Systems Design Engineering Graduate Symposium

Winter 2023

Hello and Welcome!

The Department of Systems Design Engineering is delighted to announce that we will be holding our 2023 Graduate Symposium! The symposium will take place on Tuesday, April 11, 2023 in the E7 Ideas Clinic (E7-2409).

Schedule

The Symposium has been broken into three sessions, with breaks and lunch hour between sessions

1 Human Factors

Time: 9:30 AM - 10:45 AM
Chair: Nasser Lashgarian Azad
Speakers: Naomi Paul, Sneha Srinivasan Rammanoharan, Jose A. Alguindigue, and Rory Ewing.

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2 Biomedical Engineering

Time: 11:00 AM - 12:15 PM
Chair: Eihab Abdel-Rahman
Speakers: Behzad Danaei, Hossein Mohammadi, Marco Moran-Ledesma, Arya Amiri, and Ali Asghar Mohammadi Nasrabadi.

3 Vision, Image, and Signal Processing & Mechatronics

Time: 1:30 PM - 2:45 PM
Chair: Tais Sigaeva
Speakers: Weidong Liang, Aravind Ravi, Faizan Sana, Samed Kocer, and Carl Azzi.

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Session 1: Human Factors

An Experimental Comparison of the Effectiveness of Various Levels of Simulator Fidelity on Ab Initio Pilot Training

Naomi Paul

Flight simulators have long been used to great levels of success with studies demonstrating that pilots who first train using a simulator reach acceptable levels of competence in less time than pilots who start in the cockpit of an actual aircraft. However, the high costs of simulators are not economically sustainable for the aviation industry and is one of the barriers to entry for those of diverse backgrounds. To address these challenges, there is hope that medium- and low- fidelity simulators including virtual reality head-mounted displays and desktop simulators may be approved for ab initio pilot training as a supplement to real flight training. Ab initio pilot training is pilot training "from the start", training pilots with no experience until achievement of their commercial pilot's license.

Natural tactile interaction is traditionally associated with effective pilot training tasks. Despite the lack of natural tactile interaction in virtual reality, some tasks, such as procedural tasks, simply require exposure to the aircraft environment. This exposure may be achieved through 3-dimensional simulated models of the aircraft in virtual reality.

My research proposes a between-subjects experiment, with 10 participants per group (30 participants total), to quantitatively address this question by analyzing the improvement of pilots completing simple procedural and aircraft handling tasks using either a high-fidelity flight training device, medium-fidelity desktop simulator, or low-fidelity virtual reality simulator. All participants are student pilots at the University of Waterloo with under 20 hours of flight experience, participated in 5 consecutive days of the study, with training effectiveness evaluated through the improvement in performance from Day 1 to Day 5. This research collected objective flight performance assessed by both a flight instructor and through flight data, as well as subjective rating data regarding mental workload, stress level, and experience of simulator sickness. One-way and repeated measures ANOVA analyses were used to analyze the improvement in participants' performance for ab initio procedural and aircraft handling tasks, comparing three between-subject conditions of using a high-fidelity flight training device, medium-fidelity desktop simulator, or low-fidelity VR simulator.

It was found that virtual reality and desktop simulators are as effective as high-fidelity flight training devices for pilot training of procedural tasks, without increasing the risk of experiencing simulator sickness. However, for aircraft handling tasks, participants training using virtual reality or desktop simulators did not improve to the same degree as those training on the high-fidelity flight training device. This provides evidence for the argument towards approving the strategic allocation of virtual reality for pilot training in combination with existing simulator methods for handling and other tasks, leading to potential cost savings which make training less expensive and more accessible to future pilots.

Comparative Data Analysis of Older Driver's Vs Younger Driver's Gap Acceptance Behaviour at Signalized left turns - A Driving St

Sneha Srinivasan Rammanoharan

Drivers aged 60 and older are very prone to motor vehicle crashes. Intersections appear to be hazardous for drivers of this age group due to the driver's cognitive, perceptual, and psychomotor challenges. Literature notes that older drivers find it incredibly challenging to safely navigate left turns at signalized intersections. Older drivers have problems to adequately detect, perceive, and accurately judge the safety of a gap. The increase in number of elderly drivers has been paralleled by an increase in road-related accidents due to age-related fragility. Previous studies did not consider much about the effect of randomized gap on physiological factors and their impact during driving.

