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ABSTRACTS BOOK

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Elena Nardi, Ivan Corazza, Laura Cercenelli, Pier Luca Rossi

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19 September

Plenary Talk

Hand Biomechanics and Rehabilitation

Fong-Chin Su
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The hand receives sensory stimuli and executes motor commands that are integrated in the various functional manipulations for daily tasks. Awkward and inefficient finger movements, poor force coordination and strength, sensation deficit of motor control of the affected hands are most common phenomena in patients. Therefore, our research team developed a series of hand function control training systems to explore characteristics of force patterns when conducting functional tasks and to enable training and assessment of finger force control in functional postures. Patients' motivation is boosted through interactive games, while visual and auditory feedback are integrated for better intervention outcomes. As for the patients with carpal tunnel syndrome, they grasped with greater digit force associated with weaker pair-digit correlation and higher force variability on specific digits in different task demands. Also, the custom-designed computerized evaluation and re-education biofeedback prototype was developed to analyze hand grasp performances and monitor the training effects on hand coordination for stroke patients with sensory disturbance and without motor deficiency. Finally, training in patients with mild cognitive impairment significantly enhanced hand dexterity and cognitive function, consistent with previous findings that fine motor performance can distinguish patients with cognitive impairments from healthy individuals.

S1M: ORTHOPEDICS – BIOMECHANICS

Finite Element Analysis of Human Knee Joint for Futuristic Customized Knee Implants

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An alternative approach to design patient specific knee implants has been investigated in this paper with respect to morphological measurements taken from the patient. In this work, patient specific customized knee implants have been designed and analysed. 3D model of the bones was derived using CT scan of the patients and morphological measurements were taken, using which the femoral, tibial components and the polyethylene spacer were designed. Mechanical strength of these implants was tested for different loading conditions i.e., during compression and flexion extension using finite element analysis (FEA) and the results were compared to the same loading conditions for the normal knee. The results showed that the implanted knee showed similar stress strain values as the normal knee. Curved surface of the femoral implant helped in smooth transfer of load from the femoral component to the tibial plate avoiding any malfunctions such as aseptic loosening. Results showed that the effective stress and strain observed on the knee implants were like the normal knee, thus implying that the designed knee implants behave closely to the normal knee joint and produce similar biomechanical properties. Thus, it can be considered as a valuable implant and could replace the standard off- the-shelve knee (OTS) implants. This study will give opportunities to specialists and surgeons to enhance the quality of total knee replacement (TKR) surgery by improving the decision-making criteria, as well as, by improving the standards of TKR process with providing more data that help to define the ideal knee implant.
***Keywords**: off-the-shelve knee; patient specific knee implant; finite element analysis.*

Analysis of Variability in Active Muscle Stiffness with Myoelectric Activity during Incremental Isometric Loading

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Active stiffness is considered as a noninvasive measurement of the loading level of skeletal muscle. Present study aims to assess the association between active muscle stiffness and myoelectric activity during incremental isometric loading in dominant and nondominant hands. For this purpose, myotonometric measurements and electromyographic data are bilaterally recorded from the muscle belly at multiple loading levels of biceps brachii such as no-load, 3 kg, and 6 kg in an isometric elbow flexion task with an elbow angle of 90º. Dynamic Stiffness values of muscle tissue is calculated from the myotonometric signal, while muscle activation is estimated from RMS of the preprocessed sEMG signal. The association between Dynamic Stiffness and RMS values at three loading levels is assessed using canonical correlation analysis. The results show a monotonic increase in both muscle stiffness and muscle activation with the increasing magnitude of loading for both dominant and non-dominant hands. Although significant correlation between muscle stiffness and activity of more than 0.9 is observed for both hands across all subjects, the variation is more consistent in the non-dominant hand. The results indicate that muscle stiffness can be utilized as a surrogate parameter along with sEMG for the prediction of subject-specific loading levels and can be useful for rehabilitative purposes.

Keywords: *Muscle Stiffness; Myotonometry; Surface Electromyography; Isometric Loading*

Longitudinal functional assessment of a transfermoral amputee patient treated with osseointegration surgery

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The purpose of the study was to provide the functional assessment of a transfemoral amputee patient before osseointegration surgery and after rehabilitation by wearable sensors. A transfemoral amputee patient scheduled for osseointegration surgery was enrolled. The patient performed a gait test the day before surgery with his standard socket-type prosthesis, consisting in 10-meters walking. The test was repeated 3 and 6-month after surgery. A set of 15 wearable inertial sensors was used. Complete gait cycles were isolated and spatiotemporal and kinematical parameters were extracted. The differences between the amputee (AL) and the sound (SL) limb among the follow-ups were reported. Shorter step length and longer swing phase were found for the AL at pre-op, with greatest differences in the midstance. Also, hip abduction and rotation, pelvis forward tilt and obliquity, trunk forward tilt, and lateral bending on the AL were also noticed. At follow-ups, symmetry index progressively improved. Asymmetries in hip abduction, hip rotation, and pelvis rotation decreased at follow-ups and no more trunk forward and lateral tilt were found. After rehabilitation, the patient showed higher time spend on the AL and lesser kinematical asymmetries. The osseointegration surgery showed to progressively restore a physiological kinematics in the transfemoral amputee patient.

Keywords: *osseointegration, transfermoral amputee, assessment*

Numerical study for primary stability assessment in osseointegrated transfemoral prostheses

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The bone remodeling is a cyclic and continuous biological process during which bone tissue modifies and adapts its internal structure, stressed by an external load. In the prosthetic field, the bone adaptation is

stimulated by the direct interaction between a biocompatible metal component and the surrounding bone tissue. The efficacy of this process is identified by the primary and secondary stability assessment. The aim of this study is to evaluate by finite element (FE) analysis the primary stability in osseointegrated transfemoral prosthesis, comparing different geometrical shapes. A 3D femoral model of an amputee was rebuilt by processing TC images. Three different femoral stems, with different geometrical shape (straight, planar curvature and bi-planar curvature), were modeled following the medullary canal morphology. The FE model has been performed applying a compression load of 1000N. The micromotion between metal implant and cortical bone was assessed by CSLIP variable, representing the relative tangential displacement at the bone-implant interface. The displacement trend has been evaluated for all different femoral stems. The femoral stem modeled following a bi-planar curvature provides the smallest relative displacement. However, the tangential displacements are within the allowable range for the formation of new bone tissue, 50-150 μm in all femoral stems analyzed.
Keywords: *Osseointegration; Micromotion; Finite Element Analysis.*

Phenomenological approach to human chest modelling

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A new approach to human chest modelling was proposed. We modeled the chest as an elastic truss consisting of rigid beams and spiral springs that resist the relative rotation of the beams. The approach was applied to model the effect of a rib flaring. Such effect is observed in patients with pectus carinatum in the process of bracing treatment. The model of a chest of a patient with keel pathology was biult in Ansys using its CT scan. When compressive force was applied to the keel the effect of a rib flaring was confirmed. We also investigated the limits of applicability of modelling such elastic trusses in Ansys by building models of 2-beam system under bending. The solution obtained by method of general mechanics was compared with the solution obtained in Ansys.
Keywords: *chest; pectus carinatum, mathematical model; elastic beams; finite element analysis.*

S2M: MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

AI and AR-based image processing, navigation and robotics in computer assisted cranio-maxillofacial surgery

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Cranio-maxillofacial (CMF) surgery is the surgery to treat the entire cranio-maxillofacial complex: the anatomical area of the mouth, jaws, face, skull and associated structures. However, the limited intraoperative visibility, especially the anatomical intricacies, makes this kind of surgery a demanding procedure. Recently, there has been an explosion of interest in artificial intelligence (AI) and augmented reality (AR) based applications in multimodality image computing, visualization, navigation and robotics for CMF surgery. In this lecture, the recent development of our research outcome in computer assisted CMF surgery will be introduced: 1) Deep learning based image processing: convolutional neural networks together with attention mechanism, edge supervision, and statistic shape model were built to automatically segment and register various rigid and non-rigid anatomical structures (e.g. mandible, maxillary sinus, etc.). 2) Surgical planning: state-of-the-art algorithms for 3D model cutting, implant placement design were proposed and relevant preoperative planning and surgical template design softwares were developed. 3) Virtual surgery simulation: key technologies for collision detection and haptic force computing were achieved, and then integrated into our self-developed virtual surgery simulation system using the immersive workbench and haptic device. 4) AR-based surgical navigation: the algorithms regarding virtual-physical calibration, registration, and dynamic navigation using head-mounted-display were proposed. The feasibility and reliability of AR-based navigation system for zygomatic implant placement, mandibular reconstruction surgery were demonstrated through phantom and cadaver experiments. 5) Surgical robotics:

key technologies including the human-robot interaction, force feedback, and intraoperative safety strategy were realized and a novel robot for CMF surgery with high precision and stability was developed. Finally, future research trends for computer-assisted cranio-maxillofacial surgery will be also discussed.

Recognition of abnormalities in gastrointestinal tract from endoscopic images using deep learning architectures

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The gastrointestinal tract (GI tract) is a pathway by which food enters the body and solid wastes are expelled. The Endoscopy is an invasive, non-surgical procedure to examine a person's GI tract. Thus, the automated classification of anomalies in endoscopic images is becoming necessary to assist medical diagnosis and reduce the cost and time of the medical process. In this Proposed work, the publicly available Kvasir medical datasets are used for analysis purpose. It consists of gastrointestinal endoscopic images that belong to eight different classes. The automated recognition of GI tract landmarks and diseases, for classes that are available in Kvasir, with the use of Convolutional Neural Networks (CNNs) is analyzed. CNNs are widely used for visual recognition due to their ability to capture local features and their computational efficiency compared to fully connected networks. A dense model based on DenseNet architecture is employed on the dataset. In the proposed methodology, a DenseNet and a Xception model to classify the abnormalities in the GI tract are developed and by using the experimental results its performance is analyzed. During the training phase of the methodology, the Xception has faster training rate than the DenseNet.

Keywords*: Endoscopy, Kvasir Medical Dataset, DenseNet, Xception*

Interactive visualization of biological network structures in Virtual Reality: a study experience

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Networks provide a powerful instrument to represent complex associations and hidden relationships between agents and structures. Their usage in Systems Biology is pulling the biomedical research, guaranteeing an efficient visualization, quantification, and readability of non-trivial correlations between system components. Many of these results could be already appreciated by a visual inspection of these complex connections. The introduction of virtual reality (VR) on standard research has the potential to further simplify this kind of visualization, providing an immersive experience for the manipulation and interaction with network structures and complex 3D shapes. In this work we introduced our preliminary experience on VR and its integration within the course of Complex Networks of the master's degree in applied physics at the UNIBO. The project takes part of the innovative teaching program performed by the Physics and Astronomy Department of the University of Bologna, and it aims to facilitate the integration of our students with the emerging VR technologies and their usage in scientific research. We have already integrated several of our research topics in VR applications, providing exam projects and thesis to our students about the visualization of protein structures, exploration of biomedical databases, and geometrical alignment of molecular architectures.

Keywords*: virtual reality; network theory; graph visualization; biological network; systems biology*.

A User-Friendly Tool to Compute the Infection Probability of COVID-19 in Closed Environments

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The tool presented in this work is an easy-to-use software tool, written in Python, which allows to compute the infection probability of COVID-19 indoors and which helps in the creation of passive methods for containment of transmission. We use a rescaled version of the Wells-Riley model of airborne transmission by taking into account the specific viral load due to SARS-CoV-2. We use the model to assess the effect of masks in reducing transmission and infection probabilities by introducing mask efficiencies as additional parameters of the model. Viral particles (either virions or virus-loaded droplets) are removed from the environment by room ventilation, relative humidity, presence of HEPA filters, and natural UV irradiation. The tool outputs on file relevant input parameters such as user ID, room characteristics (volume, humidity, filters), number of infectious and susceptible individuals with their respective masks type and time spent inside the room. The user is guided in the choice of parameter values, e.g., the number of quanta is automatically determined by the tool depending on the activity which user selects through a drop-down menu. Plots of viral concentration vs. time, and infection probability with respect to time spent in the room, are added to the text file which summarizes the results of the specific evaluation.
Keywords: *COVID-19; infection probability; software tool.*

S3M: MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

Synthetic Data Generation of Histopathological Images

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Histopathology involves the analysis of microscopic tissue images for the purpose of diagnosing and studying the progress of diseases, such as cancers. Recently, Artificial Intelligence algorithms reached encouraging success in diagnosing diseases related to these types of medical images. However, research in this area can be hampered by several problems. Indeed, due to the sensitive nature of medical data, it is extremely difficult to access real datasets making impossible to train Deep Learning models. Moreover, real datasets often contain biases or imbalances that hinder the generalization of the results on new unseen data. Variational Autoencoders are a popular class of probabilistic generative models that enable consistent training and a useful latent representation of the original input. However, there are theoretical and practical obstacles that hinder their generative potential. We consider different approaches in order to address the challenges of synthetic data generation of histopathology images and discuss the potential impact in improving the performance of diagnosis models.
Keywords*: Synthetic Data Generation; Histopathology; Variational Autoencoders.*

Proposal of a Framework for the Analysis of Comorbid Conditions using Intelligent Extraction of Multiple Fluid Biomarkers

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Fluid biomarkers provide significant information that serve as indicators of various physiological and pathological conditions of the human body. They are large in numbers, extracted from many types of fluids, and are used to characterize the underlying body conditions. Analysis of these fluid biomarkers could help in improving the diagnostic accuracy and thereby, aid in therapeutic interventions. This work proposes, a framework to characterize co-occurrence of more than one disease in individuals using the data obtained through multiple biomarkers using intelligent information processing and analysis. For this, the co-occurrence of hypertension and diabetes conditions and their corresponding fluid biomarkers are considered from the available datasets. The basic components of the proposed framework include identification of appropriate biomarkers, intelligent approaches in decoupling the interdependencies among the considered biomarkers and evolving computational methods that are suitable for patient-specific diagnostics and therapeutics. Through this framework, it is also aimed to explore significant biomarkers that are indicative of the severity of disease states using data driven algorithms. This paper would discuss the characteristics

of co-occurrence conditions, extractable biomarkers, possible computational approaches and potential clinical applications.

Evaluation of Machine Learning models for the detection of Antimicrobial Resistance based on Synthetic Data

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Antimicrobial Resistance (AMR) is a global health problem which is estimated to cause ~10 million deaths every year by 2050. The possibility to detect antimicrobial resistant genes and bacteria in environmental and biological samples is crucial for the detection and monitoring of AMR, as well as to identify effective strategies. To this aim, a promising approach consists in the combination of high-throughput technologies (e.g. shotgun sequencing) with bioinformatics and Machine Learning. However, the high complexity of real metagenomic samples makes the validation of the results a challenging task. In order to evaluate the capability of Machine Learning models to predict the presence of AMR in shotgun sequencing samples, we exploited a modified version of the CAMISIM simulator to generated synthetic data with different resistance profiles, starting from annotated genomes retrieved from the PATRIC database. Our approach allowed us to compare the performances of different bioinformatic and Machine Learning pipelines.
Keywords: *Antimicrobial resistance; Synthetic data; Machine learning.*

Multi-class Twin SVM with deep features for classification of acute myeloid leukemia cells

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Acute myeloid leukemia (AML) is a blood cancer in adults. Precise diagnosis and early treatment are essential to ensure faster recovery rate and reduced fatalities. The main objective of this research work is to suggest a fast and efficient method to diagnose and classify the AML cells. Munich AML Morphology dataset with 4000 mature and immature single cell images under 4 categories of AML is utilised for this purpose. The images are resized and then subjected to augmentation. The augmented images are given to the pretrained neural networks such as ResNet- 50, DenseNet-121 and Inception V3 models for deep features extraction. The best features are obtained by using Binary bat optimization algorithm. The selected features are given to multi-class Twin SVM classifier to classify the different types of AML cells like lymphocyte, monocyte, myeloblast and neutrophil. The observed classification accuracy is 96.73% which is higher than multi-class SVM classifier and other preferred deep learning network classifiers such as ResNet- 50, DenseNet-121 and Inception V3. The proposed method outperforms other classifiers and aids better clinical decision making.
Keywords*: Acute myeloid leukemia; Twin SVM; classification*.

CYTOFastUrine: An Innovative Integrated Solution For Automated Urine Cytology AI supported Diagnostics

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In EU new cases of bladder, kidney and prostate cancer were more than 715,000 in 2020. A proper diagnosis and follow-up could save lives up to 12% of this population. The urine cytology diagnostics performed by pathologists is an expensive and time-consuming process. We are developing an innovative computerized diagnostics AI-assisted platform for urine cytology, based on The Paris System standard. The overall saving of early diagnosis through CYTOFastUrine approach in EU can be estimated at around 37 billion €/year, considering that about 18.7% of urinary tract tumours can be cured if early diagnosed. We developed the complete prototype of CYTOFastUrine made of sample processing with CYTOfast+ system, digitization of samples slides, computerized analysis capable of identifying suspected morphology and aggregates,

remote diagnostics reporting through WaidX telemedicine platform. The digitization is managed with automatic slide scanners. Computerized diagnostic algorithms are integrated into the digitization platform. A team of remote pathologists takes care of the validation and quality control of the diagnostic platform. We completed the first step tasks and several other tasks are ongoing, mainly concerning the algorithm development. CYTOFastUrine enables the possibility of installing laboratories everywhere, giving a valid answer to the increasing shortage of pathologists dedicated to urinary cytology.

Keywords*: Digital Cytology, Telepathology, Artificial Intelligence.*

S4M: ORTHOPEDICS - BIOMECHANICS

Push-Pull Locking Plate VS Standard Locking Plate in Proximal Humeral fractures: a finite element study

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Varus fractures of proximal humerus have high recurrence and/or screw penetration risks. The novel push-pull principle (a subchondral pulling anchor at the humeral head apex, combined with a locking plate with downward angular-stable calcar screws) has clinically shown lower recurrence and secondary screw penetration rates. This FEA study compares the biomechanical performances of a dedicated push-pull plate with a traditional locking plate. The humerus 3D geometry was extracted from Sawbone CT-scans; a traditional locking plate, and the newly designed plate was used as the push-pull. A defect below the humeral head was implemented and the plates were virtually implanted on the bone. The pull mechanism was simulated through connectors; two levels of tension were aplied to address sensitivity analysis. Three test set-ups (axial, torsion and compression bending) were simulated. The stress distributions on bone, plate and screws were measured. Stress distribution on the distal humerus was similar for both plates. Stress distribution on the proximal humerus was more homogeneous for the push-pull model, showing less unloaded areas; similar patterns were found on the plate, the traditional plate showing elevated stress concentrations at the bone wedge.Each screw was loaded in at least one test set-up. More homgeneous stress distribution is found with the push-pull plate in all three set-ups, showing lower stress-shielding compared to the traditional plate; the screws implemented all cooperate to obtain results.

Keywords*: Traumatology, Humeral Head Fracture, Push-Pull Plate.*

Combination of functional and morphological data for the mechanics of high-tibial osteotomy

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In abnormal varus knees, a force increase on medial compartment occurs. High-Tibial-Osteotomy (HTO) is performed to restore physiological knee alignment and to delay replacements. Combination of motion analysis and medical imaging is necessary to better comprehend knee load distribution. We report on this original methodology and its exploitation on a large HTO-patient cohort in order to give evidence of pre- versus post-operative load at this joint. 25 patients were assessed pre- and post- HTO. These were gait-analyzed during daily living motor tasks using an established protocol. Additional markers were stuck for knee bone track, and weight-bearing CT scans were taken. Bone models were registered to gait data by means of the common markers; registration matrices were used also to superimpose ground-reaction-force vectors on the tibial plateau. Intersections of these vectors with the plateau plane were calculated. Pre-operative intersections were located medially to the tibial plateau; post- HTO, these were observed

lateralized, closer to the tibial plateau spine. Related pre-post difference in mm was 54.5±18.3 mm (min÷max: 30.7÷80.5 mm), and in % of medio-lateral width was 73.3±24.2 (44.9÷89.3).
The present original approach provides a clear depiction of the original unbalanced loading at the knee and of the effect of joint realignment.

Keywords: *Hight Tibial Osteotomy; Gait Analysis; Ground Reaction Force; Knee Varus Deformity; Knee Osteoartritis; Weight-bearing CT; Medical Imaging; Multi-Instrumental Data Registration.*

Biomechanical analysis of the knee joint during flexion in healthy, cruciate deficient and cruciate substitute conditions

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Computational models are widely used to analyse knee kinematics under healthy and pathologic conditions. This work aims to understand how much the knee joint function is influenced by the cruciate ligament damages and verify how the replacement strategies allow to restore the proper joint stability. A three-dimensional knee model was developed to simulate an open chain motion from 0 to 90 degrees. Different cases were considered: firstly, a native healthy knee, and then only anterior, only posterior and both cruciate deficient knee. To simulate the substitute conditions, two replacement strategies were studied: autologous replacement (with native patellar tendon) and artificial (with the LARS synthetic graft). Finally, the values of tibial internal-external rotation and femoral anterior-posterior translation were investigated. The analysed cases followed the same kinematic trend with an alteration of the magnitude from the native knee. All the cruciate deficient conditions presented altered joint kinematics, according to their role in joint stability; with the replacement strategies giving results close to native values. This study provided a better understanding of the joint performances both before and after the reconstructive surgery: starting from a cruciate-deficient condition it is possible to verify the effectiveness of the reconstruction comparing the results with the native control model.

