to help the patient to exercise the flexion and extension until he feels the limitation produced by a disease, this thing helping the gradual recovery, using a kind of training which is based on overcoming the previous limit. By direct actuating without stopping the flexion-extension movements during the recovery, the patient can regain control of the finger faster, especially if he suffered a stroke and lost partial capacity of moving one or more fingers.







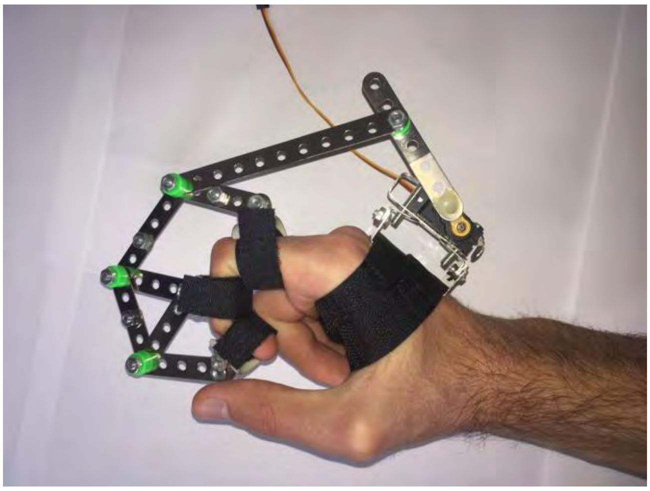


Fig. 11. The different positions that the exoskeleton exercises over the finger

All those specifications have been thought in order to help the patient as much as possible during recovery, and to be easy to use during any activity. For the paralyzed persons it is a simple method to recover movement and to exercise activities by themselves with the help of another person.

IX. TECHNICAL DATA FOR THE MOTOR

- Operating temperature: -10~ +50 degrees Celsius;
- Operating tension: 4.5 V – 6 V;
- Operating speed (without charge): 0.11 seconds/ 60 degrees – 4.8 V, 0.08 seconds/60 degrees – 6 V;
- Empty current: 130 mA – 4.8V, 140 mA – 6V;
- Couple in lockup: 1.2 kg*cm – 4.8 V, 1.5 kg*cm – 6 V;
- Current in lockup: 670 mA - 4.8 V, 830 mA - 6 V;
- Empty current consumed: 4 mA – 4.8 V, 5 mA – 6 V;
- Limit angle of rotation: 180 ± 10 degrees;
- Rate of the redactor: 1/265;
- Control with PWM;
- Dimensions: 31.7 x 12 x 22.9 mm.

X. CONCLUSION

The approach of this project had as a main role the understanding of all the stages involved in building an exoskeleton, starting from the anatomy of the hand to the engineering mechanisms used in designing the prototype. By using all the elaborated knowledge for this thesis, building a device for the rehabilitation of a person with disabilities of the hand was very intuitive.

XI. PLANS FOR THE FUTURE

A very important thing that should be improved would be compacting the control components, such as: using a small sized microcontroller, and all the linking components to be placed in a case which will be positioned on the forearm.

Another aspect is that the exoskeleton should be designed using technical drawing with very precise quotas, and, after that, the model should be printed using a 3D printer.

An improvement would be the creation of a monitoring algorithm of the patient‘s movements with the help of a camera, and with the use of virtual reality, the patient to be able to interact with certain objects from the virtual space, and the exoskeleton to be adjusted so that it can observe the patient‘s incapacity to move the finger in certain positions and to help him in executing those movements as precisely as possible.

XII. REFERENCES

[1] Oscar Sandoval-Gonzalez, Juan Jacinto-Villegas, Ignacio Herrera-Aguilar, Otniel Portillo-Rodiguez, Paolo Tripicchio, Miguel Hernandez-Ramos, Agustín Flores Cuautle, and Carlo Avizzano, Design and Development of a Hand Exoskeleton Robot for Active and Passive Rehabilitation.

[2] Richard L. Drake, A. Wayne Volg, Adam W.M. Mitchell. Gray‘s Anatomy pentru studenti- paginile: 751-755, 762-763, 651.

[3]http://www.qreferat.com/referate/medicina/BIOMECANICA-ARTICULATIILOR-MAI919.php.

[4] Journal of Technology and Exploitation in Mechanical Engineering Vol. 3, no. 1, pp. 28–33, 2017 BIOMECHANICS OF THE HUMAN HAND-Łukasz Jaworski, Robert Karpiński.

[5] http://qalmedical.com/wp-content/uploads/sites/28/2013/08/QAL-Med-6000X-WaveFlex-SS.pdf.

[6] Pilwon Heo, Gwang Min Gu, Soo-jin Lee, Kyehan Rhee and Jung Kim. Current Hand Exoskeleton Technologies for Rehabilitation and Assistive Engineering.

[7] Marco Troncossi1, Mohammad Mozaffari-Foumashi and Vincenzo Parenti-Castelli. Journal of Robotics and Mechanical Engineering Research. An Original Classification of Rehabilitation Hand Exoskeletons.

VIII. BIOGRAPHY

My name is **Cristian-Robert Zanfir**, and I‘m a student at University Politehnica of Bucharest within the Faculty of Medical Engineering, in the final year of studies. As part of my diploma project, I will build an exoscheleton for the rehabilitation of the mobility of the fingers.

After completing my studies, my goal is to get a job in a company as an engineer, working on the maintenance of medical devices.

Unconventional Micro-Accelerometers for Nanosattelite Specific Attitude Control Sytems

Ştefan Ursu
―Alexandru Proca" Center for the Youngsters Initiation in Scientific Research, INCDIE ICPE-CA
Splaiul Unirii, No. 313, District 3, 030138, Bucharest, Romania
stefan.ursu303@gmail.com

Abstract - This paper presents the development and design of unconventional micro-accelerometers that can be used for nanosatellite attitude control systems. We hope that the designed micro-accelerometers will bring better operational performances and will be able to withstand the conditions specific to the space environment. To improve the micro-mechanical contact between the proof mass and the active element, magnetic inertial masses have been proposed for the micro-accelerometer unconventional structure. Three other structures without magnetic proof masses have been proposed and approached for which experimental models were designed and developed. The experimental models have been tested with specific methods. At this moment the research project is unfolding and the developed micro-accelerometers are in a calibration procedure on a specific stall using a Modal Shop vibration exciter and a Mixed Domain Tektronix Oscilloscope.

Index Terms - Micro-accelerometer, Nanosatellite, Electrostriction, Piezoelectricity, Attitude Control System.

I. INTRODUCTION

Nanosatellites are undersized artificial satellites with a mass between 1kg and 10kg. Nanosatellites and microsatellites are often launched in groups called ―swarms" or „clusters". Nanosatellites have several advantages over conventional satellites, such as lower cost of manufacturing and launching, ease of mass production, minimal financial loss in case of failure and the ability to be launched in groups or "piggyback" along with larger satellites. Nanosatellites have increased the accessibility of terrestrial orbit both for scientific purposes and for commercial or even military purposes. Thus, the number of nanosatellite launches increases each year and it is estimated that in the near future their number will exceed the number of conventional satellites. Implicitly, this growing popularity of nanosatellites in the astronautics industry has increased the demand for development and innovation of technology and components specific to nanosatellite systems.

Among the most important components of a nanosatellite is the attitude control system (ACS) that allows the satellite to orient itself in the desired direction and maintain a stable position relative to an inertial or non-inertial reference system. In the absence of a quality guidance system, perturbation forces will destabilize the satellite and will involuntarily change its attitude, leading to loss of signal between the satellite and the ground control center.

The aim of this research project is to achieve a very agile, sensitive and high-performance unconventional micro-accelerometer that can sustain hostile conditions specific to the space environment.

Considering the dimensions of a nanosatellite (the reference dimension is 10x10x10 cmxcmxcm), the research topic proposes the research of unconventional types of micro-accelerometers for attitude control systems, where the active element is either a piezoelectric material (conversion according to piezoelectric direct effect) or a dielectric elastomeric material where the electrostrictive effect is present.

The approach of this theme includes:

- *A study of nanosatellite specific attitude control systems based on detailed documentation followed by a comparative commentary for the different types of systems including the parameters and characteristics of these systems.*
- *Calibrating the experimental models and determining the technical specifications of the developed micro-accelerometers.*
- *Identifying a design algorithm for these types of sensors.*
- *Identifying micro-technologies specific to these types of acceleration sensors.*
- *Developing experimental models.*
- *Specific tests related to the operating domain,*
- *Research on conversion method, sensitivity and, static and dynamic operational characteristics.*
- *Identifying errors that occur in determining accelerations.*

II. HYPOTHESIS

The hypothesis of this research project is that the designed micro-accelerometers with unconventional structure will have better performances than the conventional piezoelectric accelerometers and will overcome the hard conditions specific to the space environment.