This thesis aims to address the gap in the literature by explicitly examining older and younger drivers' gap acceptance behaviors during left turns at protected four-way intersections. The main objective of this thesis is to analyse the effect the Gap Acceptance Behaviour on the age, traffic volume, physiological factors like heart rate (HR), electrodermal activity (EDA), body temperature, motion sickness among younger drivers and older drivers. The data was collected from a driving simulator study comprising 40 participants aged between 20-30 for younger and above 60 years for older. All the recruited drivers were healthy. Each participant navigated twelve scenarios, six with lower traffic condition and another six with higher traffic condition. Each lower and higher traffic scenario will have varying queue length, i.e the number of cars in front of the ego vehicle varying from 0,1 and 2. All the varying queue length will also have one with pedestrian and the another without pedestrian.

The physiological data collected through the Empatica4 wristband was analyzed and compared against age, gender, another parameter like motion sickness score (MSS), driver behaviour obtained from a questionnaire the participants completed after the experiment and the accepted gap. We anticipate that the older drivers will exhibit longer gap acceptance times and a greater frequency of gap rejections than their younger counterparts while turning left across traffic at signalized intersections. The findings of the current study will have implications for older driver safety. Researchers may use the findings to understand gap acceptance behaviours further, while policymakers may utilize the results to design mobility guidelines.

Driver Drowsiness Detection System based on PERCLOS and Heart Rate Variability

Jose A. Alguindigue

Drowsy driving is a significant cause of road traffic accidents, with millions of drivers on the road and accidents increasing exponentially. This research aims to analyze the relationship between heart rate variability (HRV) and the percentage of eyelid closureover the pupil over time (PERCLOS) in drivers in a drowsy and non-drowsy state. To understand this state, a Machine Learning model will be developed to analyze HRV and PERCLOS. Telemetry data will also be collected to capture changesin driving behaviorand harsh driving changes, such as speed, acceleration, braking, and lane changes, that drivers may experience during drowsiness. The majority of accidents occur during late night or mid-afternoon periods, and driving for extended periods raises the mental workload of drivers, increasing the likelihood of drowsiness. Therefore, this study will collect data from 40 participants in a controlled scenario, with half driving in a non-monotonous scenario and the other half in a monotonous scenario.

A Machine Learning model can provide enough information to determine the relationship between PERCLOS and HRV with drowsy and non-drowsy driving. Previous research with similar data has used different combinations of Machine Learning models, such as Back Propagation Neural Networks(BPNN) with Long Short-term Memory (LSTM), Autoencoder (AE) with LSTM, and 1D Convolutional Neural Networks (1D CNN). These Machine Learning models, along with others such as gated recurrent unit (GRU), Transformers, Mogrifier LSTM, Momentum LSTM, Difference Target Propagation, and Decoupled Neural Interfaces Using Synthetic Gradients, will be tested on the collected data to find the one that provides the best performance. This study aims to detect fatigue approximately 3 to 5 minutes before drowsiness occurs or improve this margin, allowing drivers to pull over before any accidents occur, thereby reducing the overall number of vehicle accidents, as previous research has shown. With the application of machine learning models, we hope to obtain true positive results close to 75% and accuracies ranging between 80% and 88%.

The resultsobtained will be verified with the help of vehicletelemetry to furtheranalyze driving behaviour changes during drowsy and non-drowsy driving.

