

Book of Abstracts

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Using A Novel Wristband to Measure Circadian Rhythm and Sleep

Jing Wei

Sleep is one of the most important biological processes inside of our body and is mainly coordinated by circadian rhythms. As everyone has distinct circadian rhythms, different people have preference to different sleep habits – early to bed or late to bed. However, most people cannot choose their sleep time freely due to many reasons: fixed schedule because of school and work, blue light emitted by digital devices suppress the secretion of melatonin, etc. On the other hand, many people believe the commonsensical saying – “early to bed and early to rise makes a man healthy wealthy and wise” and try to sleep earlier, even if their internal rhythms would prefer a later routine. In order to obtain quality sleep, it is crucial to know what our own circadian rhythm is and try to schedule our sleep according to our own rhythm.

In this research, we designed a wristband based on off-the-shelf sensors (see Figure 1) that contains a temperature sensor and a 3-axis accelerometer. The temperature sensor measures the temperature of the arterial region of the wrist, which has been shown to be a good alternative to a gold standard (Core Body Temperature) for measuring circadian rhythms. The wrist temperature increases before people fall asleep and remains at a high, relatively stable value during sleep. After people wake up, it drops drastically. Wrist temperature increase onset has also been shown indicative of circadian phase. Wrist temperature patterns together with motion collected from the accelerometer sensor will be used to develop a personalized sleep analysis algorithm.

The study will recruit people from three different groups: (1) 10 younger adults, (2) 10 healthy older adults, (3) 10 older adults living with dementia. All the participants will wear the prototype wristband and a Mi Band 2 for 2 weeks. Circadian rhythms extracted from wrist temperature patterns will be compared to investigate how wrist temperature patterns may change with age and/or dementia. Our goal is to explore the role of wrist temperature in sleep monitoring system and how to integrate the individual’s rhythms into supporting better sleep health. We hope our study can deepen people’s understanding of the mechanism of sleep and provide a way to improve sleep through daily monitoring of circadian rhythm.

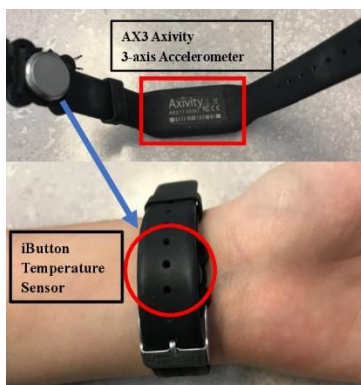


Figure 1. The prototype wristband

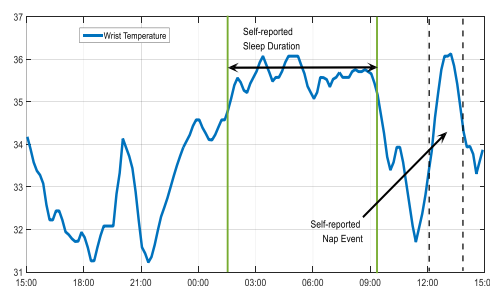


Figure 2. Example of wrist temperature pattern for 24-hour period

Development of a Seat Cushion for Heart Rate Monitoring Using Ballistocardiography

