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American University of Sharjah

COLLEGE OF ENGINEERING
كلية الهندسة

Current Biomedical Engineering Research Activities

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As the first program of its kind in the Gulf, the Master of Science in Biomedical Engineering (MSBME) offers a stimulating academic environment and outstanding research capabilities. Based on high standards similar to those followed in the United States, our program pursues quality research in a number of areas pertinent to the growing biomedical industry in the region.

From cancer research focusing on motion modeling and volumetric image generation, to the development of biodegradable and lightweight orthopedic implants, our highly qualified and experienced faculty members are conducting research on a wide variety of topics of great significance to hospitals, clinics, medical colleges, medical technology suppliers and the biomedical engineering industry.

Our distinguished research team is keen to collaborate with industry partners throughout the MENA region to pursue projects that are relevant to the needs of and challenges facing the industry.

Together with partners from the healthcare and biomedical industry, our College of Engineering is committed to setting new standards of excellence in research and innovation in the field of biomedical engineering.

Multi-Sensor Testbed for Intelligent Patient Monitoring and Diagnosis

Investigators

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Motivation

To reduce the cost and improve the efficiency of healthcare.

Goal

To develop intelligent patient monitoring systems that will help identify risks and issues and alert patients and clinical staff so that timely preventive and/or remedial action can be taken.

Method

1. To combine multiple sensors to measure a patient's vital signs and detect key symptoms.
2. Process sensory data to build a computational model of the patient.
3. Monitor a patient, compare data to the model, and identify discrepancies, hence immediate problems and potential risks.
4. Issue alerts or recommendations based on expert decision logic.

Results

Prototype systems were developed for:

- dementia patients in hospital (to prevent falls and self-harm)
- sleep apnea patients in their home (to detect shallow breathing and heart problems).

Other applications can be realized as well.

Mining Large Patients Databases for Enhanced Clinical Decision-Support

Investigators

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Motivation

To enhance medical knowledge and improve CDS interventions.

Goal

To develop computational techniques to realize evidence-based medicine and drive clinical-decision support systems toward better information, diagnosis, recommendations and actions.

Method

1. Mine large hospital databases using AI/machine learning algorithms.
2. Analyze patients' records to uncover medical knowledge.
3. Improve understanding of the relationships between illnesses, symptoms and complications.
4. Further increase the efficacy of tests and treatments.

Results

Prototypes were developed for:

- diabetic patients in hospital (to predict possible complications) and in their home (to improve glycemic control)
- lung cancer
- leukemia (to increase early diagnosis accuracy and to provide better long-term prognosis).

The approach applies to many other diseases.

Medical Mobile Applications

Investigators

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Motivation

The increasing computing power of mobile phones allows us to use these devices in hosting health applications designed to be used by patients for diagnostics, continuous illness monitoring and self-management programs, resulting in a patient-centered healthcare delivery technique that is efficient and cost effective.

Goal

To facilitate the use of mobile electronic devices to support medical and public health practices.

Method

1. Smart phones are equipped with multiple sensors that are used in measuring patients' vital signs.
2. Using appropriate algorithms, develop software applications that analyze these readings and use decision logic to notify patients and caretakers.

Results

Prototype systems were developed in four cases:

- sleep apnea diagnosis
- COPD and asthma monitoring
- Parkinson's Disease diagnosis
- Autism diagnosis

Many other applications are also being explored.

Operating Room Scheduling

Investigator

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Motivation

The operating room (OR) is one of the most costly resources in a medical facility and also is the largest revenue center (40 percent). ORs generally have high costs and historically low facility and/or personnel utilization rates. Surgical patients provide a significant portion of the demand served by other hospital departments.

Goal

Improve OR efficiency and reduce costs by improvement through optimizing OR time allocation and case scheduling.

Methods

1. Mathematical models were developed to optimize: OR capacity planning and time allocation decisions. Operating room time assignment.
2. Simulation modeling was used to study the impact of different sequencing rules on the OR and PACU utilization.