III. ATTITUDE CONTROL SYSTEM (ACS)

An Attitude Control System consists of three main elements: sensors, controller, and actuators. An ACS system can apply two types of maneuver: tracking mode and attitude hold. The tracking mode involves maintaining the attitude of the microsatellite in relation to an external reference system (such as the celestial bodies or the center of the earth) constant. Instead, the attitude maintenance maneuver, as the name indicates, maintains constant attitude in relation to a non-inertial reference system.

When sensors detect a change of attitude in relation to the chosen reference system (inertial or non-inertial), the controller emits three error signals (one signal per axis) that is decreasing as the attitude returns to the initial position. Actuators (the driving element) are controlled through control algorithms by the controller for guiding the nanosatellite in the required direction.

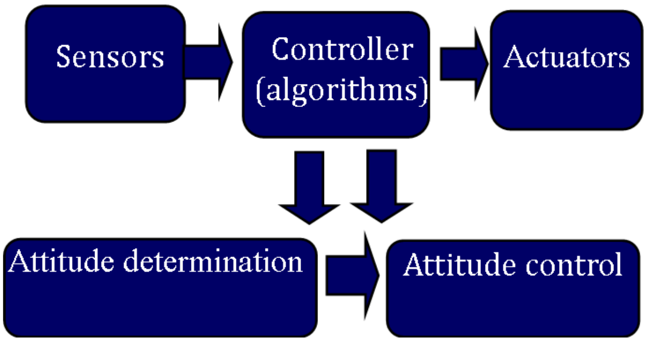


Fig.1. The operating diagram of the ACS system

IV. INERTIAL NAVIGATION SYSTEM (INS)

The inertial navigation system is a configuration of different sensors that uses a computational method to determine the position of the nanosatellite in the orbit and its attitude (orientation) without the need for external resources such as GPS or radio-location. Such an inertial navigation system is very important because the information provided can be used to determine the parameters of the orbit and if there is a risk of entering a graveyard orbit. Also, the navigation system could determine the attitude of the satellite and its variation replacing the need for an ACS system

A conventional inertial navigation system is composed of two sensor configurations. The first configuration consists of accelerometers with orthogonal sensing axes and the second configuration consists of gyroscopic sensors (for 6 degrees of freedom). Accelerometers are used to determine the distance traveled by the nanosatellite and the gyroscopic sensors are used to determine orientation. Along with an algorithm, the controller will be able to determine its position in orbit.

V. CONVERSION MODE

The proposed structure for the micro-accelerometers is composed of three main elements: inertial mass, active element, and planar electrodes.

When acceleration appears along the sensitivity axis of the microaccelerometer, the inertial mass will be induced acceleration and will apply pressure onto the active element. Based on the direct piezoelectric or electrostrictive effect, the active element, consisting of a piezoceramic plate or a dielectric elastomeric polymer will polarize and an electric voltage signal proportional to the acceleration will go through the electrodes. Thus, measuring the signal we can determine the acceleration with accuracy.

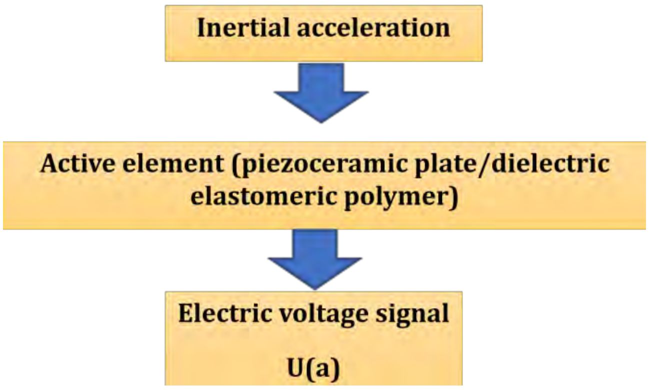


Fig. 2. The proposed conversion mode diagram

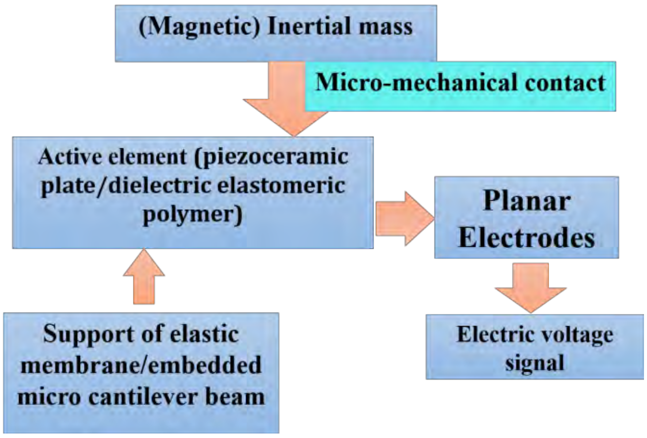


Fig. 3. The micro-mechanical structure of the designed micro-accelerometers

The mathematical model for the movement of the inertial mass is:

$$M\frac{d^2x}{d^2t} = M\frac{d^2x}{d^2t} + c\frac{dx}{dt} + kx \quad (1)$$

with, x - nanosatellite movement axis; c - active element's damping factor; k - elastic constant of the active element.

A. Piezoelectric effect

Piezoelectricity represents the linear interaction between mechanical and electrical systems in non-centric crystals or similar structures. The direct piezoelectric effect may be defined as the change of electric polarization proportional to the strain. A material is said to be piezoelectric if the application of external mechanical stress gives rise to dielectric displacement in this material. This displacement manifests itself as an internal electric polarization. The piezoelectric effect is strongly depending on the symmetry of the material. [1]

The electro-mechanical relationships between the stress vector (T_i) and the electric field strength vector (E_i) or the electric polarization vector (P_i), specific for the piezoelectric effect, are:

$$P_i = d_{ij}T_i \quad (2)$$
$$E_i = g_{ij}T_i \quad (3)$$

where, d_{ij}/g_{ij} are the piezoelectric coefficients.

When acceleration will appear along the sensitivity axis of the micro-accelerometer, the piezoelectric element will give the output voltage:

$$U_{piezo} = \frac{g_{33}tF}{A} = \frac{g_{33}tma_s}{A} = \frac{d_{33}ma_s}{C} \quad (4)$$

Where, t represents the thickness of the piezoceramic plate, F represents the force that is applied on the piezoelectric plate, C represents the electrical capacity of the accelerometer, A represents the piezoelectric plate section area, m represents the mass of the inertial body and a_s represents the acceleration.

B. Electrostrictive effect

Electrostriction represents the property of all dielectric materials and is caused by the displacement of ions in the crystal upon being exposed to an external electric field. Positive ions will be displaced in the direction of the field, while negative ions will be displaced in the opposite direction. This displacement will accumulate throughout the bulk material and result in an overall strain (elongation) in the direction of the field. [2] For sensing systems we use the direct electrostrictive effect (stress-electric charge).

The electro-mechanical relationships between the strain S, electric field strength E and the electrostrictive coefficient K_{els} is:

$$S = K_{els}E^2 \quad (5)$$

VI. PROPOSED STRUCTURES

A. Magnetic inertial mass micro-accelerometer

A very important aspect of the structure of a piezoelectric micro-accelerometer represents the contact between the inertial mass and the active element. When there is no good contact between the two elements, there will be mechanical errors that will lower the precision of the sensor. To improve contact, permanent magnetic inertial masses (neodymium magnets) have been used that attract each other in the structure and apply initial mechanical stress on a dielectric elastomeric plate equally on both sides, creating an initial contact area. When acceleration will be induced onto the proof mass, the contact area between the two elements will increase or decrease (in case of negative acceleration).

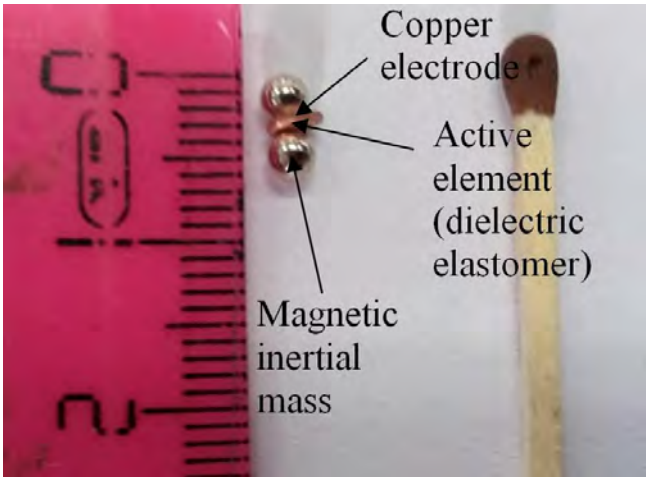


Fig. 4. Second generation of experimental models micro-accelerometers with magnetic a 3 mm diameter spherical inertial mass

The advantage of this micro-accelerometer is that the magnetic inertial masses are unconstrained and can represent better vibrations and accelerations (better than the conventional piezoelectric sensors with constrained proof masses) and can offer high sensitivity and better operational performances.