Ahmed Raza Malik

According to the Public Health Agency of Canada, there are 2.4 million people living in Canada with a diagnosed heart condition. Every hour, 12 of these people die, making heart disease the 2nd leading cause of death in. For most individuals with cardiac conditions, continuous monitoring of cardiac vitals is essential part of ongoing care. Frequently visiting a hospital or some other clinical setting for vitals monitoring is not feasible, so most individuals prefer to monitor their vitals at their homes. Current monitoring technologies for at-home monitoring, such as wearables, are obtrusive. They require significant effort from the person to use them, including compliance and correct usage. To address these concerns, my thesis research has developed a prototype seat cushion that can capture heart rate by a person simply sitting on it. The seat cushion acquires a cardiovascular signal called the ballistocardiogram (BCG). BCG is a measure of the recoil forces exerted by the body in response to the heart pumping blood. These forces, although very minute, can be captured using appropriate transducers and signal conditioning methods. The seat cushion I created has embedded load cells that generate a signal corresponding to the body recoil forces. This signal is then conditioned using analog signal-conditioning circuits and digitally processed to acquire a BCG and calculate heart rate. For validation of the acquired BCG signals, an electrocardiogram (ECG) is acquired simultaneously. ECG serves as the “gold standard” for heart rate and is widely used in clinical settings. ECG is a measure of the electrical activity of the heart, whereas the BCG is a measure of the mechanical activity (Figure 1). The objectives of my research are to analyze the quality of BCG signals obtained from the cushion by comparing them to the gold standard ECG and observe how different daily-life activities affect the signal quality. Results obtained so far show that the seat cushion can obtain an average accuracy of 98.6% for heart rate calculation compared to the gold standard ECG. These results are similar or better than commercial wearable heart rate monitoring devices. The seat cushion presents an ambient solution for cardiac monitoring that is portable, cost-effective, zero-effort and easily integrated in a person’s home.

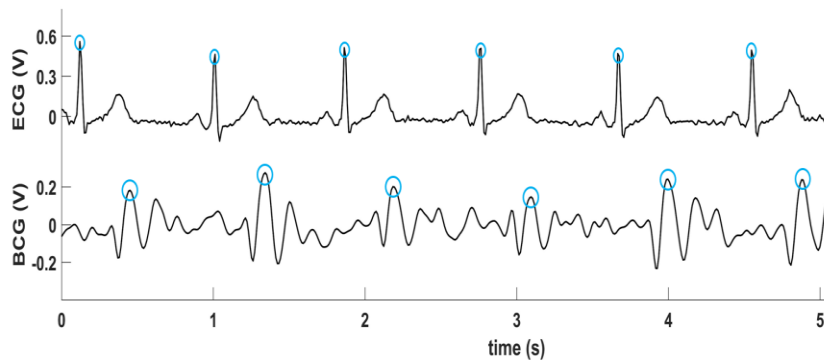


Figure 1. BCG and ECG recordings from a subject. The blue circles correspond to the peaks.