Keywords: *Knee model, cruciate ligaments, cruciate deficient*

Mapping the Young's modulus of cortical bone via atomic force microscopy

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Small-scale mechanical characterization of bone tissue is critical to investigate regenerative or degenerative phenomena, as structural or compositional changes often take place at submicrometric distances, thus beyond the reach of traditional nanoindentation experiments. In this respect, Force-volume maps (FVM) of mechanical properties obtained by atomic force microscopy (AFM) represent an elegant and exhaustive tool for non-destructive and high-spatial-resolution analysis of the bone tissue, thanks to the ability of the instrument's probe to detect force variations on the order of nN during its interaction with the surface. Despite this, FVM are not routine on hard bone tissue due to the difficulty in applying the biomechanical models available and some experimental issues. We show that a standard AFM setup operating in air, when combined with a solid validation of the experimental protocol, can be used to obtain FVMs of cortical bone in a reproducible and reliable fashion. This allows to accurately monitor the gradual change in tissue's biomechanics due to structural and/or compositional changes, possibly induced by altered state or the presence of implants, biomaterials, etc. In particular, we discuss a suitable procedure to estimate both elastic and elastic-plastic deformations for moduli up to a few tens of GPa.

Keywords: *Atomic Force Microscopy; Nanoindentation; Young's Modulus.*

Design and Biomechanical Analysis of Stand-Alone Posterior Lumbar Cage Implant for Interbody Fusion

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Spine surgery for interbody fusion using intervertebral cage implants has become a prescribed method in the treatment of disc degenerative disease and spondylolisthesis. Cage implant provides stability for functional spinal units; however, this is accomplished with rods and plates that require additional penetration and space in vertebrae. Hence, stand-alone cage devices are being used, but the designs and their effectiveness are still investigational. This work aims at designing an intervertebral cage with a self-locking mechanism. The design includes a titanium body with two screws and a slider arrangement, to provide locking of the implant body with the spinal bones. The dimensions of the implant were chosen to best suit the lumbar L4/5 Intervertebral disc. The final element analysis was performed on the modeled implant that is placed between the modeled L4 and L5 vertebrae, to analyze load and stress distribution within the implant during flexion, extension, lateral bending and axial rotation. The biomechanical analysis displays a higher stiffness in lateral bending. In flexion, higher load is taken by the titanium body and in extension, the screws and the slider take the maximum stress. Results indicate that the proposed design with the locking mechanism withstand load, provide fixation and stability.
Keywords: *Interbody fusion; spinal implant; biomechanics.*

S1D: ADVANCES IN CARDIOVASCULAR RESEARCH

Coronary Physiology Based Diagnosis of Ischemia-Inducing Stenoses: Basics and Clinical Applications

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Coronary artery disease (CAD) (also known as coronary artery disease, CAD) is defined as the blockage of coronary, due to a build-up of plaque inside the coronary artery. The plaque narrows the artery and impacts the blood supply to the heart and causes a damage of the heart muscle. CAD is a common disease, affecting 6% of adult general population, and up to 20% in age > 65 years old. The prognosis of CAD is poor. Revascularization of coronary territories with demonstrable myocardial ischemia, rather than anatomical stenoses per se, is imperative both for symptom reduction and outcome benefits. Invasive coronary angiography (ICA) with fractional flow reserve (FFR) measurement has emerged as the gold standard for assessment of coronary flow physiology, and hence, coronary territory ischemia. However, its measurement involves invasive procedure. CT coronary angiography (CTCA) is emerging as first-line of investigation of CAD. However, CTCA alone does not determine whether a stenosis causes ischemia. Non-invasive FFR determination is an alternative approach using computational fluid dynamics (CFD) applied to coronary computed tomography coronary angiography (CTCA) images. Computation of FFRCT requires construction of an anatomical model of the coronary arteries; mathematical modeling of coronary physiology to derive boundary conditions representing cardiac output, aortic pressure, and microcirculatory resistance; and numerical solution of physical laws governing fluid dynamics. Non-invasive FFR technology could be incorporated effectively into a clinical management pathway for patients with suspected or known CAD, and assist cardiologists in diagnosing ischemia-causing lesion and assisting their decision-making in the care of patients (i.e. medical treatment or stent treatment).

Pilot study on photopletysmographic and electroencephalographic monitoring of candidates to atrial fibrillation electrical cardioversion.

(Multiparametric monitoring in candidates to atrial electrical cardioversion)

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This study explored the feasibility of a multiparametric approach with wearable devices in atrial fibrillation (AF) patients undergoing electrical cardioversion (ECV). In particular, photoplethysmographic (PPG) and electroencephalographic (EEG) signal registrations were integrated with clinical and instrumental data to evaluate autonomic and cognitive function, sleep pattern, and their relationship with clinical outcomes. The effect of AF on heart rate variability (HRV) and vascular age using PPG signals and on sleep pattern derived from EEG were considered. 24 patients underwent home recording of PPG and EEG signals using wearable devices before and after ECV procedure. We observed a reduction in most HRV parameters after ECV. Considering vascular age, it was observed a significant reduction in both TPR and a wave (p<0.001). A tendency to higher coherence of sleep pattern was observed in registrations acquired during AF than in presence of sinus rhythm, or considering signals registered before and after ECV for each patient. In conclusion significant modifications of HRV and vascular age parameters were observed after ECV, and a possible role of AF on sleep patterns; however, more data are necessary to confirm these preliminary results.
***Keywords**: Multiparametric monitoring, Cardioversion, Peripheral flow, Sleep pattern*.

Personalized configuration for atrial fibrillation external electrical cardioversion to improve acute efficacy.

(Acute efficacy of atrial fibrillation external electrical cardioversion)

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Nowadays, definite recommendations on electrode configuration for external electrical cardioversion (ECV) of atrial fibrillation (AF) are lacking, so we adopted a quasi-experimental design enrolling all candidates to ECV to evaluate acute efficacy. In the first stage, two units were involved, one using antero-apical pads (AAP) and the second antero-posterior adhesive patches (APP). The results of first stage enabled the creation of a decision algorithm to personalize ECV approach, which was subsequently validated.

In the first stage, APP and AAP presented similar conversion rate (87.4% vs 86.9%, p=0,661). A body surface area ≤2.12 m² was an independent predictor in the overall population, while height ≤1.73 m was a significant cut-off value in AAP subgroup, and weight <83 kg in APP subgroup.

The adoption of the new decision algorithm determined an improvement in first shock efficacy (93.2% vs 87.2%, p=0.025), and a reduction in shock impedance (70.8±15.3 vs 81.8 ± 15.6, p<0.001).

In conclusion anthropometric parameters influence acute efficacy of AF ECV, so personalization of ECV approach has the potential to optimize this procedure in clinical practice.
***Keywords**: Efficacy, Cardioversion, Rhythm control.*

Mathematical Modeling of Myocardial Infarction Treatment with Stem Cells

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The heart has a limited capacity for regeneration and repair. This diminished ability to regrow like other tissues, as well as an annual increase in heart disease worldwide, makes it one of the most heavily researched topics in medicine. After myocardial infarction (MI), irreversible cell death and consequent reduction in the repair ability of the heart are the leading causes of morbidity and mortality worldwide. And in the first days after acute MI, stem cell transplantation reaches a higher rate of cell uptake. In this work, a new mathematical model is presented to study left ventricular remodeling after MI. The model represents the regeneration process of cardiomyocytes with the transplantation of stem cells. The resulting system of nonlinear ordinary differential equations is studied both analytically and numerically in order to demonstrate the functionality and performance of the new model. To the best of our knowledge, this model is the only one of its kind to consider and correctly apply all of the known factors in diseased heart LV

modeling. This model has the potential to provide researchers with the tools to explore the potentials of different treatments, reducing the fiscal expenditure and time necessary to conduct cell-based studies.
Keywords: *Myocardial infarction; Heart regeneration; Cardiomyocytes; Immune system; Stem cells*

Influence of discordancy in umbilical arteries on the stress distribution in Wharton's jelly

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Umbilical cord connects the fetus to the placenta. It consists of two arteries and one vein, surrounded by Wharton's jelly. Although the lumen diameters of the arteries are generally similar, discordancy of up to 53 % has been reported. In this study, 2D finite element analysis is used to analyze the influence of discordancy in umbilical arteries on the stress distribution in Wharton's jelly. Lumen diameter of larger artery is kept constant at 2.8 mm and discordancy of 0 to 60 % is considered by varying the lumen diameter of smaller artery. Average and maximum effective stresses in the Wharton's jelly due to arterial and venous blood pressures are computed. The differences between the stresses developed in two halves of the jelly, corresponding to larger and smaller artery, are analyzed. According to results, the average and maximum effective stresses decrease with an increase in discordancy. The maximum effective stress in Wharton's jelly is always greater in the half containing larger artery. The discordancy in maximum effective stress is found to increase non-linearly with increasing umbilical artery discordancy. This study could enhance the clinical relevance of discordant umbilical arteries and might be useful for early diagnosis of foetal abnormalities.
Keywords: *Umbilical Cord; Discordancy; Wharton's Jelly.*

S2D: WEARABLE AND eHEALTH

Telemonitoring in ophthalmology, database and eHealth software

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The recent pandemic has unveiled the issues in the monitoring of chronic patients in ophthalmology, but at the same time has given the opportunity to test new ways to evaluate these types of patients over time and to discover new regimen of follow up. With this presentation we want to show the most recent innovations in teleophthalmology, from home devices to second opinion systems and custom medical records for clinical and research purpose, and how they are available on EUMEDA telemedicine platform since many years.
Keywords*: eHealth, telemedicine, ophthalmology.*

Optimization and Industrialization of a Metabolic Holter device and Software development

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The last decade has seen a rapid development of the Internet, especially on mobile devices. This ensemble of devices has been regrouped under the name of the Internet of Things (IoT). These devices are present in every aspect of our everyday life, from the vocal assistants Google Home to connected vacuum cleaners, passing by Tesla cars. A part of this domain is occupied by devices focused on collecting body parameters such as movement, temperature and heart rate. These parameters are then processed and presented to the user. They can be shared on social media, used to enhance sports performance, or assess health status. This specific use of IoT is known as quantified-self. This thesis aims to optimize and prepare for industrialization a prototype of such a device, specifically a metabolic holter, that has been developed last year at the

BEAMS department. Several aspects have been considered such as the large-scale production, design of the device and lastly, optimization of the device software through the results of a clinical study. Subsequently, a design and production plan is proposed as well as an enhancement of the energy expenditure model, which displays an accuracy of 80% with respect to the gold standard.

Keywords: *Metabolic Holter; Machine Learning; Energy Expenditure.*

Wearable Multiparametric Remote Monitoring: MySIGN

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MySIGN is a new wearable device for multiparametric remote monitoring developed by the Interdepartmental Centre for Industrial Research (CIRI) of the University of Bologna. The aim of this study is to assess the feasibility of data collection through MySIGN and the characterization of the signals and data recorded through the device.

Healthy volunteers were asked to wear MySIGN and perform three tasks: Deep breathing test (DB), Rest (R), and After six-minute walking test (6MWT). During each task, the following parameters were collected via MySIGN: absolute bioimpedance value (BioZ), bioimpedance variation (ΔBioZ), respiratory rate, heart rate, ECG QT interval, blood oxygen saturation, and temperature. 15 volunteers were enrolled (9 female (60%), mean age 35.8 ± 9.31 years). The six parameters collected by the device were successfully recorded during the three tasks. BioZ values did not vary either among the three tasks nor by stratifying the population according to age, whereas BioZ values were higher for subjects with a BMI>23 kg/m2. ΔBioZ remained unchanged regardless of task, age, and body weight. MySIGN allows effective multiparametric data collection. The ΔBioZ might be a good value for estimating lung congestion because it is less influenced by other variables.

Keywords: *remote monitoring; bioimpedance; wearables.*

S3D: DETECTORS AND DOSIMETRY

Sensitivity Analysis of Temperature Distribution Profiles of Breast with Tumors for varied Fat Layer Thickness

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Breast cancer is one of the prevalent causes of mortality among women. Infrared imaging can help diagnose breast cancer by detecting the thermal signature of the hypermetabolism of tumor cells. In this study, sensitivity of peak detection from the temperature profile of breast surface with varied morphology with two embeded tumors of 1.0 cm radius is analysed using 2D finite element models. Multiple simulations are performed to obtain the temperature profile for varied fat layer thicknesses ranging from 0.5 mm to 5 mm and tumor depths of 2.5 cm, 3.0 cm and 3.5 cm. Parametric sensitivity analysis is performed using fully factorial general linear model considering both the fat layer thickness and depth of tumor in order to predict difference in the peak temperatures (ΔT) pertaining to the tumors. Results show that temperature peaks become less distinguishable with both increasing fat layer thickness and tumor depth. General linear model shows that percentage change in ΔT is not significantly associated with tumor position, but rather with fat layer thickness and interaction of depth of tumor with fat layer thickness. Partial effect size is observed to

decrease with increasing tumor depth indicating loss of sensitivity in distinction of deep-seated tumors. This analysis may be useful in callibrating thermal imaging systems to diagnose breast cancer and thus be relevant in theraputic purposes.
***Keywords**: Breast Cancer; Sensitivity Analysis; Finite Element Method.*

Medical Applications of Flexible and Large area X- and gamma-Ray Detectors

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High-energy solid-state detectors based on novel organic and hybrid semiconductors present important features which make them promising candidates for medical applications. In fact, this class of sensors fulfill crucial tasks, not provided by traditional detectors, such as the mechanical flexibility and conformability, the low-cost of production, the low-power operation, portability, and the possibility to print them onto large-area panels. In addition, their low material density and the chemical structure rich of C and H atoms, make them human tissue-equivalent and very appealing for dosimetry. Here we present the results regarding a X- and Gamma-rays detector based on solution-grown hybrid 2D layered perovskite films, implemented, and tested for different medical applications. These devices are fabricated onto flexible plastic substrates, and they work at low bias (<5 V), granting the possibility to be powered by a battery-operated, wearable readout electronics, with wireless data communication. We demonstrate how this sensing system can be exploit for the detection of high energy photons emitted by radioisotopes typically used in nuclear medicine (18F, 99mTc and 177Lu). We also show its capability to follow the radioactivity path scheme at the patient skin during the intravenous injection of radiopharmaceutical drugs in a dummy phantom.
***Keywords**: perovskite, dosimetry, radiotherapy*

Organic thin films as flexible, large area X-ray and proton detectors for medical therapy

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Proton therapy is currently one of the most advanced medical therapy tools for cancer treatment allowing the sparing of healthy tissues surrounding the cancer target thanks to the possibility to tune and focus the peak of the maximum released energy by the protons (the Bragg peak) on the selected volume. We report on novel, fully organic detectors for a real-time beam and dose monitoring over a large area, that permit to verify the actual dose delivered during the proton-therapy session improving the care quality and preventing long-term toxic effects. The use of organic semiconductors as active detection layers allows to implement devices that achieve two key goals: i) their thin, flexible and large area structure permits their comformable use directly on the patient during therapy; ii) their organic composition results a tissue-equivalent device, a very relevant advantage for medical dosimeters.
We will discuss two different device geometries: one operates in the direct mode (direct conversion of the proton beam into an electron-hole pair collected by the organic thin film device) and the other in the indirect mode (an organic scintillator coupled to an organic phototransistor). To date, there is no example of organic semiconductor detectors used as proton beam dose monitoring systems.
***Keywords**: proton therapy: radiation detectors; real-tima wearable device*

Target Effects vs. Non-Target Effects in Estimating the Carcinogenic risk due to Galactic Cosmic Rays in Exploratory Space Missions.

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Space radiobiology is an interdisciplinary science that examines the biological effects of ionizing radiation on humans involved in aerospace missions. The knowledge of the risk assessment of the health hazard related to human space exploration is crucial to reducing damages induced to astronauts from galactic cosmic rays and sun-generated radiation. Galactic Cosmic Rays (GCR) have been identified as one of the primary sources of radiation exposure in space. In this context, an accurate characterization of the possible risk of carcinogenesis induced by exposure to GCRs particles is a significant concern for human exploratory space missions. In this talk, the tumour prevalence is used to investigate the effects of Non-Target Effects (NTE) in predictions of chronic GCR exposure risk. The NTE model led to a predicted risk 2-fold higher compared to a targeted effects model. Therefore, it is nowadays accepted that the detrimental effects of ionizing radiation are not restricted only in the irradiated cells but also to non-irradiated bystanders or even distant cells manifesting various biological effects. In this talk, an extensive study will be presented about the risk increase due to the Non-Target Effects that the GCRs radiation will imply when added to the Target one. Status of the art results will be summarized, recent observations and theoretical framework presented, and some new hints derived from the data collected from the AMS02 detector. Finally, the possible future development will be highlighted about the possibility of an accurate estimate of the tumor prevalence function for different exposure exploratory space mission scenarios.

Keywords: *Space Radiation, Space Radiobiology, Target Effects, Non-target Effects, Tumour Prevalence, Galactic Cosmic Ray*

Pediatric vs adult dosimetry in CBCT: a challenge?

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Concern about the radiation dose to children from diagnostic radiology examinations has recently been popularly expressed, particularly as related Computed Tomography (CT) procedures. This involves the idea that children can receive higher doses compared to adults. Since the dosimetric quantities are essentially defined for adult patients, if related to effective dose, it becomes important to study and derive methods applicable also to pediatric cases. In fact, the “commonly” statement implies that size, shape, and data for pediatric organs will be derived from adult ones, numerically reducing dosimetric problems to the definition of scaling algorithms. The aim of this study is to analyze the differences in pediatric vs adult dosimetry, starting from measured organ doses in Cone-Beam Computed Tomography (CBCT) procedures for maxilla-facial region. Two different anthropomorphic phantoms (child vs adult phantoms) were scanned, acquiring all data: results will be presented in terms of organ and derived doses, discussing the approach and differences.

Keywords: *Dosimetry, CBCT, TLD*

S4D: PET AND NUCLEAR MEDICINE

Role of ^{99m}Tc-DPD scintigraphy in quantification of myocardial uptake of Hereditary Transthyretin-Related Cardiac Amyloidosis

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The aim of this work is to highlight the role of planar scintigraphy and tomography in diagnostic accuracy and in the search for quantification methods of myocardial amyloid infiltration. In a cohort of 186 patients, the geometric mean between the early image scan, obtained a few minutes after injection of 99mTc-3,3-diphosphono-1,2-propanodicarboxylic acid (99mTc-DPD), and the late image scan, acquired 3 hours later, was used to outline the regions of interest (ROI) of the heart, kidneys, bladder, whole body, and background. The Whole-Body retention (WBr) was evaluated considering the total counts in WB and subtracting the total counts in bladder and kidneys, by comparing decay and scan speed-corrected counts in the late images with early WB counts. The Heart retention (Hr) was evaluated by comparing decay and scan speed-corrected counts of the heart in late images with counts in early WB images. The Heart Whole Body ratio (H/WBr) was obtained by dividing the counts in the heart by the counts in late WB images. The H/WBr median value was 4.6 % (1.4%-10.7%) and was in good accordance with the visual score, assessed by a nuclear medicine physician, depending on whether there is no or high cardiac uptake compared to bone uptake. The H/WB was positively correlated with intraventricular septum (IVS) (Pearson's r= 0.35, p= 1.4e-06) and negatively with left ventricular (LV) ejection fraction (r= -0.2, p= 0.0054). The Hr median value was 4.0 % (1.1%-9.8%) and was in good agreement with heart failure outcome (p=0.013). The H/WBr and Hr calculation are used to quantify the cardiac uptake in correspondence with the amyloidotic fibrils deposited in the heart tissue, therefore they can be effective in predicting major adverse cardiac events (MACE).

Keywords*: Heart Whole Body ratio; cardiac uptake; geometric mean method*

PET-derived radiomic applications in breast cancer: State of Art

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The aim of this study is to provide an updated overview of the published PET-derived radiomic applications in breast cancer. A Pubmed/MEDLINE search was performed up to 15/06/2022 using the query string "PET BREAST AND (RADIOMICS OR TEXTURE OR MACHINE LEARNING OR DEEP LEARNING OR ARTIFICIAL INTELLIGENCE) NOT REVIEW". Screened papers were classified into the following aim-class: Diagnosis and Biological Characterization, Neoadjuvant chemotherapy assessment, Staging/re-staging, prognosis, technical papers, multiple aims. Radiomics workflow, technical issues and clinical findings were investigated.

A database was created for the qualitative synthesis of the papers. Overall 79 articles were screened. Among those 51 fulfilling inclusion/exclusion criteria were analyzed. Papers were classified as follows: 18 diagnosis and biological characterization, 7 neoadjuvant chemotherapy assessment, 9 staging/re-staging, 3 prognosis, 7 technical papers, 7 multiple aims. The studies were performed in different imaging modalities (CT-PET, MRI-PET) using F-18 with different radiotracers (FDG, FES, FLT). Radiomic analysis was performed using in-house, open-source or commercial software. The methodology of the included studies was discussed. Due to the great interest in this topic, a critical analysis of the state of art was necessary. Clinical and technical issues could invalidate radiomic application in PET practice.