Defining Expertise in Requirements Elicitation

Rory Ewing

The tools of Human Factors research have often focused on time-constrained, reactive work, with less attention given to deliberative knowledge work. Design requirements for prospective systems are developed through a collaboration between requirements elicitors and a variety of subject matter experts selected for their knowledge of, and stake in, the envisioned work related to the prospective system. The success of requirements elicitors is key to avoiding costly changes made to a system for which the design is complete, and manufacturing may be underway. Study participants were experienced requirements elicitors drawn from sectors with cultures of high reliability. Semi-structured interviews were conducted using a multiple-pass, retrospective approach. Participants were guided by probe questions through their recollection of a “Critical Incident” which was both demanding of their skills and impactful to their goals. The probes were used to focus discussion on the decisions specifically made by the participant and the cues, memories, tools, and other factors they weighed in making them.

Responses were initially processed by Thematic Analysis. The themes drawn from this analysis broke down participants’ actions during these critical incidents into a set of activities. Two activities in particular – “Constructing a Coalition” and “Selecting a Strategy” – stood out as unanticipated in their centrality to the participant’s responses. “Selecting a Strategy” especially highlighted the use of low-fidelity, tailored simulations to elicit stakeholder feedback which might otherwise have gone unnoticed or discarded as unimportant. These activities are further developed into Decision Ladders which break down these large scale activities into states of knowledge and the smaller scale activities that make up them up. The Decision Ladders serve also to highlight the cognitive leaps or “shunts” that experienced requirements elicitors make that separate them from novices. Future work is expected to include further development of Decision Ladders into training products which can be used to aid the development of novices in the field.

Session 2:
Biomedical Engineering

Model-Based Optimization of Acetabular Cup Orientation Based On Functional Pelvic Tilt Following Total Hip Arthroplasty

Behzad Danaei

Introduction: Total Hip Arthroplasty (THA) is a surgical procedure in which the articulating surfaces of a damaged hip joint (e.g. due to severe osteoarthritis) along with the neck and head of the femur are replaced with artificial materials. Hip dislocation is the biggest cause of complaints following THA [1]. Hip dislocation occurs when the head of the implant is pulled out of the acetabular cup. Proper cup orientation is reported as the most significant factor to reduce the risk of dislocation. The widely adopted guideline for cup orientation is the Lewinnek safe zone [2]. In this project, a musculoskeletal model-based method is used to study the effect of pelvic tilt (PT), which refers to the orientation the pelvis in relation to the spine, on the optimal orientation of the cup for THA. In this method both kinematic and dynamic factors, namely impingement between the acetabular cup and implant neck and edge-loading of the acetabular cup, are taken into account for determining the optimal cup orientation.

Methodology: In the presented method, motion capture (MoCap) data obtained from the patient is artificially modified by changing the pelvis tilt angle ranging from −20° to 20°. Then, the time-varying hip contact force and the orientation of the femural implant with respect to the pelvis are calculated by the use of a musculoskeletal model. Finally, the safest orientation of the acetabular cup is calculated by concurrently minimizing the risk of impingement and edge-loading for three different daily activities. In this research, Carnegie Mellon University's Graphics Lab MoCap database [3] was used as the motion input to the model. Three activities of daily living: walking, sit-to-stand, and picking up an object from the ground (without bending the knees) are selected as case studies.

Results and Significance: Based on the results, optimal anteversion and inclination cup angles become larger as the pelvis is tilted forward, and vice versa. The results show that the optimal cup orientations for large pelvic tilt angles are not covered by the Lewinnek safe zone. Therefore, the Lewinnek safe zone may not always be optimal, or even safe. This indicates the importance of considering the subject-specific pelvic tilt during the pre-operative planning stage of THA. The low computational complexity of the model due to analytical formulas makes it suitable for both pre-operative and intra-operative planning.

Acknowledgments: This research was funded by Intellijoint Surgical, the Natural Sciences and Engineering Research Council of Canada, and the Ontario Centres of Excellence.

References:

[1] Biedermann et al., 2005. J Bone and Joint. 87: 762-769.

[2] Lewinnek et al., 1978. J Bone and Joint. 60: 217-220.

[3] CMU Graphics Lab Motion Capture Database.