Results

Increase in OR utilization as a result of:

- better allocation of OR time to surgical specialties
- better allocation of OR to surgical groups
- smooth flow inside the surgical theater between the OR and PACU
- reduce waiting times for patients and surgeons

Resource Planning for Medical Equipment Maintenance

Investigator

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Motivation

Medical equipment maintenance is one of the most important aspects within the healthcare industry as it minimizes and eliminates most of the risks associated with failures. This results in less dangerous situations, accidents and possible loss of life.

Goal

To improve maintenance planning in order to ensure that all medical equipment is maintained and restored to its optimum operating condition by increasing its reliability and availability, thereby reducing its failure rate.

Methods

Applying the Reliability-Centered Maintenance (RCM) methodology as a building block of the maintenance plan for medical equipment, which will result in making the management of medical devices more feasible.

Results

Implementing the RCM maintenance program results in increasing the equipment's reliability level and reducing the associated maintenance costs.

Other Projects

- Emergency room simulation
- EMS location analysis
- Appointment scheduling systems

Healthcare Management Focus Areas

- Scheduling and capacity management
- Inventory management
- Supply chain management
- Enterprise resource planning
- Operations improvement
- Facilities planning and operations
- Quality management and Six Sigma

Motion Modeling and Volumetric Image Generation for Lung Cancer Image-Guided Radiation Therapy

Investigator

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Motivation

Respiratory motion introduces uncertainties in lung deformation and tumor localization. Using motion models to generate volumetric images at the time of treatment has the potential to help reduce uncertainties.

Goals

1. Develop patient-specific motion models.
2. Use them to generate time-varying volumetric (3-Dimensional) images at treatment delivery time.

Methods

Step 1: Build the motion model:

Apply deformable registration (DIR) on an initial set of images (reconstructed from different respiratory bins).

Apply dimensionality reduction methods (PCA in this study) on the resulting Displacement Vector Fields (DVFs) to distil the DVF dataset into a few principal components (up to three) representing the patient anatomical motion pattern.

Step 2: For every 2D X-ray image captured at treatment time, the motion model is being optimized to generate a 3D image simulating the respiratory phase of the patient in the x-ray image captured.

Results

- The generated 3D images were able to capture the anatomical variations of the patient's anatomy at the time of treatment.
- The images have the potential to improve tumor localization and delivered dose calculations.

Ultrasound-Triggered Drug Delivery for Cancer Treatments

Investigator

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Motivation

Chemotherapy kills tumor cells and healthy tissues alike, causing various side effects including cardiac toxicity, hair loss, nausea and pain, among others. Encapsulating the drug along with specifically targeting tumor cells has the ability to significantly improve the therapeutic index and reduce these side effects.

Goal

Our goal is to reduce the side effects of chemotherapy by encapsulating the drug into active nano-carriers and release the drug by applying ultrasound.

Methods

1. The nano-carrier – liposomes (phospholipid bilayer structures with hydrophobic and hydrophilic phases), micelles, metal organic frameworks (MOFs), etc. are synthesized in the lab.
2. Chemotherapeutic drugs (including doxorubicin) are physically entrapped inside these drug delivery nanovehicles.
3. We use passive, active and ultrasound targeting. Ultrasound is focused on the tumor and has the capability of releasing the chemotherapy contents at the desired location, sparing the other healthy cells in the body.

Vitamin D Treatment Monitoring Using Microwave Imaging Techniques

Investigators

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Motivation

Microwave imaging is a non-invasive modality that uses low-power non-ionizing electromagnetic radiation to estimate the bulk electrical properties of human tissues. The electrical properties (permittivity and conductivity) vary for different types of tissues within the human body. A microwave imaging system can be developed to monitor the effectiveness of Vitamin D treatment of low bone mass.

Goal

Develop a microwave imaging system for monitoring Vitamin D treatment.