Keywords*: breast cancer, PET, radiomic*

A novel tool for predicting dose distribution of non-sealed 188Re resin in NMSC patients.

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We present and validate a novel Monte Carlo (MC)-based tool for 188Re-based resin activity and dose calculation for Non-Melanoma Skin Cancer (NMSC) patients.

MC simulations were carried out using FLUKA and MC-based Look Up Table was incorporated in an ad-hoc developed tool for personalized calculation of treatment parameters. The proposed tool was compared using Bland-Altman analysis to the previous approaches conducted using VARSKIN in a retrospective cohort of 76 patients. The tool was ad-hoc validated using stacks of calibrated Gafchromic EBT3 (GAF-EBT3) films exposed using a homogenous activity distribution of 188Re eluate and a heterogeneous activity distribution of 188Re resin mimic the patient treatment. The agreement between the proposed tool and VARSKIN, in terms of minimal target doses, ranged from 1% to 10% for intermediate depths (1.2±0.7mm), while showing significant differences for superficial doses. The agreement between MC calculation and measurements at different plans in a stack of GAF-EBT3 films was within 10% for both (homogenous/heterogeneous) 188Re activity distributions. Worst agreements were observed for absorbed doses ≤0.3Gy. Our results support the implementation of our MC-based tool for calculating the 188Re resin activity and treatment parameters necessary for obtaining the prescribed minimal target dose.
Keywords: *High-dose brachytherapy; Monte Carlo simulations; Non-Melanoma Skin Cancer.*

Optimal parameters of a Bayesian-Penalised-Likelihood algorithm for improving the activity distribution accuracy in ^{90}Y trans-arterial radioembolization.

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In trans-arterial radioembolization, 90Y is administered to primary/secondary hepatic lesions. An accurate post-treatment verification using 90Y PET/CT images is mandatory to determine the actual absorbed dose distribution and establish dose-effect models. Unfortunately, PET/CT is affected by intrinsic physical limitation affecting the accuracy of activity distribution. To identify the best parameter combination of a Bayesian-Penalised-Likelihood(BPL) algorithm we analysed image quality and quantitative recovery factors. NEMA IQ phantom was acquired and reconstructed with ordered-subset-expectation-maximization (OSEM) and BPL algorithm at various β-values. Recovery Coefficient (RC), contrast recovery(CR), background variability(BV) and a new index called CRBV were calculated. Highest CRBV values were used to identify the optimal β-value ranges. BV monotonically decreased for all the spheres at increasing BPL β-values, while the CR values increased for the sphere diameters>15 mm. The CRBV indicated an optimal β-values range [i.e.,4000÷9000] for the sphere diameters>10mm. The BPL outperformed the OSEM algorithm in terms of RC for largest spheres, while it outperformed for β-values<1000 and 7000 in sphere diameters >17mm and >22mm, respectively. Our study highlighted that BPL algorithm outperformed the OSEM one for most of analysed sphere diameters and figures-of-merit, but the optimal β-value parameter should be selected on the patient-specific tumour basis.
Keywords: *Bayesian-Penalised-Likelihood algorithm; PET/CT; 90Y radioembolization.*

S1L: ADVANCED METHODS IN NEUROSCIENCES

Evaluation of Zernike moments of corpus callosum for discrimination of autism using Random Forest

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Autism spectrum disorder (ASD) is a non-progressive neurodevelopmental disorder characterized by abnormal structural alterations in the brain, resulting in difficulties in learning and behavior. In this study, we analyzed the performance of Zernike moments extracted from the corpus callosum (CC) to diagnose ASD. For this, we used the structural magnetic resonance imaging(sMRI) data available in the ABIDE-I and ABIDE-II databases. We considered sMRI data of ASD and typical developing (TD) individuals from the KKI site and used the distance regularized level set evolution (DRLSE) method to segment the CC from

the midsagittal view of 2D sMRI. The segmented images were then verified against the ground truth using Sokal and Sneath-II (SS-II) measures. Zernike moments extracted from the 2D segmented regions were then trained on a random forest classifier with five-fold cross-validation. The results showed that the segmented images highly matched the ground truth with the mean similarity measure value of SS-II =0.9931, which signified that our method could segment the CC region successfully. We achieved the highest fold accuracy of 74.07% and an average accuracy of 66.28%. We suggest that the proposed method could be used to screen ASD-like neurodevelopmental disorders with lower computational complexity.
Keywords: *Autism spectrum disorder, Corpus callosum; Zernike moments and random forest*.

Investigation of brain networks in autism using fractal, non-fractal and pearson correlation methods

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Autism spectrum disorder (ASD) is a neurodevelopmental disability with altered functional brain connectivity networks. The brain networks corresponding to ASD were inconsistent and understudied. In this study, the brain networks of ASD and typical developing (TD) were analyzed using functional magnetic resonance imaging data (fMRI) publically available in ABIDE-I and ABIDE-II database (ASD=314, TD=397). Initially, the fMRI data were preprocessed using standard pipeline and then BOLD time series were extracted from 236 ROI's using Gordon's, Harvard Oxford and Diedrichsen atlases respectively. We computed the fractal, non-fractal and Pearson correlation functional connectivity matrices and resulted in 27,730 features which were ranked using XGBoost feature ranking algorithm. Results revealed that most important connections were within the default, cerebellum to cingulo opercular task control (COTC), default to none region from fractal, non-fractal and Pearson correlation method respectively. We analyzed the top 1% of the important features and found that COTC contributes to more brain connections. Normalization results state that salience (50%), default (36.84%) and ventral attention (31.25%) contributed to the major number of connections in each method. The results suggest that the identified brain networks may serve as a biomarker in diagnosis of ASD.
Keywords: *Functional brain connectivity; Fractal and non-fractal; Pearson correlation.*

Detection of Schizophrenia using 4-Dimensional attention based Deep Learning Model

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Schizophrenia (SZ) is a severe neurological condition often associated with functional deterioration in sensory and frontal brain areas. Electroencephalogram (EEG) offers an effective means of evaluating brain functions particularly in serious neurological conditions. Although, EEG does not precisely determine the etiology of brain dysfunction, the subsequent processing of the data using deep learning networks, has recently provided an accessible way of modeling and analyzing complex and subtle variations of neural patterns. In this work, an attempt has been made to analyze EEG recordings of 39 healthy and 45 schizophrenics using 4D attention based deep learning networks. EEG signals from 16 channels over one-minute duration are split into one second segments with each segments decomposed into various frequency bands. A 3D tensor is formed from 2D sparse map of differential entropy feature extracted from each segment. The channel and spatial attention maps are created by applying multilayer perceptron to these feature descriptors and are convolved by sequential convolutional layers. Results show that an accuracy of 75% is achieved with the proposed deep learning model. The embedded attention mechanisms enable four dimensional spatial-spectral-temporal representations of EEG signals to adaptively capture discriminative patterns of brain dysfunctions and could enhance the accuracy by 5%.
Keywords: *Schizophrenia; deep learning; attention.*

Optimization of preprocessing routines in Speech Imagery based EEG Signals

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Speech imagery (SI) is a type of mental imagery specific to the processing of verbal sequences. It is a form of inner speech with no vocal cord movements and plays a vital role in human thought processes. SI is an important paradigm in neuroscience research as it has high similarity to real voice communication. Analysis of SI has been carried out through EEG signals acquired during the imagery protocols. As EEG signals have a low signal-to-noise ratio, artifacts occur during acquisition. This work focuses on employing various pre-processing techniques for artifact removal and identifying the optimal methods for Speech imagery-based EEG signals. Multi-trial EEG signals were recorded from five healthy volunteers while imagining speaking English vowels. Various pre-processing techniques such as filtering, normalization, and smoothening of signals were implemented and tested to obtain artifact-free signals. The Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) values were estimated. Results show a high PSNR and a low MSE across all subjects when Butterworth filters, min-max normalization, and Savitzky-Golay smoothing pre-processing routines were employed. The identification of an optimal pre-processing sequence can thus be impactful in analyzing artifact-free speech imagery-based EEG signals for further investigations.

Keywords: *Speech Imagery; Electroencephalography (EEG); Signal to Noise Ratio (SNR); Mean Square Error (MSE); Peak Signal to Noise Ratio (PSNR).*

Entropy analysis of EEG patterns for effective classification of Huntington's Disease

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In this analysis, 89 subjects are analyzed for effective diagnosis of Huntington's Disease (HD). HD is a rare autosomal neurodegenerative disease. The assessment of brain activity using EEG signal could help in planning the treatments to lower the effect of HD. The data used in this work is obtained from open-source repository in which the subjects are classified as symptomatic control HD (CSHD), pre-symptomatic control HD (CPHD), symptomatic HD (SHD) and pre-symptomatic HD (PHD). EEG signal was recorded using 16 channel system for 20 minutes and sampled at 1.2KHz. Tsallis Entropy, Shannon Entropy, LogEnergy Entropy, and Renyi Entropy are extracted from the EEG signal. The electrodes F3 and Fp1 were found to exhibit better discriminating ability between the classes. AUC measure is found to be CSHD (0.711), CPHD (0.708), SHD (0.957), PHD (0.839) for F3 electrode and the feature from Fp1 electrode have AUC as CSHD (0.722), CPHD (0.731), SHD (1.000), PHD (0.979). The changes in the pre-frontal cortex regions of HD subjects are effectively captured by Fp1 electrode. The features from electrodes O1, P4, P7, P8 and T7 are found to possess the ability in distinguishing CPHD, SHD and PHD effectively. This analysis is in par with several analysis proving the significance of EEG signal for effective category classification of HD.

Keywords: *Huntington's Disease, Autosomal Disease, Rare Disease, EEG, Entropy, Tsallis Entropy, Shannon Entropy, LogEnergy Entropy, Renyi Entropy.*

S2L: CO2 ANGIOGRAPHY

Biomechanical aspects involved in CO_2 Angiography

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CO_2 angiography has been introduced in clinical practice to limit the dangerous effects of iodine, the contrast medium used in standard angiographic procedures. Initially the injection of the CO_2 gas in the vessels was made manually, with results strongly dependent on the operator experience and skills and only

a little possibility of comparison. With the introduction of a programmable injector, it has become evident how the diagnostic imaging is strongly dependent on the way the bubbles move and fill the vascular cavities, suggesting different approaches and regulations in the different conditions. This evidence highlights biomechanical aspects the clinicians had never considered and that each optimization of the CO_2 angiographic procedure must be studied also and above on the side of vascular biomechanics. The clinical staff limited knowledge of biomechanics, and the limited experience of engineers and physicists on angiographic procedures are the major limitation of CO_2 angiography optimization.
Keywords: *CO_2 angiography; bubbles movement; biomechanics*

Radioprotection in CO_2 Angiography

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Why to focus on radioprotection in a Conference of biomechanics? Because a deep analysis of the radioprotective problem of this quite new diagnostic procedure, demonstrates that the optimization of radioprotection is strictly related to the optimization of gas injection, which changes in the different biomechanical conditions. A particular attention is focused to the differences, in terms of radiological dose between iodine and CO_2, and some protocols are on course to clarify this aspect, frequently with incoherent results. In this paper the radioprotection problem of CO_2 angiography will be clearly outlined, with procedural references to vascular biomechanics. It will be demonstrated that the radioprotection problem and imaging results depend only and how the clinicians manage the diagnostic procedure: it depends only a little on the contrast medium, it mostly depends on the scientific knowledge of clinical staff: doctors, technicians and physicists. If everyone plays his role in the best way, knowing that the imaging result is strictly related to the vascular biomechanics, (which has to be deeply known), a global positive result is achieved.
Keywords: *CO_2 angiography; Radioprotection; Imaging.*

Optimization of gas injection in CO_2 Angiography

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The use of programmable gas injectors has demonstrated how it is necessary to adapt the parameters (gas pressure and flow) in the particular diagnostic context to obtain the best imaging result with minimum radiological exposure. Imaging of a big vascular cavity, or medium size artery or small peripheral artery is a completely different game, which requires different regulations and management of the instruments. In this paper the focus will be on small peripheral arteries imaging (BTK), where the required low injection gas flow interferes with the low hydraulic resistance of the catheter and the wide arterial pressure pulsatility, producing an irregular gas injection, with reflow and pain. To overcome this problem, a calibrated adjunctive resistance in series of the catheter is proposed, with theoretical analysis and optical simulation.
Keywords*: CO_2 angiography; Imaging; BTK; gas flow; hydraulic resistance*

CO_2 Computed Tomography

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CO_2 angiography is demonstrating his value in vascular imaging on patients with Iodine intolerance or renal failure. This evidence suggests using CO2 as a contrast medium also in computed tomography, mainly in peripheral arteries (BTK), where a high resolution is required, and the vessel is immobile. To face this problem two aspects must be faced: 1) the non-continuous filling of the vessel by the gas, which may produce false positives and incorrect anatomical reconstructions; 2) The difficulty to execute vascular interventional procedures in the CT rooms, not equipped for this activity. To face both these problems with

a feasible solution, we tested the possibility to place a small CT cone beam system in an interventional angiographic room. We used a Cone Beam TC system planned for oral CT anatomical reconstruction (suitable for a BTK imaging) with a vascular phantom with physiological pulsatile pressure and flow. We tested the possibility to have good images with a very low iodine concentration and gas injection. The test demonstrates the feasibility of this approach and opens a new prospective in the BTK imaging and intervention.

Keywords: *CO2 angiography; Imaging; BTK; vascular; iodine intolerance.*

S3L: BIOMATERIALS AND PROSTHESIS

Emerging technologies in Green biocomposites for orthoses and external prostheses

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Currently, prosthetic sockets are made from a mould that is derived from the residual limb. This ensures that the best possible design with a comfortable and effective fit can be achieved. The prosthesis is laminated by carbon or glass fibres reinforcing plastics, which are lightweight and offer good flexibility. However, as world-wide drive to address the existential climate challenge, such as moving away from our reliance on oil and gas, which are the main sources from which plastics and carbon fibres are derived, the cost of the plastic materials for making the prosthetic sockets could increase as they get more difficult to come by. In this talk, I shall present an overview of our strategy to exploit natural fibres, such as kenaf fibres or pineapple leaf fibres (generated as agricultural waste from the agricultural industry), for use in reinforcing plastics that are used to make the lower limb prosthetic socket. I shall present key ideas in the environmental impact of products, and how this could implicate the prosthetic device at key stages of its life cycle and opportunities to reduce the overall impact of the device.

Bioactive polymer grafting impacts on silicone breast implants' mechanical properties and cell responses.

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Breast implant issues have raised many concerns and attention these past years. Part of the top 10 most implantable biomedical devices, breast implants are widely used for different reasons (plastic and reconstructive surgeries). However, as with any devices, they are subjected to healthcare-associated infections as the development of capsular contractures or, more rarely, large cell anaplasic lymphoma a cancer-related to breast implants. The grafting of bioactive polymer has been actively demonstrated to improve metallic and polymer-based surfaces' bio-integration by conferring them an antibacterial property and improving their biocompatibility. On silicone surfaces, among the numerous strategies developed to overcome bacterial biofilms in the literature, we have recently achieved a simple way to directly graft bioactive polymers on silicone breast implants outer shell only using UV irradiation according to a grafting "from" strategy. In the biomedical field, it is necessary to fulfill the regulation in force. ISO standards state the requirements a material should respect to guarantee the safety and quality of any device. The present study aims to evaluate the grafting parameter's impacts and the presence of the grafted polymer on both silicone shell initial mechanical properties along with the biological responses using a standard L929 fibroblast cell line.

Keywords*: Breast implant; silicone; Bioactive.*

Grafting phosphonic acid polymers onto titanium implant for craniofacial prostheses

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Titanium (Ti) is the most commonly used material for cranial prostheses. These materials have excellent physical and chemical properties such as good corrosion resistance, acceptable biocompatibility, and mechanical properties close to the human bone. However, Ti-based materials are passively integrated into the bone, resulting in a purely mechanical attachment. Consequently, the loss of osseointegration often leads to implant failure. Therefore, enhancing bone formation surrounding the implant is primordial. Previous studies assessed in our laboratory have shown that grafting bioactive polymers such as poly (sodium styrene sulfonate) (polyNaSS) favors osteoblast cell adhesion and differentiation. In this context, this contribution proposes to functionalize Ti with a phosphonic acid-based polymer, poly (vinyl benzyl phosphonic acid) (poly(VBP)). A two-step UV-initiated grafting polymerization was developed to covalently graft VBP onto Ti surfaces. The Ti substrates were evaluated for cell viability, spreading, alkaline phosphatase activity, and calcium nodules formation using MC3T3-E1 osteoblast cells. Ti grafted samples showed significantly better interaction with osteoblast cells and enhanced cell/surface interaction. Together, these findings demonstrated that the presence of poly(VBP) grafted on Ti surfaces improved osteoblasts' early cell adhesion and spreading processes, which is crucial for applications aiming at improving osseointegration.
Keywords: *Titanium; Osseointegration; Bioactive implant.*

Micro-CT and uniaxial loading to reveal the 3D microstructure under increasing strain of tendon-ligament scaffolds

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Electrospun PLLA/collagen bundles (EB) and hierarchical structures (EHS) are under research as bioinspired tendon-ligament scaffolds. Understanding how the hierarchical structure evolves with increasing strain is of the utmost importance to relate scaffold geometry under load and mechanical characteristics, to define and validate constitutive models. With this aim, a micro-CT in-situ uniaxial loading procedure is under validation. Firstly, 20-mm-long samples are prepared. Weight and diameter are measured in dry condition, to normalize applied load. Then, samples are soaked in phosphate-buffered saline for two minutes and clamped for tensile loading in the micro-CT apparatus (Skyscan1172, Bruker, Belgium). After two scans at the minimum strain allowed by the load cell sensitivity (EB: 2%; EHS: 0%), progressive strains were imposed (EB:3-4-5-7%; EHS:1.5-3-5-7%) after 15 minutes of stress-relaxation followed by micro-CT acquisitions. The latter have been optimized balancing image quality, i.e. contrast and spatial resolution (source voltage 40 kV, current 75 μA; no filter; image pixel size 9 μm; frame averaging 4; 180° rotation; rotation step 0.8), and scanning time (17 minutes). Tests show strain-load curves consistent with reference characterizations, showing that the procedure does not alter scaffold original characteristics, adding possibility to study the internal structure. Collected data will be analyzed with Digital Volume Correlation.
Keywords: *electrospun hierarchical scaffolds; micro-CT; In-situ tensile tests.*

The choice of hernia meshes according to age of the patients

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The abdominal hernias become more prevalent with age. The objective of this study was to investigate the choice of the proper brand of hernia mesh according to age of the patients.
78 samples harvested from 19 fresh cadavers were subjected to uniaxial tension tests and divided into four groups according to age. Group A -age up to 60 years, Group B (61–70 years), Group C (71–80 years) and Group D (81–90 years). Median stress–stretch ratio curves with respect to age, sex and direction of loading were obtained. The elastic modulus of samples was calculated at 5% strain. Uniaxial tensile tests were

performed also using three standard meshes (Surgimesh®, Surgipro™, TecnoMesh®) and five light-weight meshes (Optilene®, TiO2Mesh™, Parietex™, Vypro™ II, Ultrapro). The elastic modulus at 5% strain and the level of orthotropy (the ratio between tensile stress in the longitudinal and the transversal direction) at 5% strain were calculated.
Vypro™ II and Parietex™ display properties similar to those of fascia in both directions. Only the orthotropy of Vypro™ II is similar to that of fascia. As the elasticity of light-weight meshes is closer to the elasticity of fascia this type of meshes should be preferred in hernia operations.
Keywords: *hernia meshes; abdominal fascia; mechanical properties.*

S4L: ADVANCED METHODS IN NEUROSCIENCES

Deep-learning framework for ECG based categorical emotional states assessment

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Accurate recognition of human emotions plays a vital role in the human-computer interaction. Electrocardiogram (ECG) is one of the widely used techniques to classify various emotional states. However, differentiation of categorical emotional states is less explored. In this work, an attempt has been made to classify categorical emotional states using ECG signals and configurable convolutional neural networks (cCNN). For this, annotated ECG signals are obtained from publicly available "A dataset of continuous affect annotations and physiological signals for emotion analysis" (CASE) dataset and downsampled to 250Hz. Short-time Fourier transform with an overlap window (0.8s) is applied to obtain spectrograms. cCNN with two convolutional and two fully connected layers are employed to discriminate categorical emotional states namely relaxed and scary. k-fold cross validation (k=6) is used to evaluate the robustness of the proposed method. The results show that the proposed approach is able to discriminate categorical emotional states. We achieved a high f-score of 72.45% and a positive predictive value of 80% using fewer learnable parameters. The proposed framework yielded a sensitivity of 67.41% to distinguish between relaxed and scary states. Thus, it appears that the suggested technique could be helpful in the diagnosis of clinical conditions linked to stressful emotional states.
Keywords: *Emotion detection; deep learning; time-frequency transforms.*

Characterization of seizure subtypes using time-frequency features from scalp EEG signals