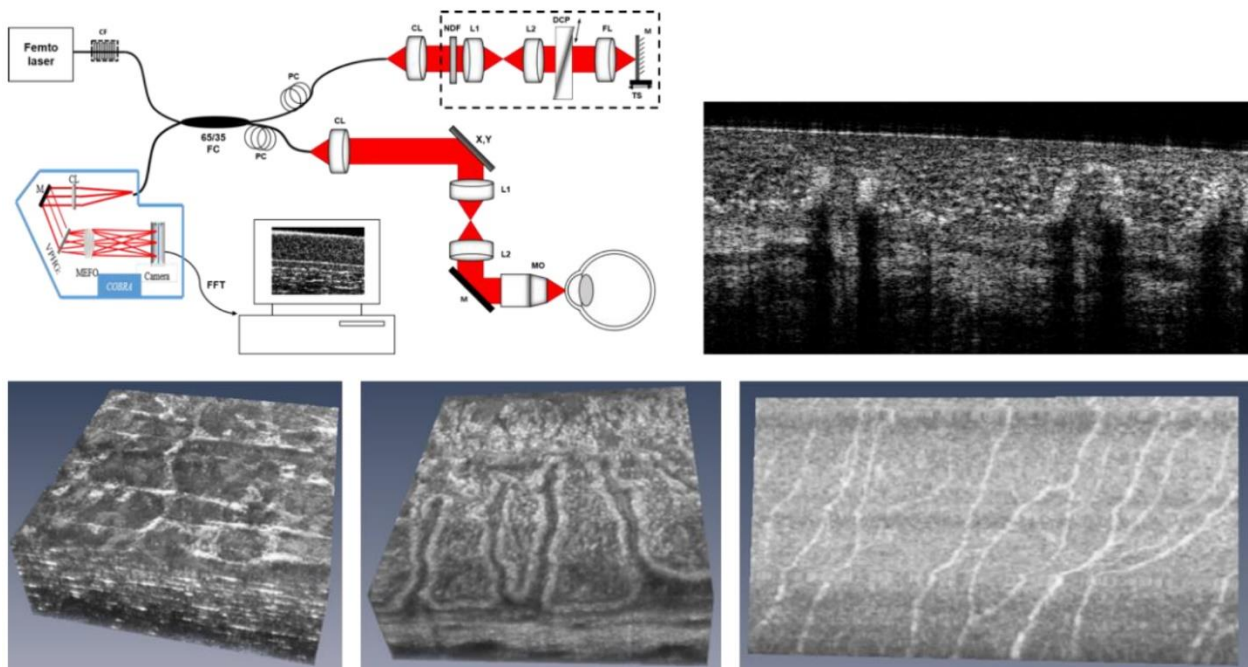


Figure 2. Participant seated on the cushion.

System design and image processing algorithms for achieving cellular level resolution in optical coherence tomography images

Zohreh Hosseinaee

The cornea is a thin, transparent tissue located at the front of the human eye comprised of multiple cellular layers. It has many functions, including transmission and focusing of light on the retina to form sharp images. The corneal epithelium is continuously regenerated over time by stem cells located in the peripheral cornea, also known as the corneo-scleral limbus. Morphological, physiological and vascular changes in the human cornea and limbus induced by diseases such as Keratoconus (KC), Limbal Stem Cell Dystrophy (LSCD) etc., can reduce significantly normal vision, and eventually cause permanent blindness. Currently, there is no clinical imaging modality that can image *in-vivo* the cellular structure of the human cornea and limbus with sufficient resolution to observe and characterize individual cells, without direct or indirect contact of the imaging probe with corneal tissue. Optical Coherence Tomography (OCT) is a non-invasive optical imaging modality capable of generating cross-sectional and volumetric images of biological tissue with cellular level resolution. Recent developments of light sources and high speed cameras resulted in development of ultrahigh resolution OCT (UHR-OCT) technology with axial resolution close to or below 1 μm . One major limitation of the current OCT systems design is that increasing the lateral resolution comes at the expense of limited depth of focus. This prevents the acquisition of volumetric images of the cornea and limbus at cellular resolution. It also increase the susceptibility of the OCT images to axial motion artefacts associated with breathing and heart rates. The main goal of my PhD project is to combine novel UHR-OCT design with novel image processing algorithms to allow for *in-vivo*, non-invasive imaging and morphometric characterization of the cellular structure of the human cornea and limbus.



Real-time Focused Transcranial Ultrasound Effect on Electrographic Sensory Evoked Potentials

Benjamin Lambert

The objective of this work is to characterize the real-time effect that transcranial focused ultrasound (tFUS) has on the somatosensory evoked potential (SSEP) in electrocorticographic (ECoG) recordings. SSEPs are an electrical potential observed over the somatosensory cortex of the brain and are thought to be created by multiple neural generators along the dorsal-lemniscus thalamo-cortical sensory system [1]. The structure of afferent volleys of neural information resulting in SSEPs, is critical to perception [2]. Modulation of the structure of SSEPs could be associated with modulation of the perception of a somatosensory stimulus. Thus, defining the relationship between SSEP structure and modulation parameters could allow for designed perception. In this work SSEPs were measured from the left somatosensory cortex of male Sprague-Dawley rats. Somatosensory signals were elicited by stimulating the right hind paw with constant current pulses while focused ultrasound was targeted at the left somatosensory cortex and operated in a pulsed scheme at a center frequency of 500kHz and varying duty cycles, pulse repetition frequencies, sonication durations, and sonication intensities. Sonication was applied in two paradigms: 1) beginning at SEP onset, ending after a variable sonication duration and 2) ending at SSEP onset, beginning a variable sonication duration prior to hind paw stimulation. These two paradigms will be used to investigate sonication preconditioning and real-time control of SSEP structure. It is hypothesized that specific combinations of ultrasound operation properties will affect specific features of the SSEP significantly differently than other combinations. A result from the pilot experiment of this work is shown below in Figure 1. With the complete results from this work, a control system will be able to monitor the SSEP while outputting sonication to achieve specific SSEP features. This work will support future efforts to define the relationship between SSEP structure and sensory perception.