Inside the National Research and Development Institute in Electrical Engineering INCDIE ICPE-CA, several profile graphs have been realized using a Veeco interference microscope for studying the contact area between the elastomeric active element and the magnetic microspherical inertial masses.

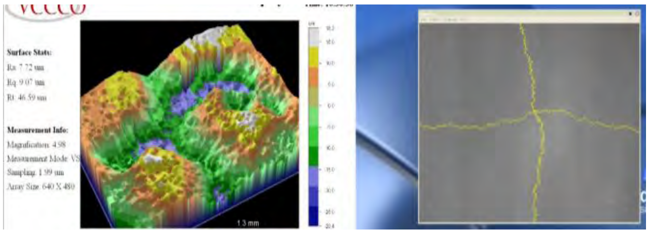


Fig. 5. A profile graph image of the contact surface of the active element realized using a Veeco interference microscope.

Further work

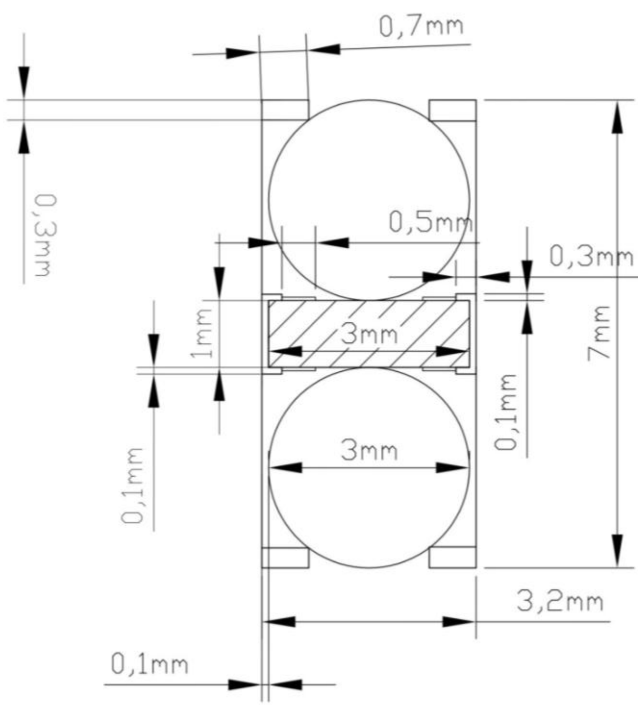


Fig. 6. The design of the third generation of magnetic proof mass micro-accelerometers (Autocad 2007)

At this moment we are working developing the third generation of unconventional micro-accelerometers that includes new elements in the structure. The active element will be circular embedded to increase sensitivity, and the magnetic proof masses will be fixed using fastening rings. The fastening ring will have the role to prevent the motion of the proof masses in other directions apart from the sensitivity axis. Otherwise, this motion can create additional instrumental errors created by the frictional force.

B. Elastic membrane structure

Building the experimental model

A copper-beryllium alloy membrane was attached to a fastening ring. On the membrane, a piezoceramic plate coated with a planar electrode was mounted as an active element. On the top of the active element, a cylindrical proof mass has been mounted (10 g mass).

Fig. 7. The first generation experimental model accelerometer on an elastic membrane structure

The elastic membrane acts as a support for the active element and the proof mass, increasing the sensitivity of the accelerometer. Also, the elastic membrane has the role of an electrode thanks to the high electrical conductivity of the alloy.

Compared to the structure with the embedded micro-cantilever beam, this structure is much more rigid by the presence of the circular embedding of the membrane.

C. Micro-cantilever beam structure

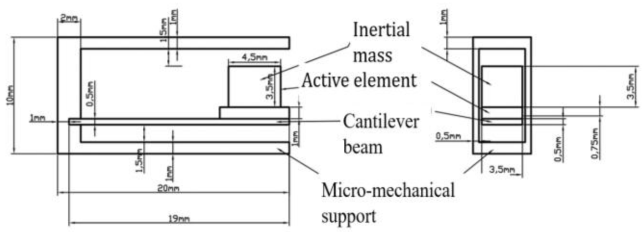


Fig. 8. The design for a micro-accelerometer on a micro-cantilever beam structure (Autocad 2007)

At the end of an elastic microcantilever beam, embedded in micromechanical support, the active element is mounted on which two planar electrodes are placed on both sides. An inertial mass is fixed on the active element. The two planar electrodes are attached to electrical connections to transmit the output signal. To reduce the noise signal, the entire microaccelerometer will be hermetically sealed.

The role of the embedded microbeam on which the piezoelectric plate is placed is to increase the sensitivity of the microaccelerometer and to increase the measurable range of vibrations.

Instead, there is a risk that the elastic microcantilever beam on which the sensor is placed, to tear up or suffer mechanical wear at high shocks, for example on launching the nanosatellite in space, so it is important in the sizing stage to take into account the displacement and maximum stress the microbeam can bear.

D. Micro-accelerometer with deposited inertial mass

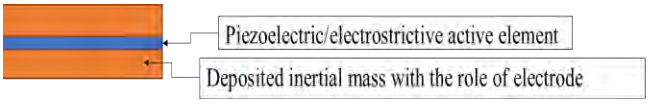


Fig. 9. The scheme of a micro-accelerometer with a deposited inertial mass structure

Another structure proposed to be developed is the "deposited inertial mass structure" where the inertial mass is deposited on the sensitive element on both sides (by means of a special apparatus) having the role of an electrode. This simple structure has the advantage that it can be undersized and can be used in picosatellite systems or NEMS technologies. Instead, the sensitivity will not be as high as the other proposed structures.

VII. MICRO-ACCELEROMETER CHARACTERISATION

After receiving signals from a sensor, these signals need to be processed. The acceptable and accurate process of these signals requires: (a) full knowledge regarding the operation of the sensors and nature of signals, (b) posterior knowledge regarding the received signals, and (c) information about the dynamic and static characteristics of the sensing systems. [3]

The static regime characteristics specific to a piezoelectric accelerometer are: Frequency response, Precision, Accuracy, Repeatability, Reproducibility, Stability, Resolution, Sensitivity

Experimental procedure: By applying using a dynamometer a series of different accelerations onto the inertial mass and measuring the resulted voltage, we could approximate the calibration slope of the developed elastic membrane micro-accelerometer.

For more precise results a vibration exciter will be used.

Based on the measurements, a calibration slope has been determined.

Discussion

We can estimate the operating range of the experimental model accelerometer on an elastic membrane structure as *0,5 g – 10 g*.

The linearity of the above calibration slope can be approximated as *1 mV*.

The maximum reported error can be estimated as *0.206*.

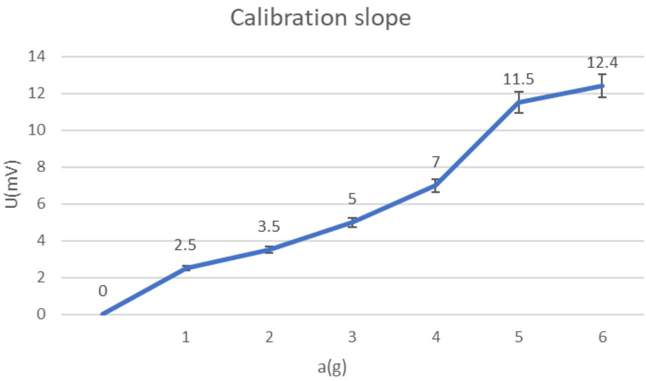


Fig. 10. The calibration slope of the elastic membrane structure experimental model

Further work

At this moment the project is unfolding in a calibration procedure on a specific stall. The developed micro-accelerometer will be attached to the head of a MODAL SHOP Inc.2060E vibration exciter and the measuring output will be connected to the Multi-Domain Tektronix Oscilloscope. The vibration exciter will be connected to a signal generator. By studying the resulted voltage on the oscilloscope according to the excited vibration, we can determine very precisely the characteristics and the vibration response of the designed accelerometers.

The more measurements we have, the more precise the calibration procedure will be. For more accuracy in this process, we may use a calibration accelerometer for comparison purposes.

It is advisable, before any calibration is performed, that the frequency response of the accelerometer is measured. This will ensure that the accelerometer will not be damaged in any way. [4]

When determining the frequency response of the accelerometer it is important that the input acceleration of the exciter to be constant in this process. The mounting of the accelerometer onto the exciter head is critical. Poor mounting can result in misleading errors in the frequency response curve.