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Epilepsy is a chronic neurological condition that affects 70 million worldwide. Seizures are the classical biomarkers of epilepsy. They can be categorized into eight subtypes based on the location of origin and clinical manifestation of symptoms. Identification of seizure subtype is essential to characterize epilepsy syndrome. Quantifying the characteristic patterns of different seizure subtypes will also promote the development of better seizure detection and classification systems. In this study, we attempted to investigate the characteristics of five seizure subtypes using scalp electroencephalogram (EEG) data on a sizable cohort of 356 patients from the openly available Temple University Hospital (TUH) database. After applying standard EEG preprocessing, we extracted a total of 56 time-frequency signal features. The one-way ANOVA statistical test was applied and 51 features (out of 56) were statistically able ($p<0.05$) to distinguish two or more groups of seizures. The Higuchi fractal, zero crossing rate and band power features (bands: 23-25, 2-4 Hz) were the best discriminative features. Further, the results revealed overall, the time domain

features were better at discriminating seizure types compared to the frequency, time-frequency domain features. This study will be an important step towards understanding the characteristics of seizure subtypes quantitatively.
Keywords*: Epilepsy; seizure subtypes; EEG*

Classification of emotional states using electrodermal activity and random forest

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Emotions are the psycho-physiological and psychological status of a human. Carrying unpleasant emotions for a long time is the root of emotional disorders and has a significant negative impact on health. Early detection of unpleasant emotional states helps to return the individual to normal life. In this study, amusing, boring, relaxing, and scary emotions were detected using electrodermal activity signals. We considered the EDA data of 30 participants (two trails) from the publicly available Continuously Annotated Signals of Emotions (CASE) database. The EDA data were pre-processed and decomposed into tonic and phasic components using cvxEDA method. We calculated 11 temporal features from the phasic component and tested the statistical significance using the Wilcoxon rank-sum test. Finally, we build a machine learning model to classify the emotions using a random forest algorithm. The statistical result revealed that eight of the eleven temporal features were able to discriminate the 5 pairs of emotions (amusing-boring, amusing-relaxing, amusing-scary, boring-scary, relaxing-scary). The six-fold cross validation achieved an accuracy, sensitivity, specificity, precision and F-score of 83.13%, 66.25%, 88.75%, 71.58%, and 66% respectively. The outcomes of our study indicate that the suggested models might be useful to identify various emotions in clinical applications.
Keywords: *Emotion detection; Electrodermal activity, Temporal features and random forest.*

Detection of Seizure Types using EMD-based Feature Fusion of Scalp EEG

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Epilepsy is a neurological disorder that causes unprovoked and recurrent seizures. A seizure is characterized by an abnormal discharge of synchronized neurons in a discrete or generalized portion of the brain. The foremost goal of treating persons with epilepsy is to render the patient seizure-free, as it is strongly correlated with quality of life, morbidity, and mortality. In this regard, an accurate detection system is helpful for providing important information on first-line treatment. The most common diagnostic modality used for this purpose is the electroencephalogram (EEG), although it has nonlinear and non-stationary characteristics. Therefore, in this study a nonlinear approach namely, Empirical mode decomposition (EMD) is proposed to detect seizure types. Electrographic, Complex partial and Tonic-clonic seizures from Temple university hospital data corpus are selected for this purpose. Hjorth activity, mobility, complexity, and first difference have been extracted from these decomposed signals. The distributions are found to be statistically significant ($p \leq 0.5$) and a random forest classifier is used to develop the model. Further, a feature fusion technique is also employed to improve the performance, yielding an accuracy of 96% and Matthews correlation coefficient of 0.92. The results show that the proposed system could be an aid in diagnosing seizure types.
Keywords: Epilepsy; EEG, seizure, machine learning.

Evaluation of fractality of brain cognition in young children using task-based EEG signals

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Cognition is the practice of processing knowledge through mental processes. Understanding the cognitive functions of the brain in young children helps in identifying neurodevelopmental disorders at early stages. Most studies used to diagnose neurodevelopmental disorders are based on behavioral scales. But, the majority of children with neurodevelopmental disorders are non-verbal. Thus, the goal of this research is to perform a task-based analysis of cognitive skills in children using electroencephalographic (EEG) signals. Spectral and fractal features of the EEG signals were acquired from pre-primary school children (N = 15) during arithmetic and a path-finding cognitive task. The acquired signals were decomposed into various sub-bands. Investigations on the time-domain Higuchi's Fractal Dimension (HFD) analysis and frequency domain Power Spectrum Analysis features demonstrated the dominance of the Theta band over the other subbands. The frontal electrode exhibited more workload in the arithmetic task, indicating the involvement of frontal regions and the temporal areas (T8) were actively involved throughout the path-finding task, showing the activity related to spatial perception and navigation. Thus, the statistical information obtained from the spectral and fractal analyses seems to provide quantitative evidence of the variations in cognitive skills of young children thereby enhancing inferences towards neurodevelopmental disorders.

***Keywords**: Cognition; Higuchi's Fractal Dimension (HFD) analysis and Power Spectrum Analysis; Neurodevelopmental disorders.*

20 September

Plenary Talk

Emerging methods in Biosignal Processing

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Our bodies are constantly communicating information about our health. This information can be captured through physiological instruments that measure heart rate, blood pressure, oxygen saturation levels, blood glucose, nerve conduction, brain activity and so forth. Traditionally, such measurements are taken at specific points in time and noted on a patient's chart. Physicians actually see less than one percent of these values as they make their rounds—and treatment decisions are made based upon these isolated readings. Biosignal processing involves the analysis of these measurements to provide useful information upon which clinicians can make decisions. Engineers are discovering new ways to process these signals using a variety of mathematical formulae and algorithms. Working with traditional bio-measurement tools, the signals can be computed by software to provide physicians with real-time data and greater insights to aid in clinical assessments. By using more sophisticated means to analyze what our bodies are saying, we can potentially determine the state of a patient's health through more noninvasive measures. The main objective of Biosignal processing is to extract the significant information about vital organs from Biosignals to help physicians in early diagnosis and prediction of deadly diseases. Biosignal processing is a rapidly expanding field with a wide range of applications, from the construction of artificial limbs and aids for disabilities to the development of sophisticated medical imaging systems. Acquisition and processing of biomedical signals has become more important to the physician. The main reasons for this development are the growing complexity of the biomedical examinations, the increasing necessity of comprehensive documentation and the need for automation in order to reduce costs. Biosignal processing research focuses on medical devices, particularly applications of advanced signal processing, machine learning and physiological modelling to develop affordable and reliable healthcare technologies, towards saving lives and reducing healthcare costs.

S5M: BIOSIGNAL PROCESSING

Analysis of surface electromyography signals under fatiguing conditions using fuzzy recurrence plot and GLCM features

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Surface electromyography (sEMG) signals are complex non-linear in nature. In this work, an attempt is made to visualize sEMG signals using Fuzzy recurrence plots (FRP) under fatigue condition. Further Gray level Co-occurrence matrix (GLCM) features are extracted from the gray scale FRP images. sEMG signals are recorded from Biceps brachii muscle of 45 healthy volunteers under dynamic contractions using a well-defined protocol. These signals are filtered and divided into ten equal epochs with first segment as non-fatigue and last as fatigue. GLCM features such as contrast, correlation, homogeneity and energy are calculated for both segments. The distance between neighboring pixel pairs in the FRP images is set as 1 with orientation angles 0°,45°,90° and 135°between them. It is observed that texture patterns in FRP are distinct for both conditions. The results indicate that the extracted features are found to be different for non-fatigue and fatigue segments with high statistical significance of $p<0.001$. A higher contrast and correlation value is observed for non-fatigue conditions. Fatigue segments exhibit higher values for energy and homogeneity. All the extracted features show higher percentage variation at 135°. This method can be used for transforming the sEMG signals to complex network for analyzing various neuromuscular conditions.

Keywords*: surface EMG; Fuzzy recurrence plots; muscle fatigue; gray level co-occurrence matrix; biceps brachii*

Surface electromyography based analysis of muscle fiber type characteristics during fatigue using frequency domain features

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In this work, fiber-type characteristics of skeletal muscles are analysed using surface electromyography (sEMG) signals. Signals are recorded from Adductor pollicis (AP) and Triceps brachii (TB) muscles of fifty healthy subjects using isometric exercise protocols until muscle fatigue. The initial and final two seconds of the recorded signals are considered non-fatigue and fatigue states respectively. Frequency domain features such as mean and median frequency, mean and total power, and spectral moments are extracted for both states and compared. Mean and median frequency values show a decreasing trend with fatigue progression for both muscles. It is observed that the signal power features and the spectral moments decrease for AP and increase for TB during fatigue. Mean values of features for the two states and their percentage variation (PV) are computed. The PV of mean frequency for TB is higher (-24.18%) and this may be due to the presence of a greater number of type II fibers. However, PV obtained for AP (-17.51%) is less and this may indicate a higher proportion of type I fibers. These features may be used as indicators for muscle fiber type analysis and can be used for analysing various myoneural conditions.
Keywords: *Muscle fiber type; sEMG; frequency domain; adductor pollicis; triceps brachii.*

Complexity Analysis of Surface Electromyography Signals Under Fatigue Using Hjorth Parameters and Bubble Entropy

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This work aims to analyze the complexity of surface electromyography (sEMG) signals under muscle fatigue conditions using Hjorth parameters (activity, mobility, and complexity) and Bubble entropy. Signals are recorded from the biceps brachii muscle of 25 healthy males during isometric and dynamic contraction exercises. These signals are filtered and segmented into ten equal parts. First and tenth segments are considered as non-fatigue and fatigue conditions respectively. Features are extracted from both segments and classified using Support vector machine (SVM), Naïve bayes (NB), K nearest neighbor (KNN), and Random forest (RF). The results indicate a reduction of signal complexity during fatigue. The activity is found to increase under fatigue for both isometric and dynamic contractions with mean values of 0.223 and 0.346 respectively. It is observed that mobility, complexity, and bubble entropy are lowest during fatigue for both contractions. Maximum accuracy of 95% is achieved with KNN and Hjorth parameters for dynamic signals. It is also observed that the reduction of signal complexity during fatigue is more significant in dynamic contractions. This study confirms that the extracted features are suitable for analyzing the complex nature of sEMG signals. Hence, the proposed approach can be used for analyzing complex characteristics of sEMG signals under various myoneural conditions.
Keywords: *surface EMG signals; non-linear dynamics; muscle fatigue; complexity; Hjorth parameters; Bubble entropy.*

Design of Biosignal Controlled Hand Exoskeleton for Assistive Purposes

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Exoskeletons are widely used for both rehabilitative and assistive purposes. Controlling the exoskeleton remains significant to perform the user-defined functions. This work presents the design of a low cost,

simple biosignal controlled hand exoskeleton exclusively meant for assistive purposes. A biosignal acquisition unit is designed and developed to acquire the EMG signals from Biceps, Extensor Digitorum and Flexor Digitorum Muscles. Two different hand movement protocols are used to obtain the EMG from 21 healthy individuals. From the acquired signal, 53 features including higher order statistical features are extracted and fed to different classifiers for the classification of three different hand movements. For both the protocols used, the Decision tree classification method shows a higher accuracy of 90.47% and 95.23% compared to other classifiers. The exoskeleton is designed, 3D printed and assembled with linear actuators. The classifier output controls the device to perform hand movements. Different hand movements specified in the protocol are executed by the exoskeleton fitted in a normally functioning hand with the help of actuators controlled by the biosignals acquired from the other hand. The inclusion of brain signals is expected to provide greater accuracy in extracting the control signal.
***Keywords**: Hand Exoskeleton, EMG, Decision tree classification*

Comparison of Machine Learning Tools for the Differentiation of Fatiguing Contractions in Biceps Brachii Muscle using Time Frequency Decomposed sEMG Signals

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In this study, a comparison of machine learning tools is performed to differentiate the muscle nonfatigue and fatigue conditions during the dynamic contractions of biceps brachii muscle using Synchrosqueezed wavelet Transform (SST) and surface electromyography (sEMG) signals. For this, sEMG signals are recorded from forty nine healthy normal participants performing biceps curl exercise. The recorded signals are preprocessed and divided into ten equal parts in which the initial segment is considered as nonfatigue and the final as fatigue. Further, the segments are analysed using SST with analytic Morlet and bump wavelets, the time frequency matrix generated is decomposed using Singular Value Decomposition (SVD) for feature extraction. The characteristics of the signals are analysed using four different Singular Value (SV) features, extracted from the decomposed matrix. To differentiate muscle fatiguing contractions, five machine learning methods namely, Ada Boost, K-Nearest Neighbor (kNN), Multilayer Perceptron (MLP), Locally Weighted Learning (LWL) and Support Vector Machine (SVM) are used and the results are compared. It is found that the LWL model classifies the conditions effectively with a maximum of 84% accuracy and 83.9% F- score in Morlet wavelet analysis. Also, Ada Boost classifier provides a maximum accuracy and F- score of 82% using bump wavelet. Therefore, the selected models could be used to differentiate the fatiguing conditions in neuromuscular conditions.
***Keywords:** Surface Electromyography; Synchrosqueezed Wavelet Transform; Machine Learning tools.*

S6M: VIRTUAL MODELING AND 3D PRINTING

3D Printing in Hospitals

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CT examinations and 3D reconstructions are used in orthopaedic surgery to obtain lesions better definition: these can be replicated with 3D printer which represents a valuable aid in surgical planning.
Our UOC conducted initial research project for manufacturing biomodels to be used in orthopaedic departments for surgical purposes. A group of TSRMs is involved in managing the workflow: from CT images acquisition to models print. Following objectives are therefore pursued: 1. 3D printing process training (printer, software); 2. fractures and tumoral lesions biomodels reproduction. 3. specifical documents generation to describe all project phases, legislative and technical references. GE “Revolution Evo” TC is utilized. Specs are displayed: layer thickness 0.6mm; STD filter; SmartMAR, ASIR and 3D VR

algorithms. GE "AWD4.7" workstation is used in segmentation and STL conversion processes, "Simplify3D" for slicing and gcoding. A large work volume FDM 3D Print model is chosen. Printed material is polylactic acid (PLA). Additive manufacture is usable within the existing workflow to become the gold standard in surgical planning process. There's need for recognition of TSRM advanced skills, figure involved together with PACS Administrator in additive manufacturing processes, see AIIC Guidelines.
Keywords*: CT, PACS, DICOM STL flow.*

Additive Manufacturing of a cranial implant with bioactive energy-absorbing polymer via Arburg Plastic Freeforming

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Additive Manufacturing (AM) brings ground-breaking opportunities to provide customised healthcare solutions with reasonable time and cost. These benefits become more evident if reducing the distance between the printing process and surgery. In this direction, the Arburg Plastic Freeforming (APF) process offers unprecedented opportunities. The absence of hazardous feedstock materials such as powders allows for the utilisation of this technology within hospitals. Also, unlike traditional AM processes, APF makes it possible to process medically approved standard granulates without compromising their certification. In this study, APF has been used to manufacture, for the first time, a Patient-Specific Cranial Implant (PSCI) using a bioactive polymer with a high energy absorption capability, namely PolyCarbonate Urethane (PCU). The main technological issue was represented by the lack of a solvable support material compatible with PCU. This obstacle was overcome by a custom support structure made of the same material, which can be removed at the end of the process with limited damage to the PSCI. The orientation of the part within the building chamber was chosen to optimise the accuracy of critical features and the surface quality of the regions facing the brain. The 3D printed cranial implant showed high toughness during mechanical impact tests.
Keywords: *Additive Manufacturing, Arburg Plastic Freeforming, Patient Specific Implants, PolyCarbonate Urethane*

Fabrication of a patient-specific 3D printed multi-material simulator for Endoscopic Sinus Surgery

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The restrictions of traditional training based on cadaveric dissection have led to the investigation of alternative training methods, including models fabricated with three-dimensional (3D) printing. Till now the use of 3D printing in endoscopic sinus surgery (ESS) has been limited because of the difficulty in replicating the anatomical details and haptic feedback of soft tissues. We describe the design and fabrication of a patient-specific 3D printed multi-material simulator for ESS, and its preliminary assessment by 12 ear-nose-throat (ENT) surgeons. Preliminary patient imaging segmentation, 3D modeling, and CAD (Computer-assisted design) of the simulator components were performed; then Polyjet printing technology was used to produce soft tissues and bony structures.

All standard ESS steps including uncinectomy, medial antrostomy, ethmoidectomy, sphenoidotomy and Draf procedures were performed on the simulator using standard instruments. All surgeons reported a high

level of anatomical fidelity and excellent response of the materials to surgical maneuvers for most of the steps. The study demonstrated that a 3D printed simulator of the sino-nasal anatomy can be generated with a high level of accuracy and haptic response. This technology has the potential to be useful in surgical training and in preoperative planning to allow the surgeon to rehearse on patient-specific anatomy.
Keywords: *Endoscopic surgery; 3D printing; Surgical training, 3D modeling.*

Analysis of different geometrical features to achieve close-to-bone stiffness material in medical device: a feasibility numerical study

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The purpose of this article was to investigate if a material could vary itself based on both patient and surgeon necessities. We thought geometry of the material could be a valuable way to address rigidity changes in the material. The aim of this study was to evaluate with computer simulation and trough Finite Element Method (FEM) if a porous material with variable gaps dimension and different in-body vacuum geometrical shapes could modify the material rigidity. Five cubes with a 20 mm thickness were generated with computer simulator and analyzed under compression load by means of finite element (FE) analysis. The displacement, strain and Young Modulus were calculated in four cubes, containing four internal gaps with different geometrical shape (quadratic, hexagonal, octagonal and cylindrical), and were compared with a full body used as control. FE analysis was conducted to assess the results in five points located inside each cube, dividing the latter into four layers (α, β, γ, δ). The most important finding of the present study was that cubes with hexagonal and cylindrical geometries show the lowest rigidity at each point, compared to the other geometries analyzed and compared to the full body cube.
Keywords: *Material stiffness, In-body gaps, Finite Element Analysis.*

Design and development of an augmented reality intraoperative guide system with stereoscopic visualization for robotic surgery

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Augmented reality (AR) technology is increasingly adopted in the surgical field and recently it has been also introduced in robotic-assisted urologic surgery. This work describes the design and development of an augmented reality intraoperative guide system with stereoscopic visualization for the Da Vinci surgical robot. As major novelty, the developed AR system allows the surgeon to have the virtual 3D model of patient anatomy superimposed on the real field, without losing the stereoscopic view of the operative field. The workflow starts with 3D model generation of the anatomical district of interest for surgery, from patient diagnostic imaging. Then, the 3D model is uploaded in the developed stereoscopic AR application, navigated using a 3D space mouse, and superimposed to the operative field using computer vision algorithms. The system was tested during 30 robot-assisted surgeries, including 20 partial nephrectomies, 1 kidney explant, 9 radical prostatectomies, and received overall great appreciation from surgeons who used it. The AR guidance helped in localizing hidden structures, such as arteries or tumoral masses, increasing the understanding of surgical anatomy with depth perception, and facilitating intraoperative navigation. Future efforts will be addressed to improve the automatic superimposition of digital 3D models on the intraoperative view.

***Keywords**: Stereoscopic Augmented Reality; Intraoperative guidance; 3D models, robotic-assisted surgery.*

How Additive Manufacturing can improve Healthcare?

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For more than 3 decades, Additive Manufacturing (AM) has risen and taken important place in our industries. AM is a new technology, which is still improving and gaining space to ease manufacturing processes. In the medical sector: the rapidity of production, the complex geometries, the customized components, the use of the qualified and validated materials, and the low volume productions are manufacturing challenges. Arburg, manufacturer of injection molding machines for more than 60 years, has developed a unique AM machine: the Freeformer. It makes it a pre-destined tool to overcome healthcare manufacturing challenges. The Freeformer is an open-system, processing a wide range of standard pellets and material combinations. This includes biocompatible, resorbable and serializable original materials as well as qualified original materials with FDA approval. The highly flexible production process enables also to configure parameters to meet specific requirements, while keeping the technical characteristics and performance of the used material. Parts production can be track by ProcessLog, the Arburg's digital application, which gather all production's data and allows the product's traceability. Our lecture will present different concrete applications (Medical devices, prosthesis, orthesis, bespoke drugs, etc.) that enables healthcare to deliver solutions in a more efficient way.

***Keywords:** Additive Manufacturing; Innovation; Medical Applications.*

S7M: MAGNETIC RESONANCE IMAGING

Static and Dynamic breast DCE-MRI radiomics in quantifying the neoadjuvant chemotherapy treatment response

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The response to Neoadjuvant Chemotherapy (NAC) treatment is one of the most powerful surrogate markers to predict breast cancer prognosis. Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is an indispensable tool for monitoring the response to therapy. Radiomic analysis of DCE-MR images using computerized systems developed by experts has become of great interest as evidenced in various breast imaging methods. However, the dynamic process of tumor enhancement is not reflected by the static radiomics procedure. Recently dynamic radiomics achieved higher robustness and accuracy for time-related images. In this work, an attempt has been made to quantify and compare the NAC treatment response on the publicly available QIN-Breast of TCIA database (N = 25) using static and dynamic radiomic features. Global, GLCM, GLRLM, and GLSZM features are calculated at 3 different visits (V1, V2, and V3) of NAC treatment. The extracted static and dynamic features are analyzed statistically with a significance level of $p \leq 0.05$. Results demonstrate that the dynamic features ΔSkewness, ΔSumAverage, ΔAutoCorrelation, ΔLRHGE, and ΔLZHGE have shown a highly significant difference between V1&V2, V1&V3 compared to static radiomic features. Hence, dynamic radiomic features seem to be more accurate in quantifying the NAC treatment response between the visits.