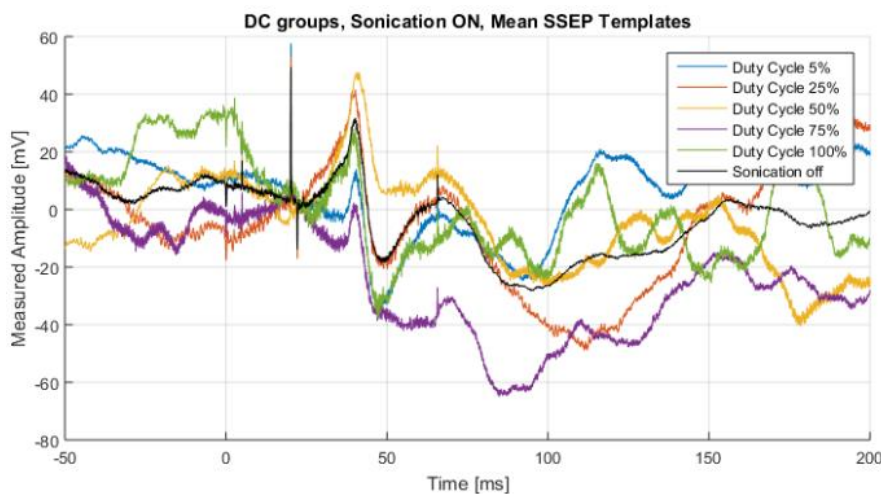


Figure 1: Pilot experiment duty cycle effect results for electrical stimulus evoked SSEP after tFUS preconditioning. Preconditioning ends at time 0. Groups are averaged over a variety of sonication parameters: acoustic intensity, sonication duration, and pulse repetition frequency

[1] M. Dimitrijevic et al, *Somatosensory perception and ...*, J. Neuro. Sci., 1983:60(2):253-265

[2] P. Walsh et al, *The clinical role of evoked potentials*, Neuro. In Prac., 2005:76(2):16-22

Full-body Inverse Dynamics Tool for Generic Motion Captured using Inertial Measurement Units

Mohsen Diraneyya

Estimating the loads on the human body is of central importance to ergonomics, where it is of use in workplace design, task loads assessment, and to establish safety limits. It is also relevant to rehabilitation studies, where it can be used to design programs, activities, and instruments. Estimating these loads requires collection of data on motion kinematics and external forces. Traditionally, Optical Motion Capture (OMC) systems and Force Plates (FPs) were used to collect kinematic data and measure the Ground Reaction Forces (GRFs). However, this experimental set-up is limited to laboratory settings and it imposes significant instrumentation costs.

The availability of wearable Inertial Measurement Units (IMUs) have allowed for the development of effective whole body Inertial Motion Capture (IMC) systems. Inverse dynamic models that use kinematics collected from these systems are also being developed. A challenging aspect in this endeavor is the need to estimate GRFs from kinematics, without recourse to FPs, in order to take full advantage of the IMC systems' portability. To overcome this challenge, some models include upper body segments only. Other models consider gait motions and apply a smooth transition assumption. The aim of this research is to continue this line of development by introducing a general-purpose full-body inverse dynamics model based on IMC kinematics. This model allows for true system portability, dispensing the use of any equipment confined to in-lab use.

I developed a whole-body model that determines the net forces and moments in body joints for generic motions captured using an IMC system. The model estimates GRFs from the kinematic data. It was validated by comparing its predictions to the results of an experimental pilot study. It was then used to analyze the forces experienced by masons during bricklaying motion. An anatomical lower-spine model has also been used to estimate the disk contact forces in the lower back. Further, static and dynamic load levels have been compared to understand the effect of movement speed and momentum on joint loads.