Experimental, modelling, and parametric study of cutting characteristics of thin viscoelastic membranes under needle insertion

Hossein Mohammadi

Cutting characteristics of thin membranes and the mechanics of their interactions with sharp aggressors like needles is critical in many industrial applications (e.g., development of more efficient protective membranes) and medical procedures (e.g., the treatment of middle-ear diseases through the tympanic membrane based on novel surgical tools). In this research, we performed needle insertion experiments to study the cutting behaviour of membranes made with polyethylene (PE) and nitrile butadiene rubber (NBR) and investigated different stages of the procedure by analyzing the needle reaction force. We developed a combined experimental-numerical approach to investigate the cutting characteristics of thin membranes during needle insertion. The experimental part is based on two consecutive cycles of insertion/extraction of the needle at the same point on the membrane, and the numerical part is established by finite-element (FE) modelling. This method exploits an energy balance description of two subsequent needle insertions to analyze different fracture features of thin membranes.

We then used the proposed approach to evaluate the effect of input parameters (i.e., needle insertion velocity, needle diameter, lubrication, angle of insertion, membrane thickness, and membrane material) on output parameters (i.e., the crack size, maximum insertion force in each cycle, puncture displacement, frictional force, and fracture toughness of the membrane). We also used our FE model to compute the viscoelastic properties of the membranes and eliminate the effect of viscoelasticity in the energy balance equilibrium to study the fracture toughness of the membranes more accurately. The FE model was also exploited to analyze the mechanical stress and deformation throughout the whole membrane which was not possible to determine merely based on traditional experimental approaches.

The results showed that, in most cases, the crack size, maximum insertion force, puncture displacement, kinetic frictional force, and static frictional force increase with the increase of needle diameter, increase of membrane thickness, or inclining of the needle. On the other hand, the effect of the insertion velocity on output parameters is negligible except for the kinetic frictional force which increases with the insertion velocity. We also showed although lubrication cannot considerably change the maximum needle insertion force into thin membranes, it can substantially decrease the puncture displacement and frictional forces. Furthermore, we observed that the maximum insertion force, puncture displacement, and frictional forces for PE are greater than the values obtained for NBR, while the crack sizes obtained for PE are smaller than those for NBR. The fracture toughness values obtained based on our proposed experimental-numerical approach were 6.66 ± 1.16 kJ/m^2 and 3.98 ± 0.56 kJ/m^2 for PE and NBR, respectively. The proposed approach and obtained results from this research can be exploited in the analysis and development of industrial membranes as well as the advancement of surgical tools and the introduction of novel medical treatment approaches.

Interactive Training Tool for Injury Assessment of a Human Joint

Marco Moran-Ledesma

Manual musculoskeletal assessments allow rehabilitation practitioners to identify soft tissue injuries (e.g., knee ligament tears) through visual and haptic cues. However, becoming proficient at assessing patients' joint integrity through manual physical exams is difficult due to 1) the wide range of joint conditions and 2) the limited practice opportunities on injured clients. Shortage of trainers in a clinical academic environment and ethical issues surrounding training involving patients also limit practitioners' exposure to a large number of injuries and cases. Novice students, for instance, find themselves limited to practicing on their peers' limbs, typically healthy, or relying on learning materials, such as lectures or demonstrations. How could we increase access to hands-on rehabilitation practitioners' education and training? How can we increase the number of controlled, low stakes learning opportunities that practitioners are afforded to improve and develop their clinical evaluation skills?

We designed and implemented an artificial human-like joint on which practitioners train in injury assessment. Together with a clinical instructor, we carefully defined a set of design considerations that suggest our tool should 1) attempt to resemble the skin look and feel of a human leg, 2) emulate the biomechanics of healthy and injured human knees, and 3) simulate different grades of ligament injury. We also aimed to carefully consider trade-offs in cost, ease of fabrication, assembly, and performance in order to make our tool readily available for, and accessible by, a large audience of instructors and practitioners.