***Keywords:** Breast Cancer; DCE-MRI; Dynamic Radiomics; Neoadjuvant chemotherapy; Static Radiomics; Treatment Response.*

Implementation of patient-specific dielectric models from MR acquisitions

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Many medical techniques are based on the application of electromagnetic fields (EMF) on the human body with diagnostic and/or therapeutic purposes. For this reason, it is important to characterize the dielectric properties (permittivity ε and conductivity σ) of the biological system, since they represent the body's response to the applied EMF. This paper describes a method to obtain a patient specific dielectric model for applications in hyperthermia therapy. Biological tissues are complex and heterogeneous, and their dielectric properties vary with the subject and the physiological and pathological conditions. For this reason, there is the need to obtain a dielectric model for a specific subject, obviously in in vivo conditions. To do that, MR (magnetic resonance) is used since the MR signal obtained from an anatomical section can be related to its dielectric properties. Here, a model is proposed to obtain a specific and accurate dielectric characterization of in vivo patients from MR acquisitions, in a wide frequency range.
Keywords: *Dielectric properties; MR; patient-specificity.*

A web-based TableTop MRI scanner for remote and automated acquisitions

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Access to a laboratory MRI system is ideal for teaching MR physics as well as for many aspects of MRI signal processing. Nowadays, compact, low-cost, open-interface tabletop MRI scanners have become viable for academic use. However, global challenges still have repercussions on component sourcing and limit the ability to access academic labs. We used an OCRA Tabletop MR at the Campus of Cesena and proved it successful in teaching MR principles and basic signal processing to undergraduate and graduate students. The sequences implemented included spin echo, gradient echo, and diffusion MRI which were applied to an imaging volume with a 1.5 cm field of view. We extended the OCRA library code to allow the scripting of batch acquisitions and visualizing results, running Python notebooks from a web interface (Jupyter Hub). Our solution allows a registered user to remotely access OCRA using any web browser, desktop, or mobile, requiring no specific software installation. Finally, the scanner was complemented by a SCARA robotic arm to allow the exchange of the analyzed sample test tube, unlocking the possibility to automate the analysis of various prepared samples.
Keywords: *MRI tabletop; Remote access; Imaging.*

Radiomics from DCE MRI and BRCA1/2 mutations in triple-negative invasive ductal carcinoma of the breast

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Radiogenomics is being increasingly used for tumors characterization. In this study, we aimed to determine whether and which radiomic features from dynamic contrast enhanced (DCE) MRI predict the presence of BRCA1 or BRCA2 mutations. We analyzed 60 patients with triple negative invasive ductal carcinoma of the breast showing 50 negative and 20 BRCA lesions, segmented manually by two radiologists. From the time-series DCE, we calculated two percentage maps of wash-in and wash-out, through a 3D Slicer code. Feature extraction was performed through Pyradiomics extension of 3D Slicer. Important feature for BRCA1/2 carriers and non-carriers classification were selected with Principal Component Analysis (PCA) and step-wise logistic regression. 107 features were extracted and reduced to 20 components through PCA. Two components from the wash-in map were selected in the logistic regression (7 and 13), showing an AUC of 0.75. Features which contributed most to the selected components were first order shape features and features from the grey level matrix, mainly concerning uniformity. There were no significant components from the wash-out map. This study shows the feasibility of a radiomic study with DCE maps of the breast and the possibility that radiomic features from DCE maps may be related to BRCA1/2 mutation.

Keywords: *Radiomics, Breast cancer, Magnetic Resonance Imaging*.

S8M: CELL AND MOLECULAR BIOPHYSICS AND BIOMECHANIC

Mechanoluminescence of Walker-256 carcinosarcoma cells in vitro by magneto-mechanochemical effects

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Magnetic nanoparticles (MNs) exert magnetic forces on cancer cells in response to external magnetic fields (MFs). The application of MNs with MFs induces mechanical stress and influences free radical reactions in the tumor. This phenomenon is commonly referred to as the magneto-mechanochemical effect. We aimed to examine the magneto-mechanochemical effects on free radical reactions in Walker-256 carcinosarcoma cells adopting the mechanoluminescence method. Free radical processes *in vitro* were measured in Walker-256 carcinosarcoma cells with core-shell Fe_3O_4-Au MNs using a modified chemoluminometer HLMC-01 (Meridian). Disc neodymium ($Nd_2Fe_{14}B$) magnets with produced non-uniform MF with the magnetic force ranging from 1.16×10^{-20} to 5.5×10^{-16} N. Changes in free radical processes were attributed to the magneto-mechanochemical effects of MNs delivered to tumor cells under MF since the temperature did not rise above 37 °C during treatment. The addition of MNs to Walker-256 carcinosarcoma cells resulted in a 2.5-fold increase in the mechanoluminescence photon count as compared with the untreated cells and 6.4 times greater than that of background measurements ($p < 0.05$). These results demonstrate that magneto-mechanical effects of Fe_3O_4-Au MNs influence free radical processes in Walker-256 carcinosarcoma cells in response to non-uniform MF.
Keywords: *magnetic nanoparticles; magneto-mechanochemical effect; mechanoluminescence.*

PEDOT:PSS OECTs as versatile devices for real-time monitoring cytotoxicity and viral infection

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Semiconducting polymers are promising materials for biomedical applications, owing to their ability to conduct both ions and electrons, biocompatibility and soft nature. In particular, poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) has high conductivity, electrochemical stability in aqueous environment and reversable electrochemical properties rendering it suitable as nano-biointerface for biological entities. Here, we present PEDOT:PSS-based Organic Electrochemical Transistors (OECTs) for monitoring cell viability, providing fast and real-time electrical analysis overcoming standard optical techniques. Cells are directly grown on transparent PEDOT:PSS-based OECTs: the cell monolayer slows down ion flux from the electrolyte into the semiconducting polymer,

allowing for an electronic readout of cell layer integrity and health. We demonstrated that OECTs can be employed for evaluating cytotoxicity of external agents, viral infection pathway and viral titration of both a cytopathic virus (encephalomyocarditis virus) and a non-cytopathic one (bovine coronavirus). Noteworthy, testing Sars-Cov-2 infected cells, we observed that OECTs can automatically perform serum neutralization assays in less than 48h (earlier than the usual 72 hours needed for actual standard screening), quantifying the neutralizing antibodies in human sera. PEDOT:PSS OECTs represent scalable and versatile biosensors monitoring different cell/virus binomials, paving the way for high-throughput and low-cost drug screenings, toxicology evaluations, viral titrations or serum neutralization assays.
Keywords: *Organic Electrochemical Transistors, in-vitro cell culture, viral replication.*

***CometAnalyser*: a user-friendly, open-source deep-learning microscopy tool for quantitative comet assay analysis**

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Comet assay provides an easy solution to estimate DNA damage in single cells through microscopy assessment. DNA damage is quantified by computing the displacement between the genetic material within the nucleus and the genetic material in the surrounding part of the cell. As broken DNA migrates farther in the electric field than the non-damaged genetic material, the cells harbouring DNA damage resemble a "comet" with a near-spherical head and a tail region, the latter increasing as DNA damage increases. Originally, comet assay was performed as a qualitative analysis, but nowadays commercial and freely available tools are available to obtain reproducible quantitative data. However, none of the freely available tools works on both fluorescent- and silver-stained images and by utilising machine learning methods to automatically identify the most appropriate class for the unannotated comets before extracting several intensity/morphological features. In this work, we present *CometAnalyser*, an open-source deep-learning tool designed for an easy segmentation and classification of comets in microscopy images. *CometAnalyser* has a user-friendly GUI subdivided into 4 main modules for: (*a*) comet segmentation, (*b*) comet classification, (*c*) feature extraction, (*d*) data visualization. Source code, standalone versions, user manual, sample images, video tutorial and documentation are freely available at: *https://sourceforge.net/p/cometanalyser*
Keywords: *Comet Assay; Microscopy; Machine Learning.*

Ratiometric Analysis of Structural Changes in Microscopic Cellular Images for Drug-Induced Cytotoxic Assessment

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Investigation of drug-induced structural changes in cell lines at different concentrations using microscopic images is essential to understand their cytotoxic effects. In this study, a ratiometric measure to evaluate toxicity effects of a particular drug in cell images is formulated. For this, fluorescence microscopic images of drug-treated and drug-untreated mouse cardiac muscle HL1 cells are considered from a public dataset. Ratio of cellular area to non-cellular area is calculated for three different thresholds at different drug concentrations namely 0.6, 1.2, 2.5, 5, and 10 μM. Statistical analysis is performed in order to characterize drug-induced variations. Results demonstrate that the proposed measure is able to characterize the cellular variations at different concentrations. A decreasing trend in the mean ratio is obtained from drug-untreated

to drug-treated at varied concentrations. A maximum mean percentage difference of 70% is achieved using the ratiometric measure of drug-treated cells at highest concentration and drug-untreated cells. This indicates alterations in cell morphology caused by drug-induced cell death. Standard deviation is also observed to decrease which indicates the reduced variability in this measure at higher concentrations. The proposed metric could be used to determine the maximum permissible drug tolerance levels during the development of new drugs.
Keywords: *Fluorescence Microscopy; Cytotoxicity; Drug discovery*

Analysis of Phenotypic Changes in Cell Painted Suborganalles Using Cell Ratiometric

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The geometrical variation in cell suborganalles is an important biomarker for the cell viability defects and breakdown in the cell regulation mechanisms. Analyzing these phenotypic changes from microscopic cell images is a challenging task due to their visual similarity in the cell structure. In this study, a cellular metric has been proposed to characterize the geometrical variations among the cell suborganalles using multi thresholding technique. For this, the public dataset acquired using Cell Painting fluorescence imaging technique which consists of nuclei, endoplasmic reticulum and cytoplasm are considered. The threshold values for different suborganalles are obtained using Otsu’s thresholding and the images are binarized to cellular and noncellular area. Cellular metric is then computed as the ratio of cellular area to noncellular area for each suborganalles. The results indicate that the cytoplasm provides high mean ratio (0.211) as compared to nuclei (0.07) and endoplasmic reticulum (0.08). The mean and standard deviation shows significant variation among the considered cell organelles. This signifies that the geometrical variations of cell organelles can be estimated using the proposed cell ratiometric parameter and can further be used for differentiation of cell organelles to identify the abnormalities in cell structure.
Keywords*: Cell Painting, Phenotypic changes, Cell ratiometric, Multi thresholding.*

Hospitex International: The Cytology Company

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Hospitex international is a small, medical tech oriented, vertical company specialized in Cytology Equipment and Solutions. In its plant in Florence, products are designed, industrialized a manufactured, both in the mechanical and chemical side. High investments in R&D, Several Patents, and cutting-edge technology deployment, allowed the development of the most advanced Liquid Based Cytology System of the market. The company is growing in national and international markets, as long as the scientific community gets awareness of the Hospitex products. Actually, the R&D program is focused both on increasing the product range and developing a multicentric Digital Pathology platform. Also, its unique LBC processor, it’s the only one able to manage the Urine Cytology, representing almost the half of the cytology market; this led to the creation of a partner network to develop the first AI algorithm for the Urinary Cells Image Analysis.
Keywords: *Digital Pathology, Urine Cytology, Artificial Intelligence.*

S9M: ORTHOPEDICS – DEVICES AND TECHNOLOGIES

Influence of pedicle screw thread depth on skeletal anchorage in osteoporotic and normal bones – Finite element study

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Various spinal pathologies are commonly treated using pedicle screw fixation systems. The geometry of the screw plays a predominant role in the success of treatment. In this study, a 2D axisymmetric finite element model is used to analyse the influence of pedicle screw thread depth on anchorage strength and stress transfer, in osteoporotic and normal bones. The base geometry of pedicle screw is obtained from experimental studies in the literature. The thread depth is varied between 0.5 mm and 1 mm, in 0.1 mm increments. The other geometric parameters of the screw are kept constant. Fixed constrain is applied to the outer surface of the bone block and horizontal displacement along the axis of symmetry is locked. In order to simulate axial pull-out test, a force of 80 N is applied on the screw head. Results show that, the displacement of the pedicle screw decreases with increase in thread depth for osteoporotic bone, while the displacement for normal bone increases. The highest stress transfer is obtained at thread depth of 0.5 mm, for both bone qualities, leading to better bone remodeling. This study might aid in improving the design of pedicle screws for the treatment of spinal disorders.

Keywords*: Pedicle screw; Finite element; Osteoporosis.*

Biomechanical analysis of femoral stem-design features in physiological and osteoporotic bone during static loading conditions

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As society continues to age, the implementation of hip stems increases every year. However, there are a variety of different hip stem designs. The aim of the project is to analyze which hip stem design implemented in a femur is most effective under different static loading conditions such as gait and sideways falling. In addition, a four-point-bending test was carried out. Therefore, the techniques were simulated in silico by FEA with Abaqus/CAE 2019.

A short stem, a straight stem and an anatomical stem were tested. All prosthesis are cementless press-fit stems. Each hip stem was examined in physiological and osteoporotic bone applying all three tests. To compare the stems the tests were also applied on a native bone model as a reference. Boundary conditions were used in order to simulate the tests. The average von Mises stress, tension, compression and the risk of fracture were extracted and compared. Biomechanical results show that the straight stem induces higher von Mises stresses compared to the anatomical stem. The risk of fracture is higher for osteoporotic bone than for physiological bone. However, there is no risk of fracture as all the results are below the risk of value.

Keywords: *hip stem; von Mises stress; risk of fracture.*

Effects of Finger Fine Motor Training with Various Music on Brain Activation of the Elderly

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The ageing population is rapidly increasing globally in the recent years. It is expected that the burden on long-term care and medical services will also increase rapidly. Previous studies had indicate that hand function which is related to life quality can be improved by finger coordination and force training. Besides, finger pressing task can effectively induce brain activation in the elderly. Recently, several studies reported that music interventions could contribute promising effects. Therefore, we developed a finger fine motor training device and included music as a positiveencouragement element, aiming to make finger fine motor training more appealing to elderly, and benefit from brain activation. The purpose of this pilot study is to investigate the effect of finger training with various music intervention on brain activation. Four healthy older adults were asked to perform finger pressing tasks with familiar songs, unfamiliar songs, and no music. Near-infrared spectroscopy (NIRS) was used to observe the brain activation towards different music when using the training device. Our findings indicated that finger fine motor tasks with unfamiliar music

showed the tendency to induce higher brain activation at Premotor Cortex (PMC), Prefrontal Cortex (PFC), and Supplementary Motor Area (SMA) than that with familiar songs.
Keywords: *Hand function; Music; Elderly.*

Experimental Analysis of Knee Joint Kinematics and Kinetics under Different Boundary Conditions

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The aim of this work is to develop a protocol to perform experimental analyses of knee joint kinematics and kinetics under different boundary conditions. This protocol is intended to be applied to cadaveric specimens.
The first part of this protocol consists in acquiring the knee kinematics. To do so, a motion tracking system is combined with a post-processing software to compute the relative angles between the femur and the tibia. The second part focuses on the implementation of an open-chain knee extension simulator. This simulator includes a motor to mimic the action of the quadriceps, resulting in knee extension. The intensity and profile of the applied force can be modulated to subject the knee to different boundary conditions.
The whole experimental protocol was applied to four artificial knees, each with a different implant design. Their kinematics could thus be obtained and compared. The experimental protocol proved to be reliable, as the kinetic analysis resulting from this protocol corresponded to what was expected from the input.
In the future, this protocol could be used to study biomechanics in the case of healthy knees and pathological knees; it could moreover allow studying the performances of different designs of knee implants.
Keywords: *Knee joint; kinematics; kinetics.*

S5D: ORTHOPEDICS – DEVICES AND TECHNOLOGIES

Dynamic Finite element analysis of malposition in mobile and fixed bearing UKA prosthesis during gait

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The present study aimed to quantify the effects of malposition in fixed and mobile bearing unicompartmental knee arthroplasty (UKA), during gait, in terms of tibial bone and polyethylene insert stresses, load distribution and ligament strains. Knee biomechanics performances with a mobile-bearing and a fixed-bearing cemented medial UKA were analyzed during gait. Totally 18 three-dimensional FE-models were used to simulate the balanced, overstuffed and understuffed UKA. The mobile and fixed bearing UKA presents different values of Von-Mises stress in the proximal and distal tibial cortical bone of medial compartment, with respect to the lateral one. Opposite results were found for the other. Similar trends were obtained for Von-Mises stress of UHMWPE-inserts. Moreover, the difference in stiffness between the interactions healthy-soft-tissue of lateral compartment and metal–UHMWPE of medial one, cause a load increment in the lateral compartment with a consequent increase in strain for the medial collateral ligaments. Kinematics of balanced and understuffed configurations for both the UKA, were close to the healthy native knee. Indeed, an understuffed configuration may avoid lateral compartment degeneration. Successful UKA depends also on the posterior tibial slope that increases the load on cruciate ligaments, especially in the ACL, leading to possible fractures of it.
Keywords: *Unicompartmental knee arthroplasty; Finite Element analysis; mobile-bearing UKA; fixed-bearing UKA.*

Dynamic Analysis of different levels of constraint in Total Knee Arthroplasty during Gait and Squat

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Total Knee Arthroplasty (TKA) is an orthopedic procedure performed to restore physiological functionality in pathological knee, but implant failures and patient dissatisfaction during activities still persist. Moreover, several TKA designs with different levels of constraint are available, but no evidence-based guidelines exist to select the best solution for each case in terms of biomechanics. This study aims to provide a quantitative analysis of TKA biomechanics during daily activities. Finite Element Analysis has been performed on five common TKA designs (Fixed Bearing (FB) Cruciate Retain (CR), Posterior Stabilized (PS), Condylar Constrained Knee (CCK), Mobile Bearing (MB) CR and Ultra-Congruent (UC)) during gait and squat, aiming to investigate the behavior of different levels of constraint of TKA in terms of polyethylene stress and tibial bone stress, tibiofemoral and patellofemoral kinematics and kinetics. The results have been compared among the different models, showing that CR designs restore more physiological knee kinematics; PS design, thanks to the post-cam mechanism, reduces anteroposterior tibial translation but induces greater stresses on the insert. This study could be used to help the understanding of TKA patient's dissatisfaction, usually related to joint kinematics and kinetics that are far from the physiological ones.

Keywords: *Total Knee Arthroplasty; Finite Element Analysis; Prosthesis design.*

Development and Validation of a Device for the Acquisition of Kinematics of Barbell during Training

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Powerlifting is an individual sport consisting of lifting a barbell with a set of weights. Exercise monitoring during training is fundamental for improving performance and preventing injuries. Most of the devices for monitoring powerlifting are focused on the "1-Repetition maximum", a single lift of target load. In addition, these devices have an elevated cost that limits their diffusion. This work aims to develop and validate a prototype of a low-cost wireless device that can accurately measure the kinematics parameters during multiple repetition training with a barbell. The prototype is based on an inertial measurement unit (IMU), 9 degrees of freedom sensor that combines a 3-axis gyroscope, 3-axis accelerometer, and 3-axis magnetometer. The software combines the IMU's measurements to obtain acceleration, velocity and displacement. To improve accuracy, the device integrates two IMU with a redundancy approach. The resulting device has been validated by using a 3D-motion capture system. A simulation of the powerlifting standard movement has been analysed during the tests. The results showed that the device estimates the movement with an error on the order of a centimeter. Thanks to its reliable monitoring features, the device represents an optimal solution to track barbell kinematics in powerlifting applications.

Keywords: *Powerlifting; Kinematics; IMU, Redundancy.*

Biomechanical analysis of use of porous meta-diaphyseal custom-made cones in knee revision surgery

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In many cases, traditional revision (TR) implant may be an effective solution to be used after primary TKA. However, it does not cover the full range of clinical possibilities, especially in patients with multiple revisions presenting an extremely weak bone and a variable geometry. Therefore, custom-made metaphyseal titanium porous cones were developed as an alternative to amputation in patients with severely pathological bone conditions. The aim of the study is to evaluate whether this innovative implant is able to restore patient's ability to perform simple daily activities, in comparison with TR. The performances of implant were compared with TKA with cementless press-fit stems and cemented stems, and using a large resection prosthesis with cemented stems. These techniques were simulated by FEA and daily activities as full-extension and chair-rise configuration were analyzed with applied static force. Stress patterns in the interface regions between prosthesis and bone and risk of fracture in the bone were extracted and compared. Biomechanical results demonstrate that the use of custom-made devices can be considered a viable option to manage the patient's bone loss because the bone stress is more homogeneously distributed than stress induced by the other three techniques, where is more concentrated in specific regions.