VIII. POSSIBLE ERROR SOURCES

In this research project, we identified different possible error and noise sources that can lower the precision and operating range of the designed micro-accelerometers.

***1)* Specific errors for the designed micro-accelerometer:[5]**

- *Errors due to the variation of the piezoelectric coefficient according to temperature;*
- *Errors created by the pyroelectric effect present in the active element;*
- *Errors due to poor quality mounting of the active element on the support membrane/micro-cantilever beam;*
- *Errors due to the high magnetic sensitivity of the proof masses;*
- *Errors created by poor contact between the active element and proof mass;*
- *Errors caused by the movement of the proof mass in directions apart from the sensitivity axis;*
- *Errors caused by the noise signal sources.*

***2)* Noise signal sources and factors:**

- *Noise caused by capacitive coupling in the structure of the accelerometer;*
- *Poor quality connections;*
- *Effect of the temperature variation on electrical connections;*
- *Solar radiation;*
- *Cosmic radiation;*
- *The electromagnetic field of the nano-satellite.*

To maximize and to improve the performances of the designed micro-accelerometer, we need to insulate the micro-accelerometer in a hermetically sealed protection to minimize the instrumental errors. All the error and noise signal sources listed above need to be studied in detail to be minimized.

IX. EXPERIMENTAL STUDY

Studied experimental models: Magnetic inertial mass micro-accelerometer (first generation experimental model), Elastic mounting membrane experimental model accelerometer.

Aim of the experimental study:

1. Studying the operating range of the experimental models and studying the output voltage signal response for different accelerations;
2. Collecting information for further optimization of experimental models.

Testing apparatus: Tektronix MDO3054 Oscilloscope with 4 channels and a 500 Hz frequency; Correx dynamometer.

Conditions: The conditions are considered constant at a temperature of 23°C and a pressure of 1 atm.

Experimental procedure: The sensor output terminals (connections) was connected to the oscilloscope. With a dynamometer, the pressure was exerted on the inertial mass and using the oscilloscope we could highlight the acceleration through the voltage signals. The resulting oscillograms were recorded, interpreted and analyzed.

The conditions are considered normal.

Resulted oscillograms:

a) *Experimental model micro-acceleromer on elastic membrane structure*

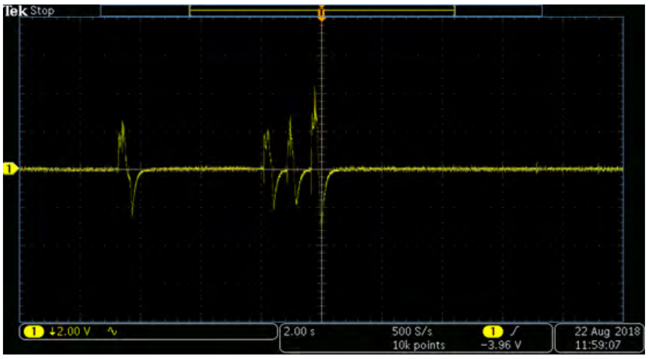


Fig. 11. 2V voltage signal after inducing several 0,5g accelerations

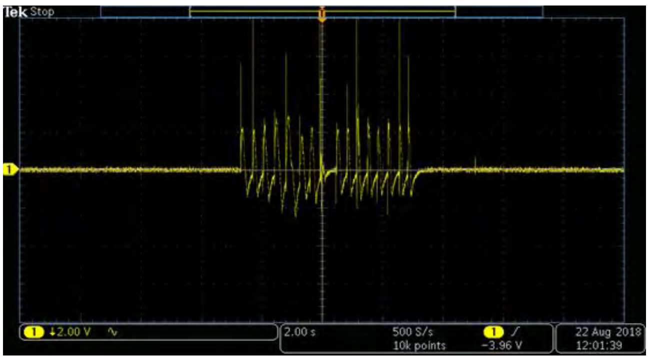


Fig. 12. Electrical voltage signal after inducing consecutive accelerations

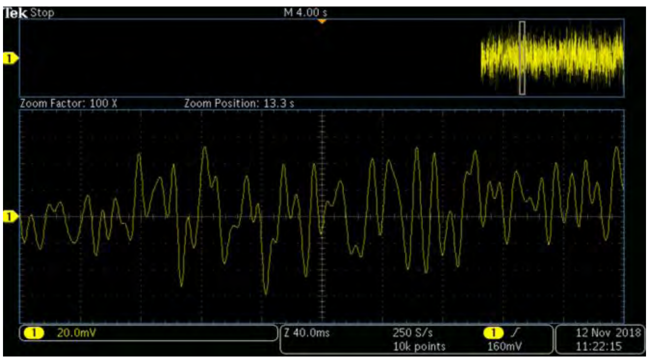


Fig. 13. Microsensor noise signal at normal and stable conditions

b) *Magnetic inertial mass micro-accelerometer (first generation experimental models)*

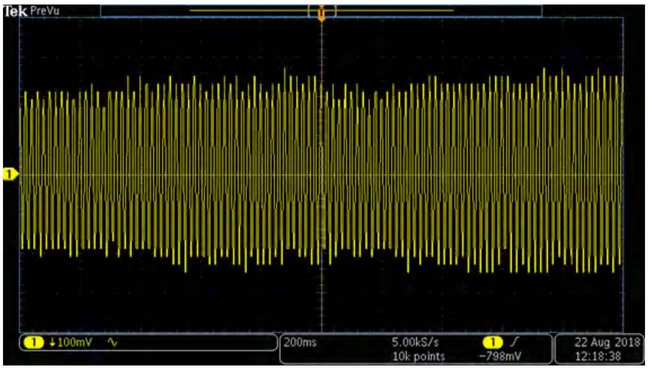


Fig. 14. Slow variations of accelerations

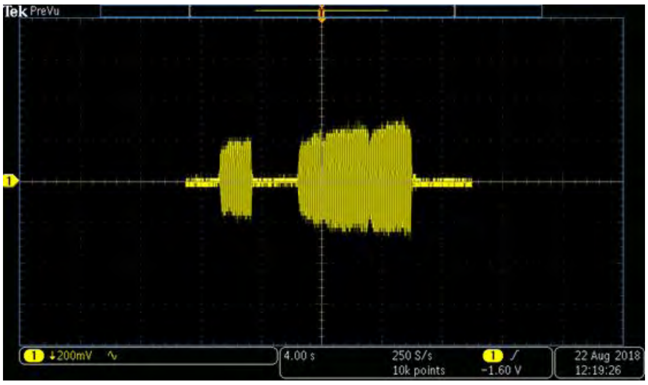


Fig. 15. Random acceleration applications

Discussions

In the oscillograph presented in Fig. 13, we studied the noise signal, at normal conditions, of the elastic membrane experimental model accelerometer. The average of the signal noise was measured as 38 mV. Noise detected by the accelerometer may vary, depending on the disturbance factors of the environment. In space, for example, there may be noise signals from solar and cosmic radiation or from the electromagnetic field generated by other components in the nanosatellite structure. Thus, isolation of the disturbing factors such as placing the microsensor in a hermetically tight casing is important to reduce noise signal and thereby increase the operating range.

In the oscillographs presented in the figures Fig. 14 and Fig. 15 we studied the first generation of experimental models of micro-accelerometers with magnetic inertial mass. In Fig. 14, we can recognize slow variations of accelerations. On this basis, it can be assumed that the magnetic spherical inertial mass entered an oscillatory motion when the acceleration was applied. In Fig. 15 we can notice random acceleration applications. In both oscillographs, there can be observed a more prominent noise signal than in the case of the elastic membrane accelerometer, which can be explained by the poor connection between the sensor and the oscilloscope.

X. CONCLUSION

In conclusion, in this paper, the author approached four structures of unconventional microaccelerometers, which he studied both theoretically and experimentally using experimental models. Possible errors and noise sources have been identified and solutions have been proposed. At this moment, the research is in a stalling procedure on a specific stall for determining the specifications of the experimental models.

XI. ACKNOWLEDGMENTS

The author gratefully acknowledges the contributions of Ph.D. Mircea Ignat for the guidance and the help he has given during the creation of the theme. Also, the author would like to thank the National Institute for Research and Development in Electrical Engineering INCDIE ICPE-CA, Bucharest, and the ―Alexandru Proca” Center (CICST) for support.

XII. REFERENCES

[1] *Fundamentals of piezoelectric sensorics*; Jan Tichy, Jiri Erhart, Erwin Kittinger, Jana Privratska; Springer 2010.
[2] https://en.wikipedia.org/wiki/Electrostriction.
[3] *Sensors, An Introductory Course*, Kalantar Zadeh, Hardcover, 2013.
[4] *Piezoelectric Accelerometers and Vibration Preamplifier*; Bruel and Kjaer, Mark Serridge and Torben R. Licht; 1987.
[5] *Analysis of errors of piezoelectric sensors used in weapon stabilizers* Igor Korobiichuk Metrol. Meas. Syst., Vol. 24 (2017), No. 1, pp. 91–100.