The objectives of this research can be summarized as follows:

- Develop a tool to apply inverse dynamics for motion captured using an IMC system
- Estimate GRFs for generic motions using kinematics data only
- Validate the model by comparing predicted GRF to those measured using FPs
- Estimate lower back disk forces using 3-dimensional 10-muscle model
- Use the model to estimate the static and dynamic loads experienced by masons during onsite bricklaying

The Effects of Algorithmic Transparency on Awareness, Trust, Usage and Satisfaction in Online Socio-Technical Systems

Murat Dikmen

Every day, billions of people like posts on Facebook, retweet on Twitter, and watch videos on YouTube. However, many users are not aware that what they see, read or watch are mostly governed by ranking and filtering algorithms that work behind the scenes.

Previous work has shown that users become aware of the existence of these algorithms when the algorithm fails, such as when they see posts from a deceased friend. Awareness of these algorithms change users' beliefs towards the system, mostly in a negative way. However, after becoming aware, how users' attitudes and behaviors change over time is not well studied. This research aims to fill this gap by looking at the effects of providing continuous algorithmic transparency (cues about how the algorithm might work) on user experience in online socio-technical systems.

We propose a study that investigates the effects of providing cues on how Twitter's ranking algorithm might work on trust in the algorithm and engagement with Twitter. We developed a browser extension for Google Chrome browsers that shows tweets tweeted from the accounts the user follows but are hidden from the user by the Twitter algorithm (Figure 1). By showing the hidden tweets, this tool allows users to make inferences about the intent and effectiveness of the algorithm. We plan test this tool in a longitudinal pre-post design and measure attitudes towards the Twitter algorithm before and after using this tool for 2 weeks. Measures include satisfaction, perceptions of effectiveness and correctness, trust in the algorithm, and behavioral data including tweets, retweets, and likes.

We expect that providing an opportunity to evaluate the effectiveness of Twitter's ranking system will help users become more informed about the system and calibrate their trust towards the system by evaluating the accuracy of the ranking algorithm on a regular basis. We will also explore how this experience affects engagement with Twitter.

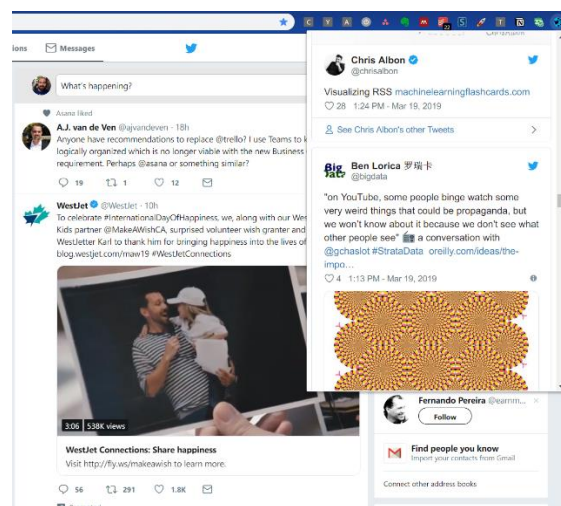


Figure 1. Chrome browser extension that shows tweets that are hidden from the user by Twitter's ranking system.

Investigating the Impact of Data Transfer User Interfaces on Communication Grounding in Cross-Device Collaborative Environments

Leila Homaeian

Cross-device environments (XDEs) consisting of a shared display, such as a digital tabletop or digital wall, and personal devices, such as tablets, have been shown to enhance co-located group work. In such environments, collaborators can use face-to-face communication and coordination channels, such as speech, gestures, and facial expressions, to build and maintain a shared understanding about the task at hand (known as *communication grounding*). Yet in XDEs, people's attention may be focused on different personal devices for independent data exploration, potentially introducing additional communication and coordination effort among team members. In my research, I will investigate the impact of digital support for coordinating a specific action, i.e. data transfer, on communication grounding in complex data analysis scenarios around XDEs. This type of coordination is particularly important when the addressee's timely attention to shared data is necessary to make optimal progress in the analysis task.