We have implemented version 3.0 of our tool with an affordable passive human knee joint model, 3D printed attachments, silicone-based skin layers, and off-the-shelf electronic components. In the near future, we will be conducting formal evaluation sessions of the tool with clinical instructors and kinesiology students.

Our work could have implications for further research and education:

1) How could educators formally deliver remote/in-person courses and hands-on laboratories with it? Teaching anatomy has historically been based on lectures, cadaveric dissections, and illustrated printed materials, which students often find difficult to understand. Our work may help address this challenge, but a thorough understanding of the feasibility, benefits, and challenges of delivering hands-on laboratories or online courses with an artificial human-like joint is necessary.

2) Is our approach valid for other human joints? The human body is composed of a large number of joints. It will be worth exploring whether our approach followed for the knee joint can be applied to build other joints (e.g., ankle, elbow, etc.).

3) How could we make our joint customizable? Practitioners are required to be proficient at assessing joints of people of all ages, for which we may work towards a set of different 1) sizes of 3D models of bones, 2) ligament structures, and 3) skin layers that practitioners use to assemble and assess a toddler's joint, a senior's, a young adult's, etc.

Regional Heterogeneity in Aortic Aneurysms: A Method for Finite Element Analysis

Arya Amiri

An aortic aneurysm is a balloon-shape bulge occurring in the aorta, with drastic degradation of microstructure of the material which affects some regions more than others. The weakened region may dissect or rupture: the pressure of the blood pumping can split the layers of the aorta wall, allowing blood to leak in between them, or can burst through all the layers causing massive internal bleeding and finally lead to rupture. Both outcomes can be dangerous and are often fatal. Aneurysms greater than the clinical threshold, which is currently 5.5 cm in diameter, are selected for a highly invasive surgery that is often associated with prolonged adverse effects and recuperation. However, the aneurysm diameter is not always a precise criterion for showing the rupture risk of the aorta, making the surgical intervention (or the lack thereof) a risky proposition. There is a combined effort to establish a more reliable and accurate stress-based rupture risk criterion to better manage aneurysms and facilitate surgical decision-making. Because of its stellar ability to model complex geometry, loading state and material description, finite element modeling (FEM) represents an effective tool to more accurately measure the rupture risk of aneurysm by calculating the stress distribution within the material due to blood pressure. Despite the overwhelming experimental and imaging evidence of the aortic wall being regionally heterogenous, the aortic wall is still considered as a homogenous continuum in the FEM simulations. In this work, we propose a novel method to more accurately capture the heterogeneity of the material using 1) a realistic anisotropic nonlinear hyperelastic material constitutive equation(s), and 2) a continuously gradient material description of the regional variability. The latter will eliminate the issue of stress discontinuity providing a more realistic stress distribution in the enlarged aorta. Recent studies indicated that the regional heterogeneity of the aneurysmal wall may serve as a biomarker for rupture risk assessment, which could make our model relevant and timely. The results of FEM simulations for the idealized aorta model with three different material definitions are compared. The idealized homogeneous model results in homogeneous stress mapping and identical stresses across the circumference. The material with segmental heterogeneity leads to stress discontinuities, while the material exhibiting a continuous gradient of heterogeneity, yields smooth variability in the stress distribution.

A Multibody Predictive Dynamic Model to Optimize Acetabular Cup Orientation in Total Hip Arthroplasty Surgery Considering Differ