XIII. BIOGRAPHY

Ursu Ștefan

High school student in the X[th] grade at the „Nicolae Titulescu" High School, Brașov, Romania.

Member of the ―Alexandru Proca” Center for the Youngsters Initiation in Scientific Research, Bucharest, since 2018.

Winner of the 4[th] grand award in Engineering Mechanics at the International Science and Engineering Fair ―ISEF” 2019.

A Bionic Study on the Legs of Insects with Applications in MEMs

Eric Gabriel Danciu Druțu, Mihai Mitrea
—Alexandru Proca" Center for the Youngsters Initiation in Scientific Research within INCDIE ICPE-CA,
Splaiul Unirii, No. 313, District 3, 030138, Bucharest, Romania
*ericgabrielcuber@yahoo.com

Abstract - This paper presents a study of the properties of the insect legs that can be used in creating microelectromechanic devices. The insect legs were classified in five categories: running feet (cursorial), jumping feet (jumping), grasping feet (raptorial), swimming feet (natorial) and digging feet, for which the characteristic features were defined and the possible uses for the devices that mimic the different types of legs were established. The data on the movement of different insects were collected using a piezoelectric sensor tunnel connected to an oscilloscope. Based on these data, different foot models were designed and their motion was analyzed. Experiments included the development and testing of different types of magnetic tweezers and a several types of artificial insects. Different applications were developed: liquid shaker, kit of micromanipulators and tweezers inspired by the insect's foot, tweezer designs inspired by the stag beetle's claws, movement mechanism with a switch, artificial —millipede", and polishing device.

Index Terms – Microtechnology, bionic study, insect legs, artificial insect, microelectromechanics, microrobotics.

I. APPROACHING THE RESEARCH TOPIC

The study of microtechnologies has received great attention in recent decades. With the rapid development of society, the need for high-level equipment has also increased, thus requiring the building of small mechanisms, with high efficiency and an accessible cost.

Our work is based on the idea that by studying the properties of the insect leg, we can make contributions in the areas of scientific interest, by modifying or developing our systems with different uses. The insect's leg is characterized by a fineness and fluidity, especially in the movement, as well as physical properties adapted in accordance with varied specializations of the respective body part. For these reasons, the properties of the insect's leg can be used in creating a robotic micromanipulator.

In this project we will consider a structural analysis on the insect's leg in the hope of implementing the data obtained in the design structures in our own designs, such as manipulators or robots. The objective of the study is to make contributions in the field of microelectromechanics by analyzing some special properties of the limbs of insects, with applications in microrobotics.

The theme was approached according to the following plan:

- Theoretical and experimental study of the insect foot and their movement.
- Documentation on the current state of microtechnologies and the nations of interest for the project.
- Carrying out different experiments and laboratory work necessary for the realizations of the subsequently developed applications [1].

II. A BIONIC STUDY ON THE INSECT'S FOOT

In order to facilitate the study of the properties if the insect legs, we have classified them into five categories, after use: running feet (cursorial), jumping feet (jumping), grasping feet (raptorial), swimming feet (natorial) and digging feet.

For each of these we have defined characteristics features and identified species of insects in which they are present. Also, we have established possible uses for the devices that mimic the different types of legs.

The table below shows the five types of insect legs classified after their use [2], [3].

TABLE I. The types of insect leg and their use

Functions	Applications
Running	Studying narrow spaces
Jumping	Fast travel and the ability to jump to a higher terrain level
Grasping	Handling objects at the micro level
Swimming	Aquatic exploration
Digging	Underground exploration

Next, we collected data on the movement of different insects using a piezoelectric sensor tunnel connected to an oscilloscope. The insects were allowed to move through the tunnel with sensors, which due to the piezoelectric effect, transform the force of pushing the insect's step into electrical voltage. Thereafter, the oscilloscope records and displays the voltage in the form of a graph (see Fig. 1 and Fig. 2) [4], [5], [6].

After this, we determined by using a dynamometer the corresponding force per unit of electrical voltage. Thus, we were able to obtain graphs that describe the insect‘s displacement as a function of the force exerted on the sensor in relation to time. From these graphs we were able to determine the average time required to perform a step by the respective insects, as well as the average force exerted by it on the ground when grazing.

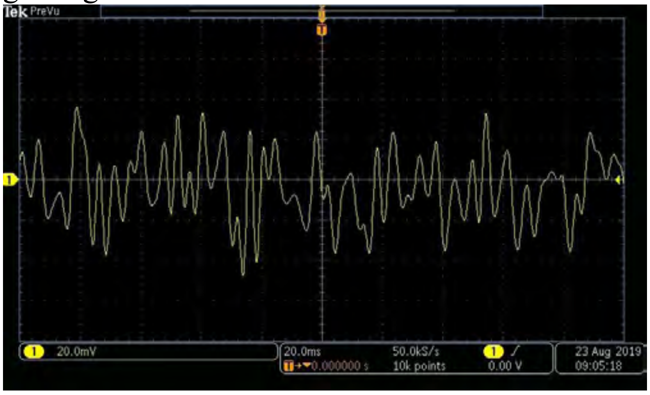


Fig. 1. Ant‘s walk on oscilloscope

Next, we used the Lagrange Interpolation polynomial to obtain a function that mathematically describes the motion of the insect, using points from the graphs obtained previously from the oscilloscope [7]. The interpolation was done with the help of a professional website, since doing the calculations manually would have taken too much time and effort. In order to test the accuracy of the interpolation, we passed one the functions obtained by the website to a program that presents us the function as a graph, noting that it mimics the graph originally obtained by the oscilloscope [8].

Additionally, we looked for an alternative method for the interpolation. Thus we have created a program that will perform the necessary calculations, without the help of a website. The program is also based on the Lagrange Interpolation, in order to calculate the descriptive function of the graph. It has a complexity of $O(n^3)$, but in the near future it will be improved, using the Fast Fourier Transform (F.F.T.) algorithm, to obtain $O(n^2 \cdot logn)$ [9], [10]. This algorithm is not only faster that ―brute force", but much more reliable, since it eliminates the approximations that the actual algorithm has to make.

Fig. 2. Flat‘s walk on oscilloscope

In order to be able to understand the mechanics behind the insect‘s foot and to be able to further study and replicate its properties in laboratory work, we needed an analysis of the physical characteristics of the insect‘s locomotion. Understanding the physical processes behind the functioning of the insect foot, we created an overview of the factors that influence its movement in various situations. Thus, we designed different foot models and analyzed their motion from a kinematic, static and dynamic point of view (see Fig. 3).

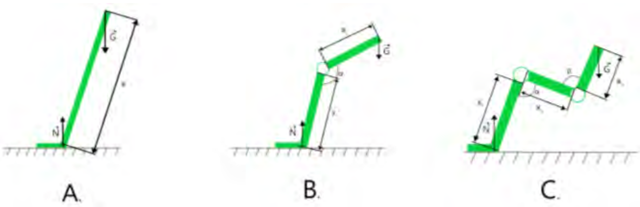


Fig. 3. Cinematic, dynamic and static models of the insect leg

III. DOCUMENTATION ON THE CURRENT STATE OF MICROTECHNOLOGIES AND OTHER NOTIONS OF INTEREST FOR THE PROJECT

Next, a series of formulations is established and there are no theoretical ones to be able to approach the proposed laboratory work and the practical chapters of the project.

Thus, we establish a documentation about insects and their anatomy, as well as about MEMs, their current state and the areas of public interest that use this type of technology (see Fig. 4, [11]). We consider it necessary to present these theoretical studies, as the project is based on the combination of several different scientific branches, and its further development requires rigorous knowledge from each chapter addressed.

In order to clarify the procedures used during the experiments discussed in the continuation of the paper. We have also explained the piezoelectric effect and the operating principle behind the piezo sensors.

Because the mechanical vibration phenomenon is the basis of many mechanisms developed within the project, we also presented a lesson on mechanical oscillations, to make the terminology used accessible to the reader.