The costs of developing a shared understanding in a conversation are referred to as grounding costs, and are impacted by the communication technology. I propose the adaptation of communication grounding principles from Linguistics as a method to analyze costs associated with communication grounding in XDEs. I am applying this method to existing cross-device interaction data to demonstrate its benefits and refine the method. The method will be applied in my proposed user studies as one of the data analysis methodologies. I will then propose two controlled user studies to investigate how augmenting an XDE software application with coordination mechanisms for data transfer will impact communication grounding. In the first user study, I will use an XDE centered on a digital tabletop. The results of this study are expected to inform the design of an XDE for the same data analysis task centered on a digital wall in the second study. My dissertation is expected to contribute an adapted methodology to analyze the costs of building and maintaining common ground in XDEs. I will also contribute three sets of empirical data on the impact of cross-device interaction techniques and data transfer techniques on communication grounding. The results of my proposed research are also expected to inform the design and development of collaboration XDEs by shedding light on the potential advantages and disadvantages of data transfer coordination techniques that are supported through software versus those that rely on face-to-face communication channels.

Design and Assessment of External Displays on Autonomous Vehicles for Safe Pedestrian Crossings

Zehao Qin

One of the most vulnerable group in road agents is pedestrians. Prior to autonomous vehicles (AV), conventional vehicles had a human driver that could communicate with pedestrian's through signals such as eye gaze, head movements, and hand and arm gestures. With the introduction of AVs, pedestrians can no longer rely on such communication signals. In the future, when all of the control and responsibilities of the human driver gradually transfers the autonomous driving program, the vehicle's intent communication to pedestrians must evolve as well.

The aim of this proposed research is to investigate the usability of different interface in communicating autonomous vehicle intent to pedestrians in crossing situations where negotiation between the AV and the pedestrian is required (i.e. jaywalking). Two research questions were asked:

1. With driverless, fully autonomous vehicles, what impact does external visual displays have on pedestrians' crossing behavior and perceived safety levels?
2. With driverless, fully autonomous vehicles, to what degree should the vehicle communicate its intent with pedestrians?

Previous studies found that (Clamann et al., 2016; Li et al., 2018) when evaluating different external displays, pedestrians more commonly relied on their own mental model of their perceived vehicle speed and gap estimation instead of relying on the information being displayed. This study attempts to bridge the mental gap between the perceived vehicle kinematics and gap estimation to the actual information by exploring visual design concepts to explicit indicate vehicle speed and gap distance.

Furthermore, studies (Habibovic et al., 2016; Lundgren et al., 2017) also found that there were significant differences when pedestrians interacted with AVs instead of conventional vehicles. The hypothesis for this study will attempt to reaffirm that external displays can enhance the perceived safety and comfort levels of pedestrians when interacting with AVs.

With each design, emotions, perceived urgency, and perceived safety level of pedestrian will be examined. The research questions will be explored through an online survey that investigates the behavior patterns of the general population in North America (Canada and US) when interacting with fully autonomous vehicles. A number of popular design solutions were included with the new designs to analyze the strengths of each design case. This will be beneficial for future research to combine various elements of each design cases to suit potentially different functional requirements

Cognitive Driver Distraction

Apurva Misra

With the advent of autonomous vehicles, there is a profound emphasis on the safety of automotive systems. Driver distraction has posed a major problem since the first car made its way onto our roadways. According to WHO findings 1.25 million people lose their lives every year due to road traffic crashes. One of the major causes of traffic crashes is distracted driving. As a result, there is a profound need and necessity to continuously observe driver state and provide appropriately informed alerts to distracted drivers.

As defined by the National Highway Traffic Safety Administration (NHTSA), there are several types of distractions including cognitive, visual and manual distractions, which may be distinguished from each other based upon the resources required to perform the task. Cognitive distraction refers to the “look but not see” situations when the drivers’ eyes are focused on the forward roadway, but his/her mind is not. Typically, cognitive distractions can result from fatigue, conversation with a co-passenger, listening to the radio or other similarly loading secondary tasks that do not necessarily take a driver’s eyes off the roadway. However, cognitive distractions can also occur in concurrence with a visual/manual distraction as the use of resources is rarely exclusive. Literature notes that in the presence of cognitive distractions, drivers’ require a greater amount of time to successfully anticipate and respond to critical threats on the forward roadway [1]. Further, it has also been shown that eye movements and dwell duration can capture the earliest onset of cognitive distraction compared to vehicle kinematic data [2]. However, limited research has explored effective methods of classifying cognitive distraction data.