Ali Asghar Mohammadi Nasrabadi

Clinical evaluations have indicated increased patient dissatisfactions, suggesting that the traditional Lewinnek safe zone, which is a clinical recommended safe zone for hip implant positioning, may not be suitable for all. We are thus motivated to evaluate the importance of assessing spine stiffness prior to Total Hip Arthroplasty (THA) to propose a new safe zone and to ensure an optimal outcome. If the spine is too stiff or rigid, the prosthetic implant may not be properly positioned, leading to joint instability, pain, and implant failure. Currently, X-ray images are used to plan the surgery but fail to evaluate stiffness. Therefore, we propose a predictive multibody dynamic simulation including spine stiffness evaluation, as an alternative to static X-ray analysis. To further evaluate spine stiffness and its effects on lower limb motion, the authors developed a functional lumbar spine unit, with nonlinear ligaments and inter-vertebral disks. The unit was used to develop a 10 degree of freedom multibody sagittal human skeletal model using MapleSim software, featuring 7 DOF for the spine and 3 DOF for the lower limbs (hip, knee, and ankle). Trajectory optimization was used to develop a predictive sit-to-stand human motion simulation that was able to simulate relative orientations of femur and pelvis for different spinopelvic stiffness and mobility. Angular Distance to Impingement (AID) criteria, which is angular distance of implant to the nearest bony part of femur, was employed to optimize the acetabulum implant component anteversion angle to prevent impingement. The results are in-line with the literature. In addition, the authors evaluated the effects of different levels of spinal fusion on implant orientation. The advantage of the predictive model is optimal anteversion values based on subject-specific predictions instead of a wide range of clinical suggestions. Also, the impingement analysis clarified that considering spine stiffness in THA is necessary. Different levels of spinal fusion were considered in stiffness evaluation and the results showed different lower limb motion and consequently different optimized cup orientations. Thus, the predictive multibody dynamic simulation provides a useful alternative to static X-ray analysis, allowing for individualized assessment of spine stiffness and its effects on lower limb motion.

Session 3: Vision, Image, and Signal Processing & Mechatronics

Detection of Small Objects in UAV Images via an Improved Swin Transformer-based Model

Weidong Liang

Automated detection of small objects such as vehicles in unmanned aerial vehicle (UAV) images of complex urban environments is one of the most challenging tasks in computer vision and remote sensing communities, with various applications ranging from traffic congestion surveillance to intelligent transportation systems. Deep learning models, most of which are based on the convolutional neural networks (CNNs), have been commonly used to automatically detect objects in UAV images. However, the detection accuracy is still often unsatisfactory due to the shortcomings of CNNs. For instance, CNN collects data from nearby pixels, but spatial information is lost due to the pooling operations. As such, it is difficult for CNNs to model certain long-range dependencies.

In this thesis, we propose an improved Swin Transformer-based model that incorporates convolutions with the Swin Transformer to extract more local information, mitigating the problem of small object detection from the complex backgrounds in UAV images and further improving the detection accuracy. By using the Swin Transformer, our model leverages both the local feature extraction of convolutions and the global feature modeling of transformers. The framework was designed with two main modules, a local context enhancement (LCE) module and a Residual U-Feature Pyramid Network (RSU-FPN) module. The LCE module is used to implement dilated convolution and increase the receptive field of each image pixel. By combining with the Swin Transformer block, it can efficiently encode various spatial contextual information and detect local associations and structural information within UAV images. In addition, the RSU-FPN module is designed as a two-level nested U-shaped structure with skip connections to integrate multi-scale feature maps. A loss function combining Normalized Gaussian Wasserstein Distance and L1 loss is also proposed so that the model can be trained from unbalanced samples. The proposed method was compared with the state-of-the-art methods on the UAVDT dataset and Vis-Drone dataset. Our experimental results obtained on the UAVDT dataset indicated that our proposed method increased the mean average precision (mAP) by 21.6%, 22.3% and 25.5% over Cascade R-CNN, Pyramid Vision Transformer and Dynamic R-CNN detectors, respectively, demonstrating its effectiveness and reliability on small object detection from UAV images.

Combined Action Observation, Motor Imagery and Steady State Motion Visual Evoked Potential Based Brain Computer Interface

Aravind Ravi

Stroke is a leading cause of serious long-term acquired disability in adults worldwide reducing mobility in more than 50% of survivors age 65 and older. Gait recovery is a major objective in post-stroke rehabilitation programs. In conventional gait therapy, highly customized programs encourage patients' involvement in the therapy, but the results of the expended effort can be slow and limited leading to sub-optimal recovery. The patient's active involvement, collaboration, and motivation are key factors that promote efficient motor learning. There is a need to develop a novel rehabilitation strategy to promote active user engagement by utilizing their movement intent. Brain-computer interfaces (BCIs) based on electroencephalography (EEG) are an attractive approach for rehabilitation as it enables the patient to actively participate in therapy. Current visual BCIs provide high decoding accuracy but typically do not activate sensorimotor areas important for motor recovery. On the other hand, BCIs based on motor imagery (MI) activate motor areas but suffer from high inter-subject variability and long user training potentially leading to high cognitive demand.