Methods

1. There are two types of imaging system under consideration: an open-ended waveguide system for non-destructive evaluation methods (NDE), and a microwave tomography imaging system.
2. The open-ended wave guide system consists of a single probe that transmits and receives electromagnetic signal. The received data can be processed in real-time.
3. As for the microwave tomography (MWT) system, it consists of several transducers to transmit and receive electromagnetic signals via a transceiver.
4. The measured electromagnetic signals in MWT are processed offline and then used as input for optimization algorithms that solve a nonlinear inverse scattering problem.

Results

- The NDE system will provide qualitative 1D images about the bone.
- In MWT, the output is a 2D image that will contain information about the location and shape of the bulk properties of tissues within the human organ as well as various electrical properties.

Biodegradable and Lightweight Orthopedic Implants

Investigator

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Motivation

There is a huge demand for implants: there are 1.8 to 2.0 million cases of artificial articulation replacements in the world. Metal-bone implants used currently are non-degradable and have high densities (weigh more). The current industry standard metal-bone implant materials (both temporary and permanent) are stainless steel, cobalt/chromium/molybdenum, titanium alloys and tantalum among others.

Goal

1. Develop biodegradable orthopedic implants using high entropy bulk metallic glasses and hollow spheres.
2. Develop lightweight implants using high entropy alloys and hollow spheres (reduce weight by up to 50 percent).

Project 1: Biodegradable and Light Weight Orthopedic Implants

1. The aim of this study is to introduce the concept of high entropy into the field of Bulk Metallic Glass (BMG), including hollow bubbles for weight reduction.
2. The feasibility of the newly developed BMGs as biomaterials for orthopedic applications will be investigated by both in vitro and in vivo evaluations.
3. Based on literature, it is expected that the developed material system will possess higher compression strength, good corrosion and controlled degradation.

Project 2: Lightweight High Entropy/Hollow Bubble Orthopedic Implants

1. There is a strong need for a new generation of light weight metallic biomaterials with superior biocompatibility and mechanical properties to meet future demands of the medical field.
2. Because of their light weight, high strength and anticorrosion properties, High Entropy Alloys (HEA) are potential candidates to replace stainless steel and titanium orthopedic implants.
3. Addition of hollow spheres with HEA will enable weight reduction with good mechanical and corrosion properties.

Cable-Driven Leg Trainer

Investigator

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Motivation

Recovery of the gait function for subjects with neural injuries such as spinal cord injury and strokes can be achieved through intensive and task-specific rehabilitation. Gait training is based on the principal "train like you walk," which consists of stimulating the nervous system to acquire new skills.

Goal

Design and test a gait training machine based on a quantitative gait analysis.

Methods

Model and simulate the gait of a person to help in determining the optimal design parameters that minimize the tensions in the cables.

Results

A first prototype was built to test the feasibility of this study. Ongoing research aims at collecting some preliminary data to be used to optimize the design.

Comparison of the Vicon System and Kinect Sensor in Capturing the Walking Motion

Investigator

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Motivation

Motion tracking systems are an essential tool to monitor and later diagnose any pathology related to the gait of a person. However, existing systems on the market are relatively expensive. New low-cost sensors (3D cameras) are being proposed in the market for video games.

Goal

The objective of this research is to conduct a comparative study between the well-known Vicon system (~$300,000) and the Kinect motion sensor (~$100).

Methods

The person is monitored simultaneously using the two systems and the motion is recorded. A post-processing phase is required to extract the motion characteristics, using the two systems.

Results

The results showed that the Kinect can give similar results for low dynamics, which can be used as a low-cost system for body motion tracking.

Flexible Implantable Electrodes Using Conductive Polymers

Investigators

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Motivation

Implantable electrodes represent a major component of the current solutions proposed to help restore motor functions after peripheral nerve injuries. Implanted electrodes function by detecting neural signals and/or stimulating muscle tissues to bridge the proximal end of the injured peripheral nerve with the respective muscle. The major challenges of designing implantable electrodes include biocompatibility, corrosion, mismatch between stiff electrodes and neurons, recording reliability, signal to noise ratio, cost (as platinum and iridium are used).