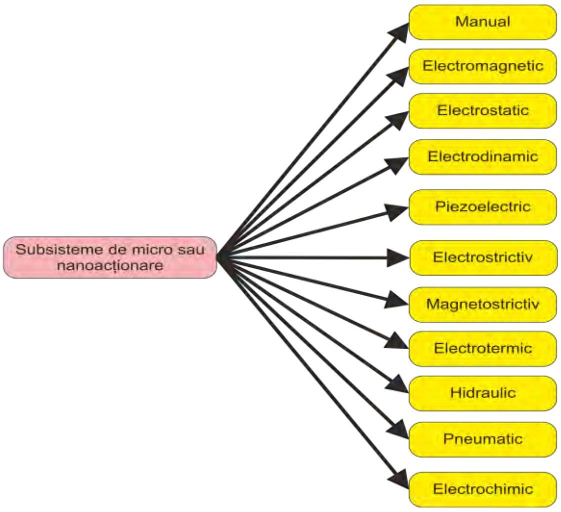


Fig. 4. Various domains in which MEMs is used in the modern world

IV. SPECIFIC STAND FOR MICROMANIPULATOR EXPERIMENTS AND TEST

A. Tweezers and magnetic tweezers

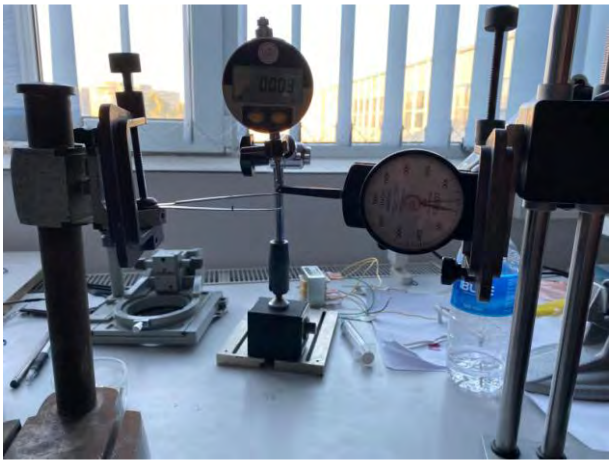


Fig. 5. Measuring the force needed to open a tweezer

Inspired by the strong grasping of the raptorial legs, we tried to develop different types of tweezers with increased tightening. Thus, we have developed a series of magnetic tweezers, whose grip is enhanced by a couple of magnets placed on the tweezers. We also tested the mechanical properties of the tweezers used (see Fig. 5, Table II.). The data below are on the force required to open an unmodified tweezer in accordance with the distance between the tweezers rods.

TABLE II. Data from measuring the force

No. measurements	1	2	3	4
Force	0.2 cN	0.45 cN	0.67 cN	0.86 cN
Displacement	2.67 mm	3.12 mm	3.62 mm	4.05 mm

B. Artificial insect 1

A DC power source with controlled properties is connected to an extremely small motor attached by a metal rod (see Fig. 6). The engine produces mechanical vibrations that subsequently propagate through the metal bar, giving rise to an oscillation [11], [12], [13], [14], [15], [16]. To study the applications of a movement system based on the vibrating rod, we attached 3 pairs of ―legs" of various shapes to the mechanism, like the locomotive apparatus of the insect. We experimented with different types of shapes, observing how the shape and number of the feet influence the movement path of the device.

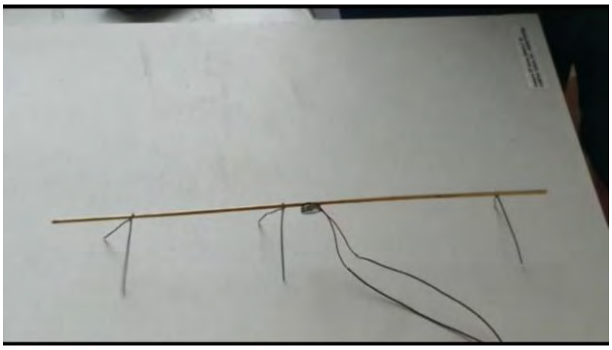


Fig. 6. Artificial insect 1

C. Artificial insect 2

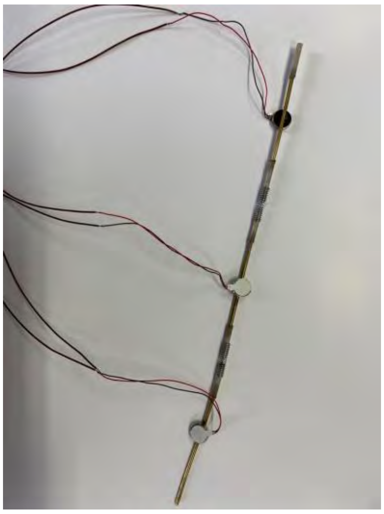


Fig. 7. Artificial insect 2

The second insect consists of three identical rods connected each to a motor powered by the DC source used previously, the rods thus becoming oscillators like the Insect 1. Each vibrator is powered by the same type of motor (identical sources), thus the insects undergoes oscillations described by the same equation (see Fig. 7.). The three metal bars are connected by two identical springs, the system, thus depending on each oscillator segment separately. Due to the connections between the rods, the movement of this mechanism is achieved in an oscillating way, each segment having an independent movement. The obtained assembly has a serpentine, fast movement, similar to the movement of a millipede. Looking at the characteristics of a locomotive apparatus of the millipede, the ability to move through narrow and slippery spaces, we performed a laboratory work to test whether our movement mechanism mimics the characteristics of a walking millipede.

The experiment consists of placing the second insect through a transparent plastic tube. The main condition of conduct for the experiment is that the dimensions of the plastic cylinder slightly exceed those of the artificial millipede, so that it can be considered a narrow space.

D. Artificial insect 3

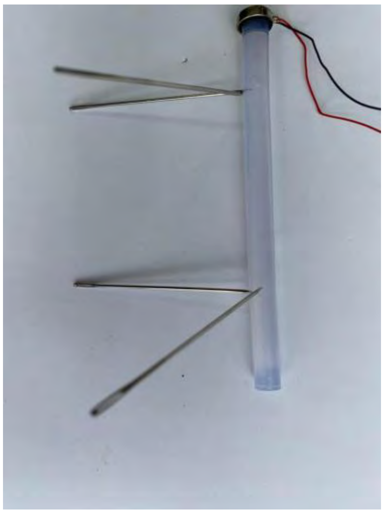


Fig. 8. Insect 3 prototype

The third insect consists f a silicone rod at the end of which is attached a motor connected to a DC source. The rod is traversed by vibrations made by the small vibrator, thus making the rod move like the first insect. Two pairs of legs are inserted into the cylinder through which the vibrations propagate and subsequently move the assembly. Because the silicone allows for a firmer grip of the legs compared to the previously used metal bar. This movement mechanism is characterized by a more fluid movement compared to that of the previous prototypes.

In this laboratory work, we consider the behaviour of the third insect when moving through a plastic cylinder, as in the previous experiment. Due to the properties of this movement system (fine and fluid motion), we tested whether it can be used as a probe to move through hard-to-reach spaces without propagating vibrations in the environment.

E. Artificial insect with solar panel

Fig. 9. Cricket toy

A toy that mimics a cricket, that is equipped with a series of wire legs and a motor (see Fig. 9). A tiny solar panel is placed on the back the figurine, collecting energy. It is used by a motor that produces mechanical oscillations through the insect‘s legs, thus giving the toy an oscillatory disordered movement.

This toy inspired us to recreate a movement mechanism based on the same operating principles, applications of which are discussed in the next chapter.

The data below is recorded in the laboratory about the artificial insect (see Table III). These data gave us an idea about the type of engine, source and compatible dimensions for such a robot.

TABLE III. Data for the locomotion of the cricket toy

Geometric parameters	Speed	Micromotor	Voltage	Electric current
5 x 5 x 5 cm	0,2 - 5 mm/s	0,5 - 5 W	0,5 - 2 V	0,2 - 1 A

V. A STUDY OF SOME APPLICATIONS

Following the experiments discussed in the previous chapter, we have developed different applications for the realized mechanisms. Thus, we have a variety of devices with applications in various fields.

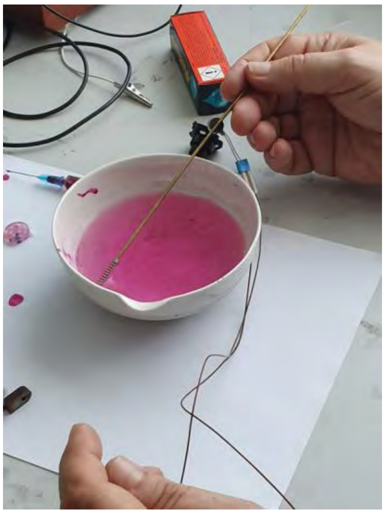


Fig. 10. Experimenting with a liquid shaker prototype

A. Liquid shaker

We used the oscillator rod from the first insect as a liquid shaker, attaching a copper wire that will make contact with the liquid in order to transmit the vibrations in the environment. Studying a shaker model, we explore how waves propagate in water depending on the specific shape of the copper wire (see Fig. 10). The liquid we performed the tests on was stained with niobium oxide, to facilitate the observation of the effect of the shaker. These shakers can have a variety of uses, being able to distribute vibrations in the liquid in a controlled manner.