In this research, we proposed a novel BCI called CAMS - Combined Action Observation (AO), Motor Imagery (MI), and Steady-state motion visual evoked potentials (SSMVEP) to induce acute changes in movement-related areas of the cortex based on observation and imagery of gait movements. The study hypothesized that a short CAMS BCI intervention can alter cortical excitability in the movement-related cortical areas manifesting as changes in the movement-related cortical potential (MRCP). A 40-minute intervention of gait observation and imagination was performed on nineteen healthy volunteers (5 Females and 14 Males, aged 19-45 years). The MRCP related to ankle dorsiflexion was measured Pre- and Post-intervention. The analysis compared several components of the Bereitschaftspotential (BP) and MRCP such as BP1, BP2, Peak Negativity (PN), Slope-BP1, and Slope-BP2 on five EEG channels (C1, Cz, C2, FCz, and CPz). A consistent increase in negativity across all MRCP components was observed. Specifically, a significant increase (between 1.2 μV and 3.7 μV) in negativity of the readiness potential was observed in channels C1, Cz, and C2 placed over the primary motor cortex. The results demonstrated that CAMS BCI enhances cortical excitability related to movement preparation and execution. Furthermore, the proposed CAMS BCI not only can evoke SSMVEP and sensorimotor rhythm but can also enhance MRCP when applied as an intervention. The proposed CAMS system and results of this study are appealing for motor recovery applications in post-stroke rehabilitation and can help inform future BCI designs for such clinical applications.

Deep Reinforcement Learning Based Navigation System to Traverse Unsignalized Intersections

Faizan Sana

With the increasing trend towards autonomy, Autonomous Vehicles (AVs) have been gaining popularity and have the potential to improve road safety, reduce traffic congestion, and offer new mobility options. However, navigation of autonomous vehicles (AVs) in situations that involve interactions with human beings -- either pedestrian, cyclists or human-driven vehicles -- is an extremely challenging problem. In particular, unsignalized intersections are a formidable problem for current AV navigation algorithms due to the increased number of conflict points with other road users (vehicles, pedestrians, cyclists etc.) as well as the lack of traffic signals which forces the AVs to rely on their own perception and decision-making abilities to safely traverse the intersection. This paper proposes a DRL-based navigation system to traverse unsignalized intersections. The system consists of two main components: the agent and the environment. The DRL takes as input the current state of the vehicle, including its position, velocity and the positions of other vehicles and pedestrians in the environment. The agent outputs a set of actions that the vehicle should take including acceleration, braking pressure and steering angle. To train the DRL, we use deep Q-network (DQN) as well as the deep deterministic policy gradient (DDPG) algorithms. DQN is a discrete algorithm wherein all the outputs have to be within a discrete action space whereas DDPG extends it to the continuous action space which is a closer representation of the autonomous vehicle domain. The reward function is designed to encourage the agent to take actions that lead to a successful crossing of the intersection, while penalizing actions that result in collisions or other unsafe scenarios. We evaluate the performance of the proposed system through a series of simulations in order to evaluate real world interactions between vehicles at intersections. Future work will include experimenting the Polaris Gem e2 in simulation as well as the real world.