***Keywords**: Revision TKA; Bone stress; Custom-made cones.*

S6D: CELL AND MOLECULAR BIOPHYSICS AND BIOMECHANICS

AC amplification gain in organic electrochemical transistors (OECTs) for impedance-*based single cell sensors*

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Research on electrolyte-gated and organic electrochemical transistor (OECT) architectures is motivated by the prospect of a highly biocompatible interface capable of amplifying bioelectronic signals at the site of detection. Despite many demonstrations in these directions, a quantitative model for OECTs as impedance biosensors is still lacking. We overcome this issue by introducing a model experiment where we simulate the detection of a single cell by the impedance sensing of a dielectric microparticle. The highly reproducible experiment allows us to study the impact of transistor geometry and operation conditions on device sensitivity. With the data we rationalize a mathematical model that provides clear guidelines for the optimization of OECTs as single cell sensors, and we verify the quantitative predictions in an *in-vitro* experiment. In the optimized geometry, the OECT-based impedance sensor allows to record single cell adhesion and detachment transients, showing a maximum gain of 20.2±0.9 dB with respect to a single electrode-based impedance sensor.

***Keywords:** Biosignal amplification, Organic electrochemical transistors, Single cell sensing*

Relationship between blood and blood cells microrheological and micromechanical characteristics and flow and oxygen transport parameters

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The study aims to analyze the experimental haemoreological and mictomechanical data with mathematical models and to seek regression and correlation dependencies describing the interrelationship between the rheological parameters of the blood and the micromechanical properties of the blood cells as well as the parameters of the hemodynamics and the index of the efficiency of the oxygen transport in these diseases. Quantitative characteristics of the increased erythrocyte aggregation and deformability have been determined using developed microfluidic system and a methodology for assessing the microrheological properties of the blood. Their relationship with the whole blood viscosity, blood oxygen transport parameters, blood conductivity were examined in the groups of patients and healthy subjects. A comparative analysis of the models describing the rheological behavior of blood and blood cells was done. The role of increased plasma and blood viscosity, RBC aggregation and deformability, leukocyte aggregation and adhesion in patients with type 2 diabetes mellitus (T2DM) and vascular diseases, leading to impaired microcirculation and hence to reduced oxygen and nutrients supply. The study also envisages the development of rheological diagnostic methods based on the algorithms built from the data analysis and the resulting correlation and regression equations.

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***Keywords:** blood and blood cells; aggregation and deformability; hemorheological models.*

Nanopore long read DNA sequencing allows for higher accuracy in brain cancer analysis

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Among adult type diffuse glioma, glioblastoma-IDH WT is the most aggressive form of brain cancer, and its prognosis is currently poor with a mean survival rate of 18 months since diagnosis. The mutational profile in these tumours, particularly for some specific genes including IDH1, IDH2, H3-3A, 1p-19q codeletion and TERT, has a major prognostic role. A cohort of 24 patients with glioma has been DNA sequenced using Illumina platform. Despite its high accuracy and quality score, the use of short reads resulted in a poor performance in regions characterized by many repeats, such as TERT promoter, which is crucial for patient prognosis. In this study, a promising third-generation technique provided by Oxford Nanopore Technology, has been used to sequence and characterize these glioma samples, also including the methylation status of MGMT promoter. Nanopore sequencing allows for long read length and, moreover, it represents a cheaper and faster approach, even if its accuracy is lower than that of Illumina platform. Results are encouraging: the better alignment and the reduction of artifacts in TERT promoter is a direct consequence of the use of long reads. Additionally, the methylation level in promoter, enhancer and gene body of MGMT can be easily assessed.

Keywords: *Nanopore sequencing; mutations; glioma.*

Development of an electrospun patch for the treatment of myelomeningocele

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Myelomeningocele is a congenital nervous system defect that is characterized by meningeal and spinal cord protrusion through the open vertebral arches. Although fetal surgical repair has been shown to reduce cognitive symptoms, a less invasive approach, applicable earlier in gestation, is preferred to reduce the motor neurological symptoms, as well as reducing the maternal and fetal risks. Several studies have proposed an attractive alternative approach to prenatal surgery. It involves covering the defect with a patch to protect the exposed neural tissue. Previous work by the LBPS team has led to the successful development of Polycaprolactone based bioactive membrane with excellent mechanical and biological properties. Based on this work, the aim of this project is to develop a waterproof and bio-degradable patch, designed to cover and protect the spinal medulla exposed in utero, allowing the proliferation of a covering epithelium tissue and consequently limiting the leakage of cerebrospinal fluid. This patch is functionalized by grafting poly(sodium styrene sulfonate) (PNaSS), a bioactive polymer known for its excellent biological properties previously demonstrated by our team. A cytotoxicity test and a study of cell morphology (fibroblasts, keratinocytes and endothelial cells) are performed to evaluate the cytocompatibility of the electrospun and PNaSS-grafted membranes.

Keywords*: Myelomeningocele; PCL; Electrospinning; Bioactive polymer.*

Applications of tissue-engineered plant scaffolds and introduction of a novel model for cardiovascular research

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An increasing need for the production of cardiovascular implants due to the high rate of human death by cardiovascular diseases demands preclinical investigations within vascular models. Because of crucial limitations of animal and synthetic models such as ethical concerns, test complexity, high cost, and undesired mechanical properties, plant-based scaffolds have gained great attention. Decellularized plant scaffolds have been used as natural, cost-effective, biocompatible materials for the proliferation of mammalian cells including endothelial cells. Besides, the natural microstructure of plant tissues induces cell migration, proliferation, and differentiation. Recently, tissue-engineered plant scaffolds have been applied as vascular patches, accelerating the healing process in vivo. In this work, we review the various applications of tissue-engineered plant scaffolds, and furthermore, present our novel vascular model

obtained from special plant tissues based on our own selection criteria. These models, which are prepared after the decellularization of tubular plants, have been tested via mechanical and microstructural experiments to investigate the feasibility and then to introduce the most promising plant-based vascular models. The mechanical properties are measured by the tensile test, and to investigate the available micropatterns on the lumen of the decellularized plants, SEM and confocal imaging have been performed.
***Keywords**: Decellularized plants; cell proliferation; 3D scaffolds; tissue engineering*

Deep learning models for segmenting brightfield images of cancer multicellular spheroids used for radiomics analysis

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Today, more and more biological laboratories are using cell aggregates and 3D tissues created in vitro as 3D models of in vivo tumours and metastases. In particular, multicellular spheroids of cancer cells amply demonstrated to be an efficient model for testing the effects of drugs and radiotherapy treatments. However, the lack of validated methods for quantitative analysis limits the current use of the spheroids as an in vitro model used in a standardized and routine manner. In recent years, the number of tools developed to perform biological experiments using spheroids and automatically estimating morphological features (e.g. diameter, volume, sphericity) has been growing. However, these tools require extensive iteration with the user and often the segmentations obtained are operator dependent. A method for the automatic and fast definition of spheroid and background with a consequent estimation of radiomic features, would lead to important advantages in the use of spheroids in daily practice. In this work, we introduced and validated a deep learning model for the analysis and segmentation of bright field microscopy images of cancer multicellular spheroids. The module has been integrated into AnaSP, an open-source tool designed to standardize the analysis of spheroids and automatically estimate different morphological features.
Keywords: Microscopy; 3D in vitro models; machine learning.

S7D: WEARABLE AND eHEALTH

Blood Pressure Prediction using Real-world ambulatory Photoplethysmography (PPG)

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Blood pressure (BP) is a key indicator of health condition as high BP is linked to complications such as heart attack. Conventional Brachial-cuff method of BP monitoring is occluding and lacks comfortability, and many studies now focused on using Electrocardiogram (ECG) and Photoplethysmography (PPG) signals to achieve non-invasive monitoring. Many publicly available datasets such as Multi-parameter Intelligent Monitoring in Intensive Care (MIMIC) II Waveform dataset allow for machine learning techniques to be applied on BP estimation. Instead of using the available datasets, this study used a self-collected ECG and PPG signals to improve robustness of machine learning result, for the reason that publicly available datasets contain clean signals with perfect waveforms, whereas these signals in real life are usually distorted by motion and noise artifacts. The aim of this study was to compare and select the optimal feature set and machine learning algorithms that perform well on the relatively small self-collected dataset. The feature set included Pulse Arrival Time (PAT), Heart Rate Variability (HRV) features, and PPG morphological and frequency domain parameters. Based on root-mean-square error (RMSE) and mean-absolute error (MAE), four machine learning models were evaluated, namely Random Forest Regression (RFR), Support Vector Regression (SVR), Artificial Neural Network (ANN) and Gaussian Process Regression (GPR). The result showed that the best performing configuration was achieved with

SVR and despite using a small dataset with imperfect waveforms, the BP estimation results met Grade C or higher requirement set by British Hypertension Society (BHS).
***Keywords**: Blood Pressure Estimation, Photoplethysmography, Electrocardiography, Machine Learning Algorithms*

Smart bandage with textile chemical sensors for wearable healthcare

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Real-time and non-invasive monitoring of biological parameters by means of wearable sensors holds great promise for next-generation personalized healthcare. Among most challenging applications, monitoring of nonhealing wounds is a scarcely explored medical field. In daily practices, wound assessment is mainly based on a visual inspection, removing dressing and interrupting healing process. Smart tools for monitoring of several factors (i.e. moisture level, pH, uric acid etc…) potentially give direct access to the wound status without disturbing wound bed. In this contribution we present two sensors based on a conductive polymer poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS): one that discriminates wound's moisture level and one for pH. The first operates by monitoring impedance variations between dry and wet states, allowing a directly integration with a RFID chip, implementing a real-time wireless monitoring. The second is a textile pH sensor based on IrOx particles functionalization of PEDOT:PSS which exhibits a reversible response in the medically relevant pH range (pH 6−9), with a sensitivity of (59 ± 4) μA pH−1. The integration of those sensors on a fully assembled smart bandage have been successfully validated in flow analysis using synthetic wound exudate. The promising result paves the way for a textile multisensing platform for body fluids analysis.
***Keywords**: smart bandage; textile chemical sensor; body fluids analysis.*

Building a framework for handless Hw/Sw open modular data assistant

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The recent pandemic experience with the organizational complications of maintaining hygiene in data critical healthcare environments has abruptly made clear the need to phase out touch-based human-machine interfaces in favor of speech and gesture recognition. The increased computational capacity of IOT microboards coupled with their reduced power consumption, the availability of open libraries for the development of AI-based applications, the availability of lightweight and comfortable AR visors on the market, and the possibility of integrating these devices by adapting them to the anatomy of operators makes it possible to create a class of wearable devices for use as workflow management assistants.
An exoskeleton wearable by the caregiver under the sterile suit was designed to make a prototype mobile assistant. A raspberry PI board and a redundant battery system were integrated inside. The RIS/PACS system made by the AITASIT team based on open source software for educational purposes was used. The libraries for gesture recognition and gestures for basic function control and queries were integrated. Finally, a browsing scheme suitable for an integrated forearm screen or AR lens was designed. Results suggest the creation of a suite of hardware and software modules for a vendor-neutral standard of interchangeable and expandable devices.
Keywords: *Handless Data Assistant, Speech Recognition, data flow.*

S8D: WEARABLE AND eHEALTH

Revolutionary Wearable Technologies: the YOUCARE textile system by Accyourate Group Spa

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Accyourate Group SPA has designed, patented and produces a new generation of wearable technologies called YOUCARE, completely textile and washable, capable of monitoring and protecting in real time the state of well-being of the people who wear it. The wearing comfort combined with the high reliability of the bio-vital parameters detected, allow the Accyourate wearables to be applicable in all contexts and at any time of daily life.
Accyourate wearables are textile garments, with imperceptible embedded sensors, that thanks to the micro control unit integrated into the mesh, can monitor and return the life parameters of the individuals who wear them in real time. The direct parameters that we can monitor today are: Respiratory acts (frequency, depth); ECG; Beats per minute; Kinetic / postural parameters, impact and fall; Body temperature. The processed parameters are: Stress factor and Herath Rate Variability. Soon we will be able to support sweat analysis and electromyography. The use and maintenance of Accyourate wearables does not require any assistance. Accyourate wearables are ISO 9001, CE and CE MD type IIa certified.
Keywords: *Wearable device, IoMT, Artificial Intelligence.*

Wearable Devices: Challenges and Opportunities in Disease Monitoring

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Wearable devices are becoming increasingly present in everyday life. The increased rate of population aging, and healthcare cost burdens coupled with the development of new sensors and artificial intelligence algorithms are guiding this innovative technology which the Covid-19 pandemic has only amplified. In the last five years, the research efforts in this field have exponentially increased. Despite this impressive trend, the development of new wearable devices faces the challenges of data reliability, usability, data protection, and patient comfort. Considering all the opportunities and challenges, our research group is developing a new smart t-shirt that will work within a novel telemedicine infrastructure capable of monitoring different biosignals, aiming to create a user-friendly device with reliable algorithms. We are focusing our initial efforts on developing algorithms to analyze one lead ECG signal to evaluate and alert the medical personnel about diseases such as arrhythmias, hypertrophic cardiomyopathy, and sleep apnea. These algorithms prioritize result accuracy and computational efficiency, mainly because mobile devices are resource-intensive, usually run multiple applications simultaneously, and have limited ability to perform real time monitoring. The first tests demonstrate the potential of this smart t-shirt and the need for continuous development of new algorithms and features.
Keywords: *Wearables; Telemedicine; eHealth, ECG, artificial intelligence.*

Agreement between ECG and PPG in HRV analysis during provocative tests in healthy adults

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Wearable devices allow to monitor the health status pervasively and continuously, being minimally unobtrusive and integrated into daily-life objects. Photoplethysmographic (PPG) sensors, commonly incorporated in smartwatches primarily to monitor heart rate, can potentially be exploited to extract more complex parameters, such as the ones derived by the Heart Rate Variability (HRV) analysis. However,

there are still some concerns regarding the consistency between the measures obtained from PPG and electrocardiogram (ECG), especially during non-static conditions. The aim of this study is to assess the correlation and the agreement of HRV parameters extracted from ECG and PPG during provocative tests. We enrolled 40 healthy adults (20 M, 20 F; age 44.8±10.8 years) who were monitored with a 1-lead ECG and a PPG sensor embedded in a medical-grade wearable wrist device during four different experimental conditions: rest, deep breathing test, math test, and handgrip test. The results showed a moderate correlation ($0.4<r<0.6$) between most of the HRV parameters in all conditions, except for some non-linear and frequency-domain parameters. The Bland-Altman plot revealed a positive bias for most of the parameters extracted from PPG with respect to ECG.
Keywords: *Photoplethysmography; Heart Rate Variability; Wearable device.*

Vision-guided autonomous robotic system for pick and place tasks in healthcare settings

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Robots have long been seen as an alternative to humans in performing tasks that are repetitive, dangerous, and unhygienic. The COVID-19 pandemic has further strengthened the need for robotics, especially in the healthcare domain. A significant challenge in employing robots in hospital settings is the lack of ability of robots to perform object manipulation tasks in an unstructured environment. Here, we propose a vision-guided robotic arm manipulator system that can autonomously perform pick and place tasks. The proposed system consists of a robotic arm having 6 degrees of freedom and an RGB-D camera. The RGB data from the camera is used for object identification and shape detection for grasping purposes whereas the depth information is used for estimating the relative distance between the robotic gripper and the object for autonomous navigation. The complete pick and place scenario is simulated in the MoveIt package in ROS and analyzed using Rviz and Gazebo platforms. We plan to perform hardware implementation using an Intel Realsense RGB-D camera and Widow-X Robotic arm (Trossen Robotics Interbotix). The proposed system has potential applications in healthcare settings like sample testing and delivery, health care telepresence, and as a health check-up bot.
Keywords: *WidowX-autonomous arm; camera sensor; moveIt-ROS package*

HOWDY SENIOR: Single lead ECG recording and long term monitoring during medium-high intensitity exercise

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Single lead ECG recording and long term monitoring during medium-high intensity exercise in young sportsmen: evaluation of accuracy and subject's comfort of the Howdy Senior wearable device vs Holter ECG on a pilot study
Keywords: *Smart Garments; Medical Devices; Continuous Monitoring.*

HOWDY SENIOR: A comfortable, user-friendly and accurate ECG monitoring wearable device

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A comfortable, user-friendly and accurate ECG monitoring wearable device to detect different arrhythmias in elderly and cardiac patients: Howdy Senior compared to (gold) standard 24h Holter ECG
Keywords: *Smart Garments; Medical Devices; Continuous Monitoring.*

S9D: MACHINE LEARNING AND ARTIFICAL INTELLIGENCE

Semi-supervised active learning in automated wound image segmentation via smartphone mobile App

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Appropriate wound management shortens healing times and reduces management costs. Image analysis of wound area is becoming one of the cornerstones of chronic ulcer management. In this work we introduce a fully automated model for the identification, segmentation and characterization of wound areas that can completely automatize the clinical wound severity assessment, starting from images acquired by smartphones mobile App. The method is based on an active semi-supervised learning training of a convolutional neural network model. We used a dataset of images acquired during clinical practice and built an annotated wound image dataset consisting of 1564 ulcer images from 474 patients. Only a small part of this large dataset was manually annotated by experts (ground truth). A multi-steps active semi-supervised training procedure was applied to improve the segmentation performances of the model. The developed training strategy mimics a continuous learning approach and provides a viable alternative for further medical applications. The set of features extracted from automated wound areas correctly predicts the PWAT scale values with a Spearman's correlation coefficient of 0.85 on a set of not previously used samples. The possibility of integrating the model on smartphones App allows a wide spread of our system on clinical centers.

Keywords: *computer-aided diagnosis; deep learning; image analysis; wound healing; image segmentation; PWAT scale.*

Fully automated estimation of glomerular basement membrane thickness via active semi-supervised learning model

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The thickness variation in Glomerular Basement Membrane (GBM) is commonly used as diagnostic criteria for several renal diseases, including membranous nephropathy and Alport syndrome. The GBM thickness measurement is performed by hand by expert clinicians on transmission electron microscopy (TEM) images, therefore, it is highly subjective and poorly reproducible. The automation of this clinical exam could drastically improve the clinical practice and the reliability of the measurement. Only a few methods have been proposed in the literature to address the automated segmentation and measurement of GBMs thickness task, showing several limitations in low contrasted images and detection of complex geometries and shapes. In this work, we propose a fully automated pipeline based on a convolutional neural network model and computer vision algorithms for the automated estimation of GBM thickness in TEM images. Our pipeline obtained state-of-the-art performance in GBM segmentation, proving its robustness under image variations, such as magnification and contrast, and complex geometrical shapes. The obtained segmentations were used for the automated estimation of GBM thickness via computer vision algorithms and compared with manual measurements, achieving significant confidence levels.

Keywords: *computer-aided diagnosis; deep learning; image analysis; image segmentation; nephrology; image microscopy*.

Preliminary Detection of COVID-19 using Hybrid Deep Learning Approach

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COVID-19 is proclaimed a global pandemic by world health organization. This causes severe health hazards and high fatal rates. There is a need to find an appropriate method for precise detection and treatment of infected subjects. Chest radiography (CXR) is a cornerstone modality widely used for

radiological examination. These images are obtained from QaTa-COV19 dataset. In the proposed study, segmentation is attempted with hybrid U-Net architecture with two Transfer Learning (TL) techniques such as VGG16 and VGG19 to quantify the lung anomalies for clinical evaluation. Hybrid architecture such as U-Net VGG16 and U-Net VGG19 are executed by replacing the conventional U-Net encoder path. These TL techniques improve the learning instances of U-Net using smaller kernel size and reduced number of convolution layers. The segmentation is validated with various performance measures. The result shows that hybrid architecture such as U-Net VGG16 and U-Net VGG19 outperform conventional U-Net methods. Also, U-Net VGG19 shows a higher Dice coefficient and accuracy of 94.36% than U-Net VGG 16 for considered images. Hence, this approach will allow the radiologist to provide better decision making.
Keywords: *Hybrid architecture, Transfer Learning, COVID-19*

Explainable Machine Learning Framework for Age Prediction using Brain Complexity Features.

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SHAP (SHapley Additive exPlanations) is a framework for Explainable Artificial Intelligence (AI) that makes explanations locally and globally. In this work, we propose a general method to obtain representative SHAP values within a repeated nested cross-validation procedure and separately for the training and test sets of the different cross-validation rounds to assess the real generalization abilities of the explanations. We applied this method to predict individual age using brain complexity features extracted from Magnetic Resonance Imaging (MRI) scans. In particular, we used various implementations of the fractal dimension (FD) of the cerebral cortex - a measurement of brain complexity. Representative SHAP values highlighted that the recent implementation of the FD had the highest impact over the others and was among the top-ranking features for predicting age. SHAP rankings were not the same in the training and test sets, but the top-ranking features were consistent. In conclusion, we propose a method that allows a rigorous assessment of the SHAP explanations of a trained model in a repeated nested cross-validation setting.
Keywords: Brain complexity, explainable AI, fractal dimension, machine learning, SHAP.