B. Kit of micromanipulators and tweezers inspired by the insect's foot

Based on the experiments performed with the tweezers we developed a kit with various modified tweezers. This kit includes:

- Magnetic tweezers - Inspired by the adhesive present of the insect claws, we have attached magnets that will draw on both sides of the tweezer to create a stable and immobile locking system.
- Circuit tweezers - Tweezers with extended ends with gold-plated tridents. These are crossed by an electric current, the gold being an excellent transmitter.

C. Tweezer designs inspired by the stag beetle's claws

Model 1

Using the stag beetle's claws for inspirations we designed an ideal type of manipulator for grasping spherical of slippery objects. It consists of 4 flexile metallic ―claws” accompanied by a support rod. When pushed to an object, the claws will open and grasp the object.

Model 2

It is a modified version of the model 1, using other materials and a different grip mechanism. In the case of this manipulator, the grip exerted on an object is controllable by being able to move the claws independently.

D. Movement mechanism with a switch

As an alternative to the artificial insect set in motion by mechanical oscillations, we have developed an insect model whose movement can be controlled by a switch (Fig. 11). On a very thin metal plate, through which vibrations can be propagated, two thin pairs of copper legs, a battery, a switch and a conductor cable are attached. Connected to a 1.5 V battery the switch determines the activation motor which, on the same principle used by the first insect, moves.

E. Applications of the artificial "millipede"

When developing the mechanism, we considered a movement system for a probe to explore extremely narrow, slippery and deep spaces that ordinary displacement mechanisms fail to traverse. Subsequently, the probe may be equipped with different devices, depending on the intended use (video cameras, pliers to extract material samples, adhesives or other devices to repair defects in inaccessible spaces).

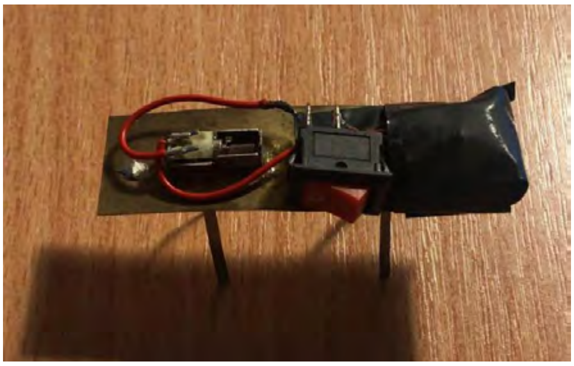


Fig. 11. Movement mechanism that replicates the locomotion of a real insect functioning with a switch

F. Applications of the third insect

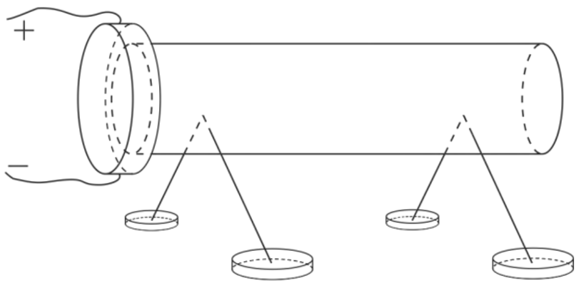


Fig. 12. One of insect's 3 applications, polishing device

The third insect can be used to develop probes. The lack of joints does not allow it to take tight curves, but it can also move more smoothly through the environment. Thus, it can be used to browse fragile environments, which do not want to propagate vibrations.

Because the energy is transmitted efficiently and evenly to the legs by the source engine, the attachment of turbines/wheels to the feet of the insect transforms a fraction of the energy of the movement into rotational energy for the wheels at the base of each foot. The force that drives the movement of the artificial insect is retained to a certain extent, so that the mechanism continues to move transversely while the wheels at the base of the insect‘s legs rotate in contact with the ground. This type of mechanism can be used for the preparation of a device for finishing or polishing surfaces, depending on the properties of the wheels chosen (see Fig.12).

VI. INTERPRETATIONS AND CONCLUSIONS

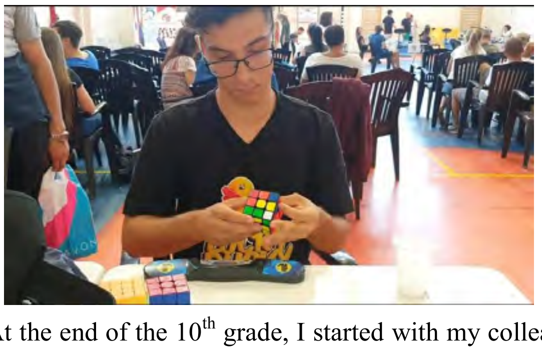
Our project started from some simple ideas, in which we considered the specific fineness of the insect‘s foot and we realized its properties could make contributions in the technology specific to the surgical procedures, as well as in other fields. Subsequently, we studied theoretically the entomology and anatomy of the insect foot in particular and transformed this study into experiments in order to collect data in vivo. In order to be able to make contributions in the field of microtechnologies based on the study of the insect, we have composed a series of documentation on the theoretical nations that underlie the project. Studying the anatomy of insects, the current state of MEM. We laid a theoretical basis that allowed us to support laboratory work based on these areas. For the practical part of the project, we conducted a series of experiments in which we tested different modified mechanisms or altered existing devices in order to give them new uses based on the data gathered in the theoretical phase. Following these experimental studies, we have developed various innovative mechanisms. Manipulators have various utilities, addressing common difficulties encountered in commonly used areas of MEMs technologies, such as surgery, pharmaceuticals, handling of objects or displacement systems for robots. The resulting prototypes are diverse and can thus be classified in a variety of ways, such as their conditions of use (manual, electric, etc.) or their basic mechanism (based on oscillation or non-oscillatory mechanism). In the continuation of the project, we want to develop a wide range of micromanipulators and applications in the field of MEMs, as well as a series of displacement mechanisms inspired by the locomotor apparatus of insects, using our previous studies and experiments. We believe that our research has potential for application and we hope to bring about improvements in the current state of microtechnologies and to develop innovative projects that can benefit humanity through their versatility.

VII. REFERENCES

[1] ”Inițiere în Cercetare Științifică” - Mircea Ignat.
[2] https://thedragonflywoman.com/2010/12/10/insect-legs.
[3] https://ro.wikipedia.org/wiki/Insect%C4%83.
[4] www.all.ro/media/attachment/file/m/a/manual_fizica_f1_clasa_11.pdf.
[5] https://en.wikipedia.org/wiki/Piezoelectricity.
[6] https://www.electronicdesign.com/power-management/article/21801833/what-is-the-piezoelectric-effect.
[7]https://ro.wikipedia.org/wiki/Interpolare_polinomial%C4%83.
[8]https://ro.wikipedia.org/wiki/Polinomul_de_interpolare_Lagrange.
[9] https://en.wikipedia.org/wiki/Fourier_series.
[10] https://ro.wikipedia.org/wiki/Polinom.
[11]https://en.wikipedia.org/wiki/Microelectromechanical_systems.
[12] https://ro.wikipedia.org/wiki/Oscila%C8%9Bie.
[13] https://prezi.com/avhoa9mq8vg-/oscilatii-mecanice.
[14] https://www.scribd.com/doc/306895919/Oscilatii-mecanice.
[15] https://en.wikipedia.org/wiki/Vibration.
[16] Gh. Buzdugan, L.Fetcu, M. Radeș, ―Vibrații mecanice” ,Editura Didactică și Pedagogică București, 1979.
[17] Calculator for the interpolation: https://www.dcode.fr/lagrange-interpolating-polynomial.
[18] Graphs made using: https://www.desmos.com.

V. BIOGRAPHIES

My name is **Druțu Danciu Eric Gabriel** and I am a 12th grade student at the International High School of Informatics in Bucharest.



At the end of the 10th grade, I started with my colleague Mitrea Mihai a research project at the "Alexandru Proca Center for the Youngsters Initiation in Scientific Research", a project with which this year we managed to get an honorable mention from the Sigma Xi association in

Regeneron Isef. I am passionate about exact sciences, puzzles, sports and economics. After graduating from high school I plan to study medicine or business.

My name is **Mitrea Mihai** and I am a 12th grade student at the International High School of Informatics in Bucharest.

Together with my colleague Drutu Danciu Eric Gabriel, I participated in the Regeneron ISEF competition, as members of the "Alexandru Proca Center for the Youngsters Initiation in Scientific Research" under the coordination of Dr. Mircea Ignat. At this competition, the Sigma Xi association decided to give us the honorable mention in the engineering category. In my free time I am interested in economics, science, computers and sports. After high school I plan to study computer science, economics or engineering.