Resonant MEMS Deformable Mirror for Fast and Wide-Field-of-View Focus Scanning

Samed Kocer

This paper reports a novel micro-electro-mechanical system (MEMS) deformable mirror that can be integrated into optical systems to shift the focal point of an incident beam. The mirror uses resonant electrostatic actuation by applying a single voltage waveform to vary the curvature of a 1.6 mm circular deformable mirror (DM). Unlike traditional bias-actuated DMs, resonant actuation exploits dynamic amplification and eliminates the need for individually addressable electrodes, complicated control algorithms, and associated hardware. It also provides faster and simpler focus modulation within simple device architecture. The DM can be a low-cost alternative to previous high-performance varifocal mirrors. The mirror is fabricated using the Micra-GEM-Si fabrication process. The natural frequencies of the DM and corresponding mode shapes were extracted using a laser Doppler vibrometer. The mirror profile and the initial curvature were measured using white light interferometry. To demonstrate its focus-shifting ability, the first axisymmetric mode (defocus mode) of the DM was used as a varifocal mirror. The DM was integrated into scattering microscopy and photoacoustic remote sensing microscopy to quantify its focus scanning range before and after an objective lens. The DM was illuminated with a 532 nm pulsed laser beam. An 8 cm distance before the objective lens was scanned using the DM as a varifocal mirror between focal lengths of 11 cm and 19 cm at a scanning frequency of 16 kHz. The curvature of the DM was controlled easily by changing the phase angle between the pulse signal of the incident laser beam and the drive signal of the DM. To measure the focus scanning range after an objective, a 1951 USAF target was imaged using a 20X 0.4 NA objective. The images were obtained at three different depths, and the focal shift provided by the DM was measured to be 205 μm. It is shown that The mirror can advance state-of-the-art focus scanning techniques in many applications, such as axial scanning, 3D multiwavelength imaging, and aberration corrections.

Advancing the Extraction of Mechanical Properties From Biaxial Data

Carl Azzi

Mechanical characterization is vital to understand soft tissue behaviour in health and pathology. In aortic aneurysms, for instance, it is used to develop techniques for rupture risk assessment. In skin wounds, for instance, it is used to assess wound healing and the effects of treatment. Biaxial testing is one of the most common tools for the mechanical characterization of soft tissues. In this testing method, boundary conditions must be specified to ensure accurate measurement and interpretation of soft tissue behaviour. Loadings such as displacements or forces are typically applied to the edges of square specimens yielding homogeneous deformations at the center of the samples that are measured using digital image correlation. It is crucial to ensure that the loading is uniform and evenly distributed across the sides of the specimen. Additionally, to prevent any unwanted movement of the sample during testing, proper gripping methods should be used. Biaxial testing is a great tool as it captures the anisotropy and nonlinearity of soft tissues' behaviour and can apply a wide range of deformation states as it can apply different combinations of loadings. However, because the deformations at the center of the specimens are not controlled, no two mechanical tests are equivalent, complicating consistent data extraction and comparisons between samples. However, this factor has been neglected in most biaxial studies, and that can lead to inaccurate biaxial data interpretation.

This study proposes a new approach for biaxial data analysis to address this issue. A surface is fitted to the biaxial data using MATLAB based on in-built functions of linear, cubic and lowess interpolation. The mechanical response is interpolated at the equi-biaxial stretch deformation state (the state at which the deformations at the center of the sample are equal). Then, the effective mechanical properties, such as high/low elastic moduli and transition stretches/stresses, are extracted from the interpolated response. Other studies, in contrast, extract properties at the equi-biaxial displacement deformation state (the state at which equal strains are applied at the sample border), which is due to the anisotropy of soft tissues varying from specimen to specimen. To demonstrate that our proposed approach can result in drastically different data sets, we apply it to previously tested aortic tissues from human donors and pigs. We compare effective mechanical properties extracted from the interpolated equi-biaxial stretch deformation state and conventionally used equi-biaxial displacement deformation state. Statistical analysis shows a significant difference between two groups of mechanical measures indicating that inconsistent measurement extraction might impact the outcome of biaxial studies. We argue that our approach allows extracting more consistent mechanical measures and might be extremely useful for studies focusing on detecting small differences between various groups of specimens, such as studies on the effects of heterogeneity and freezing. Finally, if such information is available, our approach can extract mechanical measures at the physiologically relevant deformation states.