S5L: SPORT SCIENCE

Effects of a 3-month outdoor training program on physical performance and quality of life

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A growing number of studies suggests that the practice of outdoor training in blue and green spaces induce beneficial effects on quality of life. However, several exercise programs were proposed, and different health parameters were evaluated in younger and elder people. The aim of the preset study is to evaluate the effects of outdoor high-intensity interval training (HIIT) on younger adults’ health outcomes, using innovative technology assessment such as wearable devices. Younger adults with no contraindication to practice high intensity training were recruited and divided into two groups: the experimental group (two training session per week for three months) and the control group (no intervention). Direct parameters and indirect cardio-respiratory parameters efficiency as ECG, respiratory rate, body temperature, HR and HRV, and stress factors will be evaluated using an innovative wearable device produced by ACCYOURATE®. Also, many parameters physical performance (VO_{2peak}, Strength and Speed) and QoL related will be detected at baseline (T_0) and follow-up (T_1). We expected the intervention to be feasible and effective in improving direct and indirect health parameters, quality of life and physical performance in younger healthy adults.
Keywords: *physical exercise; outdoor; wearable device.*

A 3-month exercise program performed in a green-blue space: the "Parco del Mare" pilot study

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A growing number of studies suggests that access and exposure to natural outdoor environments, in particular green-blue spaces, have beneficial impacts on health. However, evidence is limited regarding the evaluation of the effectiveness and the efficacy of physical activity interventions carried out in this type of settings involving the population. Therefore, the aim of the "Parco del Mare" pilot study is to evaluate the feasibility and the effects of a moderate-intensity exercise program carried out in a green-blue setting, on health outcomes using innovative technology assessment such as wearable devices, quality of life and physical performance. Healthy adults with no contraindication to practice physical activity were recruited and divided into two groups: the experimental group involved in the exercise sessions performed twice-a-week for 3-months and the control group (no intervention). Direct parameters to evaluate cardio-respiratory efficiency (electrocardiogram, respiratory rate, temperature) and indirect parameters (heart rate variability and stress factors) will be detected at baseline (T0) and follow-up (T1), using an innovative wearable device Youcare produced by ACCYOURATE. We expected the intervention carried out in the Parco del Mare setting to be feasible and effective in improving direct and indirect health parameters, quality of life and physical performance in healthy adults.
Keywords: *exercise; wearable device; green-blue space*

Surface electromyography based analysis of fiber type characteristics using reassigned morlet scalogram

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In this work, an attempt is made to analyze the fiber type characteristics of gastrocnemius lateralis (GL) and soleus (SOL) using surface electromyography (sEMG). Signals are acquired from GL and SOL of 27 untrained healthy participants during isometric calf raise exercise until fatigue. The first and last one second of the filtered signals are considered as non-fatigue (NF) and fatigue (F) conditions respectively. They are further subjected to reassigned morlet scalogram. The average instantaneous frequency (AIF) is extracted from reassigned time-frequency distribution (TFD) matrix and compared for both conditions. It is observed that more spectral components are present in the TFD of the NF segment in GL and that of the F segment in SOL. The extracted feature exhibits a decreasing trend in GL during fatigue due to the presence of more Type II fibers. Similarly, AIF shows an increasing trend during fatigue progression in SOL indicating the abundance of Type I fibers. Thus, the feature is found sensitive to the fiber type with a high statistical significance of p-value less than 0.001. The proposed method may be adopted for fiber type analysis in the field of sport biomechanics and biomedicine.
Keywords*: Muscle fiber type; sEMG; morlet scalogram; gastrocnemius lateralis; soleus.*

Electromyography investigation of the upper extremity muscles in 9-ball break shot between skilled and less-skilled players

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This study aimed to investigate the upper extremity muscle activations when performing the 9-ball break shot in skilled and less-skilled cue sports players. Eighteen male active players (10 in the skilled group, 8 in the less-skilled group) were recruited. The participants were required to perform 8 repetitive trials of the break shots. Electromyography (EMG) was evaluated for five upper extremity muscles, which were trapezius descendens (upper), deltoideus (anterior), deltoideus (posterior), triceps brachii (long head), and

biceps brachii (long head) of the cue-wielding arm. Maximal voluntary contraction (MVC) trials were conducted for each muscle to normalize the EMG data. The root mean square values (EMG-RMS) during the forward swing phase, determined from the kinematic data, was selected for analysis. The results of the Mann-Whitney U test showed no significant differences in the EMG-RMS between the skilled and less-skilled groups for all muscles (all $p > 0.05$). In conclusion, this study found no significant difference in muscle activation levels during 9-ball break shots between players of different skill levels. Since all participants were active cue sports players who executed the break shot regularly in training and games, the muscle activation between the skilled and less-skilled groups could be rather subtle.
Keywords: *Cue sports; EMG; muscle activation*

Reliability of Video-Based Running Gait Analysis in Recreational Runners

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Two-Dimensional video-based running gait analysis is commonly used in clinical settings, but its reliability is still unclear. Depending on the variables measured, the intraclass correlation coefficients (ICC) reported in existing literature ranged from poor to excellent reliability. The kinematic variables being tested were different between studies; some are not related to running injuries. This study aimed to evaluate the reliability of 10 kinematic variables with evidence from the literature showing that these variables are related to overuse running injuries. Forty-four healthy recreational runners (24 males, 20 females) aged between 18 and 45 years old were recruited for the study. Each participant ran on a treadmill at their preferred speed (2.59m/s±0.31). Their running kinematics were analysed from a high-speed video recording at 120 Hz. The number of steps required to obtain stable data was determined using the sequential estimation method. The intra-rater reliability of the 10 kinematic variables was then examined using two sets of data analysed seven days apart on the Kinovea software. The number of steps needed to obtain stable data was 18 across all kinematic variables. The intra-rater reliability was excellent (ICC ranged from 0.972-0.999) for all the 10 variables. In conclusion, two-dimensional video-based running gait analysis is a reliable assessment tool. It is recommended to analyse 18 steps to obtain stable kinematic data.
Keywords: *Video; running; kinematic.*

S6L: BIOSIGNAL PROCESSING

Preterm Birth Detection based on Decision Fusion and Stationary Segments of Multichannel Uterine EMG signals

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Uterine electromyography (uEMG) records uterine contractions non-invasively and appears to be a promising technique for identifying preterm birth. However, uterine contractions occur infrequently during pregnancy and could not be detected by a typical recordings. This work aims to analyze the motion artifact-free stationary segments of uEMG signals in order to predict preterm birth. Three channels of 53 and 47 stationary segments under term and preterm conditions, which were obtained from the Physionet database. The stationary intervals are segmented manually based on the annotations provided by the dataset. The signals are preprocessed and the Hjorth features are extracted. A random forest classifier is employed to distinguish between term and preterm conditions for each channels. In addition, decision fusion is performed using majority voting technique. The difference between using the contraction, stationary segments and the whole uEMG records are also compared. The results show that Hjorth features are observed to decrease in preterm, implying spectral variations of uEMG towards delivery. It is also observed to have a low coefficient of variance, suggesting to handle inter-subject variability. The extracted features yield an accuracy of 88% and an F-score of 87% using a decision fusion-based random forest classifier.

Hence, it appears that the proposed features could be utilized as a biomarker for the reliable detection of preterm birth.
Keywords: *Preterm birth, uterine electromyography, stationary intervals, decision fusion.*

Prediction of lag time for multiple infusion environments using regression methods

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Drug delivery using a smart infusion pump is crucial as precise drug concentration and flow rate is determinant for the patient. The intended drug delivery is desirable even when medical pumps are dead space and start-up delay. However, analysis of lag time is challenging to achieve desired drug delivery to the patient as it impacts startup delay. An attempt is made in this work to predict the lag time with multiple infusion for different carrier flow rates using Linear regression (LR) and Principal component regression (PCR) models. The performance of the prediction methods is evaluated using the coefficient of determination, Mean square, and absolute errors. Results show that prediction accuracy for lag time is found to be 97.8% for PCR and observed to be high compared to LR. Further, it is required to regulate the drug delivery using predicted lag time. Hence this study seems to be appropriate for multiple infusions, especially in remote environment.
Keywords: *Lag time; smart infusion pump; startup delay; PCR.*

EEG-EMG wavelet coherence analysis between C1, C4, CZ and TA muscle

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Human locomotion is a complex process that requires the integration of central and peripheral nervous signalling. Understanding the brain's involvement in locomotion is challenging and is traditionally investigated during locomotor imagination or observation. Electroencephalogram (EEG)–electromyogram (EMG) coherence analysis is an effective method for examining the functional connection between brain and muscles. An improved coherence approach is proposed in this study to enhance the estimation of EEG–EMG coherence.In this study we use C1,C4,CZ and TA muscle for wavelet coherence analysis at different movements. Results show that Subject1, Subject4, Subject8, Subject9 has more coherence.
Keywords: *Electroencephalogram; Electromyogram; EEG-EMG Coherence; Wavelet coherence.*

EEG-EMG wavelet coherence analysis during ramp descent, level walking, stair ascent, no movement, stair descent, ramp ascent

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Electroencephalogram (EEG)–electromyogram (EMG) coherence analysis is an effective method for examining the functional connection between brain and muscles. An improved coherence approach is proposed in this study to enhance the estimation of EEG–EMG coherence. The EEG signals are reassembled to effectively reflect the muscle motions. The estimation of the EEG–EMG coherence is computed by using wavelet coherence.The results of wavelet coherence analysis not only can correctly reflect the coupling relationship between the cortex and the muscles but can also distinguish the EEG–EMG coherences of the different autonomous movements.In this study we use C1,C4,CZ &TA muscle for wavelet coherence analysis during Ramp Descent, Level Walking, Stair Ascent, No Movement, Stair Descent, Ramp Ascent. Results show that during Ramp Descent, Stair Ascent and No Movement Subject has more coherence.
Keywords: *Electroencephalogram; Electromyogram; EEG-EMG Coherence; Wavelet coherence.*

Assessment of emotional states using Electrodermal activity signals and variable frequency spectral estimation

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Emotion is an internal state of a human being that arises due to interpersonal events. It plays an important role in perception, attention, memory, and decision-making. Emotions are characterized using arousal and valence dimensions. Electrodermal activity (EDA) is a widely used physiological signal to assess emotional states due to its non-invasiveness. EDA signals are non-linear, nonstationary, and multi-component in nature. In this work, an attempt has been made to classify arousal and valence dimensions using the variable frequency complex demodulation method (VFCDM) and EDA signals. For this, EDA signals are obtained from a publicly available online database. VFCDM decomposition is employed to reconstruct EDA to its backbone frequencies (0.05 Hz to 0.2Hz). Five non-linear, six morphological, and five Hjorth are extracted from the reconstructed EDA. Random Forest (RF) classifier is employed to differentiate emotional states. The proposed approach is able to characterize arousal and valence dimensions. Results show that the non-linear features, namely permutation, and phase entropy, varied significantly ($p<0.05$) in differentiating arousal dimension. Similarly, morphological feature – integral area, Hjorth feature – complexity, and non-linear feature – permutation entropy are significant in differentiating valence dimension. The RF classifier yields an F-measure of 67.7% and 58.0% in classifying arousal and valence dimensions, respectively. Thus, it appears that the proposed method could be utilized to analyze various emotional states in both normal and clinical conditions.

Keywords: *Emotion; Electrodermal activity; Time-frequency spectral analysis; Feature extraction; Classification.*

S7L: SPORT SCIENCE

Effects of muscle rub application on physical performance in athletes

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Current literature on the use of muscle rubs to improve athlete's performance are still unexplored. The objective of the present study was to examine the effects of muscle rub application on physical performance in athletes.
The experimental design was single-blinded, between-group comparison. Twenty colleage athletes (10 males, 10 females) were randomized evenly by sex to either receiving 3 g of muscle rub or a placebo cream. Before and after the application of muscle rub/placebo on the upper legs, participants were assessed using three physical tests: Sit-and-Reach test, Y-Balance test, and Standing Broad Jump (SBJ) test. The best out of three attempts were recorded for each test protocol. Muscle rub application significantly improved SBJ distance by 1.7% ($p = 0.028$) with a moderate effect size compared to placebo. There was no significant percentage change in Sit-and-Reach ($p = 0.520$) or Y-Balance ($p = 0.529$) performances. In conclusion, this study showed that muscle rub application on the upper legs had a postive effect on enhancing jump distance but not flexiblity or balance performances.

Keywords*: Muscle rub; topical analgesics; performance.*

Simulation of the upper-limb cueing movement in 9-ball

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Experimental methods can directly measure biomechanical characteristics of sport movement. However, there are limitations to experimental approaches which can be addressed using theoretical modelling approach. This study aimed to 1) create a simulation model to investigate the cueing movement in cue sports in the OpenSim environment, and 2) validate the model against the experimental results. 3D kinematic data of the 9-ball back spin shots were collected and used to drive a customized unimanual upper extremity musculoskeletal model for 10 male, right-handed participants. The model-generated results were compared with experimental kinematic data using statistical parametric mapping (spm1D). The results showed no significant difference throughout the entire waveforms for the elbow flexion/extension angles between the model-generated and experimental data ($p > 0.05$). Significant differences were identified in the shoulder elevation angles (from 0% to 100%, $p < 0.001$) and elbow pronation/supination angles (from 0% to 50%, $p = 0.005$) between the two sets of data. This study found generally good simulations of the elbow movements while further optimization should be made for the shoulder joint. Hence, it is plausible to utilize this simulation model to investigate upper extremity movements when performing cue sports shots.
Keywords: *OpenSim; upper extremity; kinematics*

Anterior cruciate ligament force during landing from different block jumps techniques in volleyball players

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Anterior cruciate ligament (ACL) plays a crucial role in constraining tibiofemoral articulation and preserving knee joint from harmful aberrations of motion, but certain high-risk movements such as landing can induce an ACL tear. Volleyball practice intrinsically requires performing jumps during attacking and defending phases: higher rate of ACL injury occurs during blocking tasks, which execution is more subjected to variability due to the necessity to adequately counter the opponents. Type of landing after blocking, as well as gender, has been related to the potential risk of injury. We analyzed three blocking techniques frequently occurring during matches: i) stick double leg landing, ii) stick single lag landing, and iii) step landing. Synchronized kinematic and kinetic data from female athletes were collected for each trial by means of inertial measurement units and force platforms. Musculoskeletal simulations were conducted in OpenSim to determine joint forces and finally ACL force was estimated for each landing technique. Stick double leg landing resulted in the less ACL stressing technique (2 body weights), whereas step landing generated the higher amount of stress in the ligament (3.1 body weights). Understanding ACL biomechanics associated to a certain task allows to better training programs aiming to injury prevention.
Keywords: *ACL force; volleyball injuries; wearable inertial measurement system.*

S8L: ADVANCES IN CARDIOVASCULAR

Feasibility of the novel IntraValvular Impedance sensing applied to biological heart valves: design and in vitro evaluation

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Subclinical valve thrombosis in heart valve prostheses is characterized by the progressive reduction of leaflets motion detectable with advanced imaging diagnostics. However, without routine imaging surveillance, this subclinical thrombosis may be underdiagnosed. We recently proposed a novel concept of sensorized heart valve prosthesis based on electrical impedance measurement (IntraValvular Impedance, IVI) using miniaturized electrodes embedded in the valve structure to generate a local electric field that is altered by the cyclic movement of the leaflets. In this study, we investigated the feasibility of the novel IVI sensing concept applied to biological heart valves (BHVs). Three proof-of-concept prototypes of sensorized BHVs were assembled with different size, geometry and positioning of the electrodes to identify the optimal

IVI measurement configuration. Each prototype was tested in vitro on a hydrodynamic heart valve assessment platform. IVI signal was closely related to the electrodes' positioning in the valve structure and showed greater sensitivity in the prototype with small electrodes embedded in the valve commissures. The novel concept of IVI sensing is feasible on BHVs and has great potential for monitoring the valve condition after implant, allowing for early detection of subclinical valve thrombosis and timely selection of an appropriate anticoagulation therapy.

Keywords: *heart valve prosthesis; valve thrombosis; implantable sensors; impedance measurement.*

The use of mixture theory to potentially help in the understanding arterial wall de-stiffening therapy.

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This theoretical contribution is conducted in order both to potentially help in understanding de-stiffening therapy, which is appearing as a possible strategy to reduce the occurrence of strokes and enhance the functional prognosis; and/or to be adopted as an effective aid to improve methods of designing prosthetic conduits for use with living tissue. For that, mechanics of interacting continua (or mixture theory), seems to be a viable framework to better understanding of the coupled interaction between steady fluid flow and solid large deformation in saturated porous soft two-layers fibrous hollow cylinder. When restricted to : a) a particular situation of an ideal fluid diffusing through a non-linearly elastic solid, b) a bi-layered thick walled hollow cylinder submitted to both torsion deformation and radially directed fluid diffusion, the effect of stiffness ratio between the two layers has been numerically investigated. As first results, one can note that: 1) when the inner layer is stiffer than the outer layer, pressure differences as well as stresses are very high and therefore damaging to the integrity of the hollow conduit, 2) increasing stiffness ratio between the two layers leads systematically to homogenize the stress field throughout the hollow cylinder wall.

Keywords: *Non-linear mechanics; Mixture theory, Steady diffusion, Transverse isotropy, Pre-stress.*

A pneumatic simulator of the venous system of a human arm for testing and tuning a novel noninvasive device for home monitoring of venous pressure

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Venous congestion can be quantified by central venous pressure (CVP) and its monitoring is crucial to follow the hemodynamic status of patients with heart failure, pulmonary hypertension, and impaired renal and hepatic function. The standard technique for CVP measurement is invasive, requiring the insertion of a catheter into a jugular vein, with potential complications. Recently, a novel noninvasive device (Venous Congestion Meter-VenCoM) has been developed for office and home measurement of peripheral venous pressure (VP) which is directly related to CVP, and is currently ready for clinical validation. In this study, we describe a pneumatic simulator designed to replicate the venous system of a human arm, to be used for in vitro testing and tuning of the novel VenCoM device. The simulator is mainly composed of an air blower to generate a constant flow rate inside a tubular chamber including an open-cell sponge that simulates the arm and is connected to a pressure sensor. Predefined VP values can be simulated by adjusting the pressure loss via a special device placed on the chamber exhaust duct. The simulator was successfully used with the VenCoM device to simulate a full range of VP values, from physiological to pathological congestive status (5÷24 mmHg).

Keywords: *central venous pressure, heart failure, noninvasive device, home monitoring, mechanical simulator.*

In vitro modelling of respiration-induced movements of the renal arteries for implant investigation in EVAR

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The aim of this study was the development and proof of concept investigation of a novel in vitro model of the abdominal aortic tract simulating respiration-induced visceral movements of the renal arteries. The in vitro model, consisting of a thin-walled aortic aneurysm model including the renal arteries as well as kidney phantoms segmented from DICOM data was manufactured by means of a combined 3D-printing and molding technology. The use of PVA hydrogel as tissue mimicking material allowed the reproduction of physiological mechanical properties as well as improved transparency of the model. Kidney density was adjusted to assure the position of the phantoms within the surrounding fluid. The movement of the kidneys was achieved by a pneumatic pump mechanism simulating diaphragm movement during respiration. For a first proof of feasibility, a branched aortic stentgraft with bridging stents was inserted into the model and optically assessed in terms of position and deformation under renal artery displacement. By implementing a physiological flow, this in vitro setup can be used in the future to investigate the behaviour of implants such as grafts and stents for treatment of the abdominal aorta and side branches, particularly in complex anatomies and under variable fluid dynamic conditions.

Keywords: *In vitro model, aortic aneurysm, visceral movement.*

Fabrication of compliant vascular models for in-vitro implant investigation

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In vitro vascular models have been used for decades to support the development of implants for the catheter-based treatment of diseases such as stenosis and aneurysm. Although in the last decade 3D-printing technologies have been developed and used to fabricate vascular models with complex anatomies, investigation of fluid dynamics and implant mechanics under pulsatile flow stands in need of models providing physiological compliance. In this work, we present the patient-specific model of a vessel with an aneurysm made of polyvinyl alcohol hydrogel using a combined 3D printing and molding technology. Geometrical as well as mechanical characterization of the model were performed. In a feasibility study, a fine-meshed implant was inserted into the model and its mechanical behavior evaluated under pulsatile flow in terms of structure deformation at the aneurysm neck. The hydrogel model with high transparency allowed for the assessment of implant mechanics in a replicated physiological environment and represents a promising alternative to former synthetic models for the realistic characterization of cardio- and neurovascular implants in vitro.