Preparation of a Formatted Technical Paper for the Bulletin of Micro and Nanoelectrotechnologies

*Gabriela Obreja, **Cristian Morari
National Institute for Research and Development in Electrical Engineering ICPE-CA (INCDIE ICPE-CA),
Splaiul Unirii, No. 313, District 3, 030138, Bucharest, Romania,
*gabriela.obreja@icpe-ca.ro, **cristian.morari@icpe-ca

Abstract - This document is itself an example of the desired layout (inclusive of this abstract) and can be used as a template. The document contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided explaining how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies. The abstract is limited to 150 words and cannot contain equations, figures, tables, or references. It should concisely state what was done, how it was done, principal results, and their significance.

Index Terms - The author shall provide up to 10 keywords (in alphabetical order) to help identify the major topics of the paper and to be enough referenced.

I. INTRODUCTION

This document provides an example of the desired layout for a published MNE technical paper and can be used as a Microsoft Word template. It contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided explaining how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors‘ biographies.

II. TECHNICALWORK PREPARATION

Please use automatic language check for your spelling. Additionally, be sure your sentences are complete and that there is continuity within your paragraphs. Check the numbering of your graphics (figures and tables) and make sure that all appropriate references are included.

A. Template

This document may be used as a template for preparing your technical paper. When you open the file, select "Page Layout" from the "View" menu (View | Page Layout), which allows you to see the footnotes. You may then type over sections of the document, cut and paste into it (Edit | Paste Special | Unformatted Text), and/or use markup styles. The pull-down style menu is at the left of the Formatting Toolbar at the top of your Word window (for example, the style at this point in the document is "Text"). Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu.

B. Format

If you choose not to use this document as a template, prepare your technical work in single-spaced, double-column format, on paper A4 (21x29.7 centimeters). Set top, bottom margins and right margins to 15 millimeters and left margins to about 20 millimeters. Do not violate margins (i.e., text, tables, figures, and equations may not extend into the margins).

C. Typefaces and Sizes

Please use a Times New Roman font. (See your software‘s ―Help” section if you do not know how to embed fonts.) Table I is a sample of the appropriate type sizes and styles to use.

TABLE I. Table name will be written in Times New Roman font.

Micromotor Code	b [mm]	a [mm]	h [mm]	Material
MPR33	33	25	20	PZT 5
MPR27	27	18	9	PZT 5
MPR15	16	10	10	PZT 5

D. Section Headings

A primary section heading is enumerated by a Roman numeral followed by a period and is centred above the text.

A primary heading should be in capital letters and bolded. The standard text format is considered times new roman 12.

The paper title should be in times new roman 20 uppercase and lowercase letters, not all uppercase.

Author name is set to times new roman 12, institution and contact address (E-mail) are set to times new roman 10.

Financial support should be acknowledged below the author name and institution. Example: This work was supported in part by the U.K. Department of Defence under Grant TX123.

A secondary section heading is enumerated by a capital letter followed by a period and is flush left above the section. The first letter of each important starting word is capitalized and the heading italicized.

Tertiary and quaternary sections are accepted only in special cases, so usually must be avoided in order to keep a clear article structure. If required, a tertiary and quaternary section heading must be italicized and enumerated by adding an Arabic numeral after each letter.

E. Figures and Tables

Figure axis labels are often a source of confusion. Try to use words rather than symbols. As an example, write the quantity "Torque," or "Torque, *M*," not just "*M*." Put units in parentheses. Do not label axes only with units. As in Fig. 1, write "Torque (cNm)" not just "(cNm)". Do not label axes with a ratio of quantities and units. For example, write "Current (A)," not "Current/A." Figure labels should be legible, approximately 10-point type.

Large figures and tables may span both columns, but may not extend into the page margins. Figure captions should be below the figures; table captions should be above the tables. Do not put captions in "text boxes" linked to the figures. Do not put borders around your figures.

All figures and tables must be in place in the text centered and written with times new roman 10. Use the abbreviation "Fig. 1" in sentence and for each figure name. Each table must be defined as „TABLE I”, with capital letters and roman numbers.

Digitize your tables and figures. To insert images in Word, use: Insert | Picture | From File.

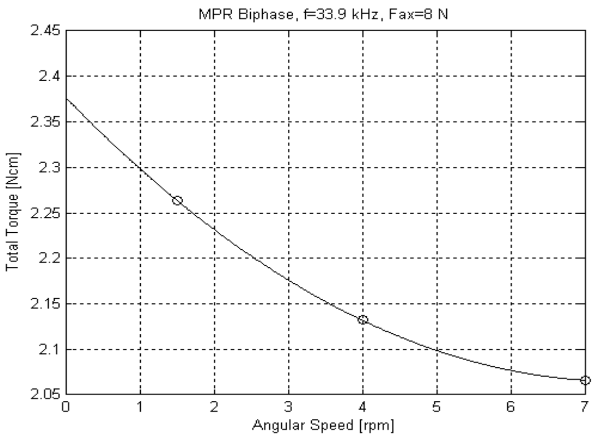


Fig. 1. Total torque function of angular speed. (Note that "Fig." is abbreviated and there is a space after the figure number.)

F. Numbering

Please number reference citations consecutively in square brackets [1]. The sentence punctuation follows the brackets [2]. Multiple references [2], [3] are each numbered with separate brackets [1]-[3]. Refer simply to the reference number, as in [3]. Do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] shows….".

Number footnotes separately with superscripts (Insert | Footnote). Place the actual footnote at the bottom of the column in which it is cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Check that all figures and tables are numbered correctly. Use Arabic numerals for figures and Roman numerals for tables.

Appendix figures and tables should be numbered consecutively with the figures and tables appearing in the rest of the paper. They should not have their own numbering system.

G. Units

Metric units are preferred in light of their global readership and the inherent convenience of these units in many fields. In particular, the use of the International System of Units (―Système International d'Unités” or SI Units) is advocated. This system includes a subsystem of units based on the meter, kilogram, second, and ampere (MKSA). British units may be used as secondary units (in parentheses). An exception is when British units are used as identifiers in trade, such as 3.5-inch disk drive.

H. Abbreviations and Acronyms

Define less common abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Standard abbreviations such as SI, CGS, AC, DC, and *rms* do not have to be defined. Do not use abbreviations in the title unless they are unavoidable.

I. Math and Equations

Use either the Microsoft Equation Editor or the *MathType* commercial add-on for MS Word for all math objects in your paper (Insert | Object | Create New | Microsoft Equation *or* MathType Equation). "Float over text" should *not* be selected.

To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize symbols for quantities and variables. Use a long dash for a minus sign or after the definition of constants and variables. Use parentheses to avoid ambiguities in denominators.

The number of each equation must be consecutively added in parentheses and arranged at the right margin, as in (1). Be sure that the symbols in your equation have been defined before the equation appears or immediately following.

Don‘t use "Eq. (1)" abbreviation instead of "equation (1)", in a sentence.

$$L_m = \frac{m}{A^2} \tag{1}$$

with m - mechanical mass, A - force factor, L_m - electromechanical inductance.

III. ACKNOWLEDGMENT

The following is an example of an acknowledgment.

The authors gratefully acknowledge the contributions of Mircea Ignat and Puflea Ioan for their work on the original version of this document.

IV. APPENDIX

Appendixes, if needed, appear after the acknowledgment.

V. REFERENCES

References are important to the reader; therefore, each citation must be complete and correct. There is no editorial check on references, only the format Times new roman 10 must be considered.

[1] Satanobu J., Lee D.K, Nakamura K., Ueha S., ”Improvement of the Longitudinal Vibration System for the Hybrid Transducer Ultrasonic Motor”, IEEE Trans. On Ultrasonic ferroelectrics and Frequency Control, vol. 47, no. 1, January 2000, pp. 216-220.

[2] Morita T., Yoshida R., Okamoto Y., Kurosawa M., ”A Smooth Impact Rotation Motor Using a Multi-Layered Torsional Piezoelectric Actuator”, IEEE Trans. On Ultrasonic ferroelectrics and Frequency Control, vol. 46, no. 6, November 1999, pp. 1439-1446.

VI. BIOGRAPHIES

A technical biography for each author must be included. It should begin with the author‘s name (as it appears in the byline). Please do try to finish the two last columns on the last page at the same height. The following is an example of the text of a technical biography:

Mircea Ignat was born in Bucharest on March 4, 1953. He graduated at 1977 and he received Ph.D. degrees in electrical engineering from Bucharest Polytechnic University in 1999.

His employment experience included the National Institute for Research and Development in Electrical Engineering ICPE-CA, coordinator of the "Alexandru Proca Center for the Youngsters Initiation in Scientific Research".

The research preoccupation includes: the synchronous generators and the high speed electric machines. He is member of IEEE.