Goal

Develop a novel implantable electrode architecture to reduce electrode-tissue motion artifacts.

Methods

1. Biocompatible conductive polymers are investigated to fabricate bio-electrodes.
2. The synthesized bio-electrodes are characterized for their electrical impedance and mechanical properties.

Results

The developed implantable electrodes should be capable of stimulating the muscle tissues and or/detecting neural signals using functional, less expensive materials and durable materials.

Adipocyte Enhancer-Binding Protein 1 (AEBP1) as a Critical Cellular Regulator of Cholesterol Homeostasis, Inflammation and Atherogenesis

Investigator

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Motivation

Atherogenesis is a long-term process that involves inflammatory response coupled with metabolic dysfunction, leading to atherosclerosis (cardiovascular disease). Adipocyte enhancer-binding protein1 (AEBP1) has been shown to impede macrophage cholesterol efflux, promoting foam cell formation, via PPAR**γ**1 and LXR**α** down-regulation.

Goal

1. Assess the role of macrophage AEBP1 in promoting atherosclerosis.
2. Evaluate the impact of AEBP1 ablation and over expression in knockout (KO) and transgenic (TG) animal models, respectively.

Methods

1. Atherosclerotic lesion formation and macrophage infiltration were assessed using AEBP1-/-/LDLR-/- double-KO mice as well as AEBP1TG mice, en face analysis, bone marrow (BM) transplantation, and immunohistochemistry of aortic cryosections.
2. mRNA and protein expression was assessed by real-time PCR and immunoblotting, respectively.

Results

- AEBP1-transgenic mice (AEBP1TG) with macrophage-specific AEBP1 over-expression exhibit hyperlipidemia and develop atherosclerotic lesions.
- Ablation of AEBP1 results in significant attenuation of atherosclerosis in the AEBP1-/-/LDLR-/-double-KO mice.
- BM transplantation experiments further revealed that LDLR-/- mice reconstituted with AEBP1-/-/LDLR-/-BM cells(LDLR-/-/KO-BM chimera) display significant reduction of atherosclerosis lesions compared to control mice reconstituted with AEBP1+/+/LDLR-/-BM cells(LDLR-/-/WT-BM chimera).
- Transplantation of AEBP1TG BM cells with normal Apo Egene intoApoE-/- mice (ApoE-/-/TG-BM chimera) leads to significant atherogenesis despite the restoration of ApoE expression.
- Macrophages from ApoE-/-/TG-BM chimeric mice express reduced levels of PPAR**γ**1, LXR**α**, ABCA1 and ABCG1 and increased level of L-6 and TNF**α** compared to macrophages of control chimeric mice ApoE-/-/NT-BM) that received AEBP1-non-transgenic (AEBP1NT) BM cells.
- AEBP1 may serve as a potential therapeutic target for the treatment of atherosclerosis.

Mathematical Modeling of Molecular Mechanisms Controlling the Differentiation of Immune System Cells: T-helper and Macrophages

Investigator

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Motivation

Immunity requires the recognition and destruction of invaders such as pathogens. The adaptive immune system consists of specialized cells (T-helper, macrophages) that differentiate into several discrete subsets to orchestrate the immune response. Although there is a wealth of information about the different subsets in vitro, features such as plasticity, heterogeneity and adaptability make them very difficult to study using conventional experimental tools and draw conclusions about them in vivo.

Goal

Obtain a comprehensive understanding of the mechanisms controlling T-helper and macrophage cell differentiation processes.

Methods

Mathematical modeling (using ordinary differential equations or logical networks) to construct a dynamic model of the molecular network controlling the differentiation by integrating available data and knowledge in the literature.