Keywords: *vessel model; endovascular implant; flow diverter; nitinol; hydrogel.*

S9L: CONVENTIONAL RADIOLOGY AND COMPUTED TOMOGRAPHY

MicroCT Contrast and Imaging Protocol Optimization for Analysis of Microstructure in Ligaments and Tendons

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Highlighting the microstructures component of ligaments and tendons in 3D images is a crucial step for extracting meaningful information impacting on both basic science and orthopedic applications. In this study, micro-computed tomography (microCT) images were used for data acquisition after performing specific staining protocols (i.e. phosphotungstic acid (PTA) in water and ethanol) to enhance the contrast of these soft tissues.. Hence, two kinds of samples were used, human hamstring tendon and bovine ligament. The tow samples were stained over different period and resulting scans were evaluated and compared. To characterize these microstructures and their organization, important parameters including diameter and orientation are required. Therefore, a digital image processing algorithm was designed and applied for this purpose. The proposed approach consists of three main stages; contrast enhancement, fascicles and fibers detection based on multi scale Hessian filter, and orientation and diameter measurement and analysis. This has been tested under different experimental conditions including contrast protocols. Interestingly, the proposed approach resulted to be adequate for the detection and characterization of fascicles features and the PTA in water staining protocols demonstrated to be the most effective.
Keywords: *microCT; Fibers detection; Hessian filter; Top-hat transform; ligament; Tendon.*

A Monte Carlo calibration approach for a dual-energy CT system

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The present work shows the effectiveness of Monte Carlo methods for calibrating a heterogeneous phantom for radiotherapy in dual-energy computed tomography (DECT). A phantom comprising 20 inserts of different compositions and densities (representing human tissues) inserted in a solid water cylinder was used. The reliability of the model built with the Penelope code was verified by comparing the results of the simulations at 80 kVp and 140 kVp with the experimental data acquired from the CT images. On a logarithmic scale, the difference between the total crosssection of bone tissues and soft tissues was evaluated using a primary beam of photons with a spectrum of 140 kVp. A comparison was also made between the calculated values of the effective atomic number Zeff for the different tissues and the data extrapolated from the DICOM on the heterogeneous phantom. Tests for calibration and dose calculation were repeated for a homogeneous phantom in PMMA and the air with an ionization chamber, evaluating the main dosimetric quantities. High-definition simulations, noise reduction, and improved tissue segmentation through the DECT scan procedure will make phantom calibration more accurate and precise.
Keywords: *Dual-energy CT; Monte Carlo simulations; phantom calibration.*

Avio-TC: a suite to provide diagnostic examinations by state-of-the-art equipment in remote African areas

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The project is to provide a fully functional and transportable mobile diagnostic unit through solutions that will allow heavy diagnostic modalities to be transported anywhere in the world by plane, truck, or ship. It will also integrate the elements setting up an entire diagnostic room. The performed work focuses on a feasibility study, for a heavy diagnostic modalities transportation system. The work has already produced a patent, of a mobile computed tomography unit suitable for operating in extreme scenarios. Specifically, the following solutions have been developed: 1. Creation of a dedicated floor, eliminating the problem of assembly and disassembly of the equipment; 2. Consolidation of the safety and resistance to gravitational stress, inside cargo aircraft; 3. Configuration of a complete mobile diagnostic room with advanced functions. Various software were tested. The system is connected through a Starlink antenna and functions as a provider or user of classes both remotely and on the local network for handless data assistants. All logistics aspects of power supply, air conditioning, reporting, and radiation protection of operators were also considered. The project has passed the feasibility study and now the development team and sponsor and partners (AMREF, AITASIT, FNO TSRM e PSTRP) are available for partnerships with private and

public funders for the first installation on aircraft and creation of a network of mobile clinics in remote areas of Africa.

***Keywords**: Innovation Modality, Cargo-CT, FLOSS-telehealth.*

Association of Chest Radiographic Geometric Changes in Mediastinum with COVID-19 Conditions

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In this work, an attempt has been made to investigate the geometric changes associated with mediastinum in Coronavirus Disease-2019 (COVID-19) chest radiographic images. For this, COVID-19 and normal chest radiographic images are obtained from a publicly available database. The lungs are segmented using reaction-diffusion level set. Further, mediastinum is segmented using region-based active contour method. Features such as lungs area, mediastinum area, and mediastinum to lungs area ratio are calculated from the segmented masks. Statistical analysis has been performed on the extracted features. The results show that the employed methods are able to segment the regions by preserving the significant edges. Mediastinum area and mediastinum to lungs area ratio are observed to be statistically significant ($p < 0.001$) in characterizing COVID-19 conditions. An increase of 40.6% in mediastinum area and 39.3% in mediastinum to lungs area ratio is observed for COVID-19 in comparison to normal images. This can be attributed to enlargement of mediastinum due to the abnormal manifestations in COVID-19 conditions. It appears that the mediastinum features are able to characterize the variations that occur due to the disease. This work could be useful in the development of a computer-aided diagnostic system.

***Keywords:** COVID-19; chest radiograph; mediastinum.*

21 September

Plenary Talk

AI and imaging frontiers applied to human biological system in medical physics

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Coronary artery disease (CAD) (also known as coronary artery disease, CAD) is defined as the blockage of coronary, due to a build-up of plaque inside the coronary artery. The plaque narrows the artery and impacts the blood supply to the heart and causes a damage of the heart muscle. CAD is a common disease, affecting 6% of adult general population, and up to 20% in age > 65 years old. The prognosis of CAD is poor. Revascularization of coronary territories with demonstrable myocardial ischemia, rather than anatomical stenoses per se, is imperative both for symptom reduction and outcome benefits.

Invasive coronary angiography (ICA) with fractional flow reserve (FFR) measurement has emerged as the gold standard for assessment of coronary flow physiology, and hence, coronary territory ischemia. However, its measurement involves invasive procedure. CT coronary angiography (CTCA) is emerging as first-line of investigation of CAD. However, CTCA alone does not determine whether a stenosis causes ischemia.

Non-invasive FFR determination is an alternative approach using computational fluid dynamics (CFD) applied to coronary computed tomography coronary angiography (CTCA) images. Computation of FFRCT requires construction of an anatomical model of the coronary arteries; mathematical modeling of coronary physiology to derive boundary conditions representing cardiac output, aortic pressure, and microcirculatory resistance; and numerical solution of physical laws governing fluid dynamics.

Non-invasive FFR technology could be incorporated effectively into a clinical management pathway for patients with suspected or known CAD, and assist cardiologists in diagnosing ischemia-causing lesion and assisting their decision-making in the care of patients (i.e. medical treatment or stent treatment).

S10M: COMPUTERS METHODS IN RADIOTHERAPY

Dosimetric characterization of a mobile accelerator for Intraoperative Radiation Therapy

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To characterize the electron beams produced by a mobile accelerator (LIAC, SIT) dedicated for Intraoperative Radiation Therapy (IORT). The dosimetric properties of the 6, 8 and 10 MeV electron beams were compared to Monte Carlo (MC) simulations. Percentage depth doses (PDDs), transversal dose profiles (TDPs) and output factors (OFs) were measured in a commercial water phantom using a PTW microDiamond detector. The detector angular dependence was measured using a home-made spherical phantom. The pacemaker dose was evaluated at several distances from the irradiation field for a full-dose 21 Gy IORT treatment. PDDs and TDPs were used as input for MC simulations. For flat-ended applicators, the average differences between measured and simulated OFs were (-1.4±0.6)%, (-0.9±0.4)% and (-1.5±0.6)% for 6 MeV, 8 MeV and 10MeV beams. The microDiamond showed a higher angular dependence for the 6 MeV beam, ranging from (1.01±0.0) at 15° to (1.09±0.0) at 45°. Correcting for this dependence, the differences for the 45°-applicators resulted (-0.9±2.1)%, (-0.8±1.0)% and (-1.2±1.0)% for the 6 MeV, 8 MeV and 10 MeV beams. At 2 cm from the applicator edge, the pacemaker dose was always below the 2-Gy recommended tolerance. Experimental results were in very good agreement with MC simulations allowing to predict the clinical dose distributions.

Keywords: *IORT; dosimetry; Monte Carlo*

Finite element biomechanical modeling of parotid glands morphing for H&N adaptive radiotherapy

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During Head and Neck (H&N) radiotherapy treatment patients are exposed to several side effects (weight loss, muscle alteration, radiation detriment): this can induce parotid glands (PGs) inter-fraction morphing and as a consequence PGs overdosage. This work aims to implement a biomechanical model of PGs morphing that can be useful in the framework of an adaptive radiation therapy protocol. A mesh representation of PG's daily morphing has been obtained by processing the CT-series of 8 H&N Tomotherapy® patients (Raystation® hybrid deformation, 3DSlicer® tools). The finite element (FEM) software COMSOL® multyphysics has been used for biomechanical modeling. PGs tissue has been defined as a linear elastic material (Poisson ratio 0.49, density 1 g/cm3). A radial force field has been introduced to mimic PGs shrinkage due to radiation detriment. Model fixed constraints have been defined to consider the barrier effect of the surrounding structures (mandible, arteries). The optimal model parameters (Young's modulus, force field intensity) have been defined by using a parametric sweep study. Our biomechanical model is able to predict PGs morphing with a mean volume difference of 1.36% [0.9 -2.0 %] for the first half of treatment and 1.5% [0.8-2.1%] for the second half.
Keywords*: finite element software; biomechanical modeling; adaptive radiotherapy.*

New techniques of radiotherapy treatment plan verifications: Radcalc 3D Monte Carlo and dosimetric ML tools

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The pre-clinical dose verifications on the radiotherapy plans done by treatment planning software (TPS) are an important aspect of quality patient care. For complex plans, where TPS and/or linac can fails, these checks allow to assess clinically relevant differences between planned and delivered dose. Applying secondary calculation systems and Machine Learning (ML) models, these verifications can be speeded up to detect major errors, to improve plan quality/adaptation, to record/reconstruct dose received by individual patients, and to free up linac occupation time. Radcalc (LAP, Germany), an independent dosimetric verification software for secondary check, equipped with Monte Carlo and in-vivo measurement tools, was uses to simulate many (>100) Eclipse plans (Varian TPS, USA) of increasing complexity. Radcalc simulations, dosimetric measurements (Octavius PTW, Germany) and inaccuracy predictions provided by ML models (Matlab) were analyzed. Initial comparisons between TPS and Radcalc simulations, or dosimetric measurements (Octavius), provided gamma passing rates of (95±5)% and (94±6)%, respectively. ML dose predictions were in line with Radcalc simulations and plan measurements, and for some plans up to 3 replanning were required before achieving an acceptable dose agreement. Radcalc and ML are effective dosimetric tools for checking plans and predicting those with inaccuracies that require a re-planning process.
Keywords: *Radcalc; Machine Learning; Dosimetry.*

Heartbeat cardiac motion model to evaluate intra-fraction dosimetric variations in radiotherapy treatments

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A heartbeat cycle model was developed to simulate cardiac motion during radiotherapy to evaluate the intra-fraction dosimetric impact on cardiac sub-structures by comparing different planning techniques. Twenty-five cardiac sub-structures were automatically contoured in 10 CTs acquired in Breath-Hold method by using a developed Hierarchical-Clustering atlas-based algorithm. Cardiac cycle was simulated by a deformable image registration algorithm based on volume variations available in literature. Synthetic CTs were so created in systole and diastole phases of cardiac cycle and automatically contoured. Ninety radiotherapy plans were calculated using 3D-CRT, VMAT and TomoTherapy techniques. Python scripts were developed for auto-contouring, automatic creation of synthetic CTs and data extraction. Ranges of variability for maximum dose during the heartbeat cycle were reported for Left Ventricle [931÷1183]cGy, for MidLeft Anterior Descending Coronary Artery [1083÷1414]cGy and for Right Ventricle [725÷902]cGy as an example among the 25 analyzed regions of interest. From analysis of radiotherapy techniques, VMAT optimization showed more robustness despite organ motion. Patient specific models for organ motion could increase accuracy in intra-fraction dosimetry of radiotherapy treatments. Organ motion models might be extended to other anatomical districts such as lungs. Robust optimization could be assessed by automatic plan recalculation on synthetic image sets.

Keywords: *Cardiac sub-structure dosimetry, Automatic contouring, Heart organ motion, Radiotherapy techniques.*

An automatic tool for LATTICE radiotherapy treatment optimization

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Lattice radiation therapy (LRT) is a modern radiotherapy approach which has demonstrated benefits, especially for large lesions. The principle of this technique is treating the tumour with a non-uniform dose, creating a lattice-like dose distribution with high-dose peak into the vertices surrounded by lower-dose valley. The rationale of this modality is to deliver ablative dose, while sparing organs at risk (OAR). Our LRT technique uses a geometric arrangement of spherical vertices, each with a diameter of 1.5cm and spaced 6cm apart. Due to the vast heterogeneity of tumour shapes, the problem of finding the be t lattice arrangement is not trivial. An automatic home-made tool was developed in MATLAB. This tool uses input parameters from the CT, the target and OAR contours and gives a lattice structure in DICOM format, maximizing the number of vertices within the tumour. Each vertex is at least 1.5cm away from OARs. A further version of this tool, which includes sphere diameters and OAR sparing optimization, is under development. This tool allowed to obtain the lattice structure automatically with considerable time saving. Automatic and manual modalities of lattice placement were compared. Improvements in terms of target coverage and OAR sparing were obtained using the automatic tool.

Keywords*: Lattice; Radiotherapy; Spatially fractionated radiation therapy.*

S10D: ADVANCED METHODS IN NEUROSCIENCE

Comparative analysis of the three-dimensional chromatin conformation changes occurring in patients affected by prion disease

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How the 3D chromatin organization changes with cellular senescence and how this influences healthy aging and neurodegenerative diseases is only beginning to be explored. We performed a comparative analysis of

the three-dimensional chromatin organization in white blood cells of Creutzfeldt-Jakob Disease (CJD) patients at diagnosis and healthy controls using Hi-C. This exploratory work represents the first application of Hi-C or any chromosome conformation capture technique to prion diseases, and one of the first in neurobiology. Whole genome sequencing data from Hi-C experiments were analyzed to obtain the pairwise frequencies of interactions of distinct genomic loci, which reflect their spatial proximity in the nuclei. Interaction matrices were then compared, and differences or similarities quantified using computational methods based on structural similarity index. This work found a significant and diffuse loss of genomic interactions in immune cells of CJD patients at disease onset, particularly significant at the loop (10kb) and topological associating domain (25-50kb) levels of resolution. This general trend was quantified as significant in a selection of genes involved in the early response of the peripheric immune system in other proteinopaties, and is particularly stressed in the prion protein locus, suggesting a possible impairment of chromatin conformation in the disease.
Keywords: *chromatin conformation; Hi-C; neurodegeneration.*

Analysis of 3D Morphometric Alterations in Ventricular Brain Structures for Differentiation of MCI Subtypes in MR Images

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Mild Cognitive Impairment (MCI) exhibits significant heterogeneity in its clinical profile which need to be investigated through Magnetic Resonance (MR) images. This analysis is essential to identify and differentiate the MCI subtypes. Morphometric alterations in MR ventricular brain structure are sensitive measures for MCI diagnosis. In this study, differentiation of Early and Late MCI (EMCI and LMCI) is carried out by analyzing Ventricular-to-Brain Ratio (VBR) measure. For this, MR images obtained from a public database are pre-processed and, third and fourth ventricles and, right and left Lateral Ventricles (LV) are segmented. Morphometric features are extracted from segmented structures and VBR is computed. Further, support vector machine classifer is employed for differentiation of MCI subtypes. Results indicate that extracted morphometric features are able to characterize EMCI and LMCI. A positive correlation is observed among third ventricle, left and right LV volumes. Further, VBR measures exhibits a distinction between the MCI subtypes. Highest classification accuracy in differentiating MCI stages is achieved using VBR measures from left and right LV individually. However, combination of these LV characteristics achieves a maximum sensitivity of 70% in differentiating EMCI and LMCI stages. As lateral ventricular VBR measure could demonstrate the underlying heterogenities in MCI condition, proposed study appears to be clinically substantial in identifying EMCI.
Keywords*: Mild Cognitive Impairment, Ventricles, Ventricular-to-Brain Ratio.*

Classification of Schizophrenia using Voxel based Morphometry and Recurrent Neural Network

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Schizophrenia (SZ) is a neurodegenerative illness associated with hallucinations and delusions. Accurate diagnosis of SZ is still a challenge as its pathophysiology remains ambiguous. Schizophrenics exhibit deficits in executive control and learning processes, coupled with alterations in Gray Matter (GM) and Cerebro Spinal Fluid (CSF) volumes. Deep learning models that learn abstracted patterns of brain anatomic variations could aid in efficient diagnosis. In this work, an attempt has been made to classify schizophrenics and healthy controls using Long Short term Memory network (LSTM). MR images of 72 Schizophrenics and 75 healthy controls have been utilized from COBRE dataset. MPRAGE images are pre-processed with standard SPM-CAT Toolbox. The whole brain GM and CSF volumes are segmented for voxel-wise estimation of their local volume using voxel based morphometry. Parcellation with 142 region neuromorphometrics atlas is carried out and the segmented volumes of GM and CSF are utilized in classification. An 11 layer network comprising two bidirectional-LSTM layer has been employed. A 5 fold

cross validation is carried out and the classifier performs with accuracy of 86.44% indicates that, usage of RNN model with GM and CSF volumes can help in better identification of SZ.
Keywords: *Schizophrenia; VBM; deep learning; RNN.*

Diagnosis of Neurodegenerative Disorder in Brain Images using Hybrid Machine Learning Methods

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Dementia is a cognitive disorder that requires early detection for severity variation using efficient computer aided methods. The proposed work is designed to examine the ventricle and whole brain variation for demented subjects using T1-weighted MR images obtained from ADNI database. Initially, the images are effectively skull stripped. Then, the multilevel thresholding based on Moth Flame (MF) and Crow Search (CS) optimizers are used to segment the ventricle region. Features such as scale invariant feature transform (SIFT) and dense SIFT (DSIFT) are extracted based on Harris-Laplace key point detector to formulate Bag-of-Words (BOW) for the ventricle and whole brain regions. The model was designed to detect and describe the features that are subjected to SVM and MF-SVM classifier. MF offered reliable segmentation results in the delineation of the ventricle region from the complex inhomogeneous surrounding tissues than CS. Appropriate codebook size of the BOW model for ventricle and whole brain are determined with the extracted features. Further, BOW based DSIFT features of the desired regions show desirable performance than SIFT. Finally, DSIFT features of ventricle region using MF-SVM classifier gave a high accuracy of 82.5% than standalone SVM classifier. Hence, this hybrid framework could be used to support clinical decisions.
Keywords*: Dementia; ventricle; optimizer.*

Detection of Tonic-clonic seizures from the band power ratio of Scalp EEG

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A generalized tonic-clonic seizure (TCSZ) is a convulsive type seizure that has a tonic phase followed by clonic muscle contractions. These uncontrolled seizures can lead to a disruption of the nervous system and physical risks such as injury and even SUDEP (Sudden unexpected death in Epilepsy). Encephalogram (EEG) is one of the generally accepted diagnosis modalities used for the identification of seizure types. An accurate and efficient system that can identify the seizure types will help the neurologist with the first-line treatment. Therefore, this study aims to develop an automated system that discriminates the seizure types early from the onset. For this purpose, TCSZ and electrographic seizures from Temple University Hospital (TUH) data corpus have been considered. The band power of delta, theta, alpha, beta, and gamma, and their power ratio are computed to develop the model. These feature distributions are found to be statistically significant ($p \leq 0.5$), but overlapping in nature. Therefore, a nonlinear classifier random forest is employed to classify these seizure types. This model yields an accuracy of 88.53% and a specificity of 91%. The results show that the proposed system could support diagnostic and therapeutic decision-making for the epileptic patients.
Keywords: *Epilepsy, EEG, signal processing, machine learning.*

Plenary Talk

Research in Total Knee Arthroplasty Biomechanics: to close the gap between surgeons and engineers.

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Knee kinematics is a complex three-dimensional roto-translation movement, which is strongly correlated to patient anatomy. In particular, the shape of the femoral condyles, the tibial plateau, the patellar proximal surface and the morphological and mechanical properties of the soft tissues are fundamental to discriminate such movement. For these reasons, each human being has a different knee kinetics and kinematics. Therefore, the understanding of the patient-specific knee joint anatomy and functionality, through dedicated methodologies for kinematic and kinetic analyses and soft tissue mechanical properties determination, is the key factor for closing the gap between surgeons and engineers.

In the last years, several study were performed using robotic simulator showing how this technique could be beneficially used to investigate accurately knee joint kinematics, in terms of both rotations and translation. Moreover, parts of these study were dedicated not only on tibio-femoral kinematics but also on the investigation of the patello-femoral joint, currently, and unexpectedly, not well investigated nowadays, together with collateral ligament strain and knee alignment.

Furthermore, the coupling of numerical analysis to experimental activity show big improvement in the results, allowing sensitivity analysis providing accurate information on contact force and pressure, investigate bone stress, or integrating with additional outcomes as risk of fracture or ligament strain distribution.

Experimental evidence showed that the kinematic and kinetic knee joint activity is highly patient dependent, both in healthy and in patient with prosthesis, moreover, a wrong position of the implant or a bad choice of the soft tissue position during modeling could induce high alteration of the joint force (up to 60%) even if the change in kinematics could be quite small (less than 5% compared with the theoretical position).

Experimental techniques combined to numerical ones showed that a close to real model of the knee joint is fundamental, especially considering the soft tissue envelope that, is neglected, could lead to a wrong tibio-femoral interaction.

As knee kinematics and kinetics is a results of a musculo-skeletal interaction, not only the bone anatomy need to be integrated in this analysis but also information on soft tissues need to be provided.

Moreover, especially in analyzing patient with knee prosthesis, results of several study highlight how kinematics is not the only and also not the most relevant parameter to predict or explain knee function but knee kinetics should be integrated in the clinical follow-up.

Dedicated patient-specific experimental and numerical methodologies showed to be the promising tool to fill this gap surgeon and engineer and to guide patients from immobility to mobility, overstepping their disease.