Results

My collaborators and I have constructed mathematical models of T-helper cell differentiation (with Dr. Josep Bassaganya-Riera's lab at Virginia Tech, USA) as well as macrophages differentiation (with Dr. Filippo Castiglione's lab at CNR, Italy). We used the models to do in silico experiments, design experiment to be curried in the lab, and suggested new hypotheses by predicting the outcome of certain perturbations, such as knock-out, knock down, and overexpression before carrying them out in the laboratory. For examples, our Th model shows that PPARg is essential for modulating Th differentiation and plasticity.

Cortical Source Imaging Using EEG

Investigators

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Motivation

Imaging cortical sources of activity is potentially useful in assisting treatment of patients with conditions such as epilepsy. Imaging is usually performed using CT/MRI, which are costly. EEG provides a cost-effective alternative. However, EEG has low spatial resolution.

Goal

To develop array signal processing techniques that will improve the spatial resolution of EEG. This will allow for an effective and low-cost solution for monitoring cortical activity.

Methods

An iterative non-parametric imaging algorithm was used in conjunction with a transfer function-based calibration algorithm to account for uncertainties in the response of the EEG system.

Results

EEG signals collected from epileptic human subjects in a clinical environment were processed. Initial results show that the developed signal processing techniques demonstrate good levels of sensitivity and specificity, and may potentially provide a useful complement to existing clinical assessment methods.

Bone Healing Monitoring Using Ultrasound

Investigators

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Motivation

X-rays are commonly used to monitor bone healing. However, regular use of X-rays is dangerous since it produces ionizing radiation. Ultrasound is an alternative low-cost imaging modality that does not produce ionizing radiation.

Goal

To develop a technique that will allow for quantitative measure for the assessment and monitoring of the bone healing process using ultrasound images.

Methods

The relationship between the B-Mode ultrasound image intensity and the acoustic impedance was studied. A quantitative measure of bone healing was developed that exploits an information theoretic criterion utilizing the intensity histogram of the bone and callus regions obtained from the ultrasound image.

Results

The developed method was applied to ultrasound images obtained from standard non-biological materials as well as a pilot experimental study on human subjects. The obtained results demonstrate that the proposed method is capable of monitoring and quantifying the degree of bone healing process. Moreover, the results provide a foundation for studying other properties, such as bone density.

Severity Assessment of Spinal Cord Injury

Investigators

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Motivation

There is a need to develop methods for evaluating the level of SCI. Such methods are important not only for evaluating the effectiveness of therapeutic mechanisms but also in providing timely surgical intervention.

Goal

To use physiological signals to develop a non-subjective and quantitative assessment of the severity of SCI.

Methods

The similarity between a somatosensory evoked potential (SEP) signal from a healthy spinal pathway (which in the event of thoracic SCI can be obtained by forelimb stimulation) and a SEP signal from an injured spinal pathway (which can be obtained by hindlimb stimulation) can be used as an objective measure of the severity of SCI, thus providing a complementary measure to qualitative behavioral based assessments.

Results

The developed SCI quantification methods were applied to SEP signals on rodents that were subjected to spinal cord transection. The results exhibit a high degree of correlation with existing subjective SCI assessment methods. Moreover, the results provide a foundation for studying phenomena such as neural plasticity.

Cognitive Vigilance Assessment and Enhancement

Investigators

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Motivation

Extreme high or low cognitive workload in active applications, which require attention and vigilance (like airport security, surveillance and driving), can lead to reduction in cognitive efficiency.

Goal

If vigilance level is measured accurately, it is possible to achieve cognitive enhancement and reach optimum cognitive efficiency by engaging the subject with challenging stimuli or task sharing.

Method

Eye saccade amplitude, saccade velocity, blink frequency and dynamic of F-theta EEG waves exhibit significant changes due to challenge integration. ($p<0.05$).

Results

Eye saccade amplitude, saccade velocity and blink frequency exhibit significant changes due to challenge integration. Dynamics of F-theta EEG waves. Red, green and blue correspond to phases 1, 2, and 3 respectively. Vertical grey bars indicate the periods with challenging events. ($p<0.05$)

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