My research consists of utilizing a fixed base driving simulator and a head-mounted eye-tracker to collect data from participants satisfying appropriate inclusion criterion based on driving experience (at least 1 year of driving experience) and age (18 – 25 years). A total of forty-eight participants navigate 8 unique virtual environment scenarios, 4 of them with cognitive distraction and 4 without cognitive distraction. Data collected from the participants include dwell times, fixation frequency, percentage of eye closure, velocity, standard deviation of lane position, steering angle, secondary task accuracy, peak acceleration, heart rate variability, and skin conductance. The labeling of the collected data leads to the extraction of features relevant to distracted driving. The results of the study not only classify distracted driving data but further lays the groundwork for a fully customizable collision warning system for drivers. The findings of this study can further help determine appropriate timings for the transfer of control from machine to humans in semi-autonomous vehicles.

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Designing a new method of text input in virtual and augmented reality (VR and AR) space

Andrew Cen

Virtual Reality (VR) and Augmented Reality (AR) experiences are becoming increasingly popular and accessible as the cost of entry decreases, the need to develop and design solutions for this industry is becoming prevalent. For example, we now have cardboard boxes that convert cell phones into head mounted displays (HMD)[1] and the introduction of the low cost Oculus Go VR headset, the AR/VR industry is expected boom by \$200 million by 2025 [2]. The increase in demand and use of AR/VR also posits an increase in demand for productivity within these spaces.

This anticipated growth in productivity will generate a need to break down productivity barriers that currently exist in VR/AR space. Current problems such as input method technologies demonstrates that users type at an average of half the speed of an average computer typist, from a rate of about 40 words per minute (WPM) to 20 WPM. The low speed typing rate severely restricts users from performing intensive productivity task within the AR/VR space. VR applications such as *VR Chat* also show that players with vocal disabilities are unable to participate in the program outside of making hand gestures to communicate. This research aims to design and develop a new method of text input for VR/AR applications. The goals of this research is two-folds; to reach average or higher typing speeds of individuals using a traditional keyboard, to tackle accessibility barriers that users with certain disabilities may face when using AR/VR applications. The research project is divided into 3 major tasks: the first task is to design and prototype this new keyboard through collaborative design, the second task is to train participants to use the prototype through a game (developed in-house), and third is to run a final evaluation testing how fast participants can type through multiple short sessions. The results collected in this study will aim to provide a performance benchmark for future research in input methods for the AR/VR technology.

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Exploration of Behaviours Associated with the Default Network in the Context of Video Game Play

Kateryna Morayko

In the field of Games User Research (GUR), a sub-domain of Human-Computer Interaction (HCI), there has been a large focus on understanding the benefits of games and play, such as engagement, motivation, and immersion. The field has benefitted greatly from applying psychology research that provides insight regarding the relationship between challenge and skill (e.g., flow theory), and motivation and engagement through the satisfaction of basic human needs as demonstrated in self-determination theory. However, little is understood about the specific cognitive mechanisms underlying all of these experiences while engaged in play. Recent research identifies the *default network* as a large-scale brain network whose activation is independent from external activity. The default network is primarily associated with internal mentation such as thinking about the past and present, self-regulation (e.g., deciding to forego dessert to maintain health), and thinking about others. It is most often observed when people are in a resting state or while daydreaming and mind wandering, behaviours often associated with play and games. The research questions for this study is, do different games and game elements allow people to engage in behaviors associated with the default network to different degrees? The link between gameplay and the default network has not been empirically tested and leaves open many questions: when and for how long is the default network active when people play video games? are there any patterns to when the default network is active (e.g., when solving puzzles, when engaging in mindless combat, etc.)? can a game designer adjust the mechanics of the game to increase/decrease time spent in the default network?

my research, I will first investigate behaviours associated with the default network using a mixed-methods, exploratory design. Participants will be asked to choose three: games, one they have spent the most hours playing, one they feel relaxed while playing, and one that they lose track of time while playing. I will use experience sampling to measure mind wandering and collect eye-tracking data and video footage. The behavioural data will be analyzed using the thematic analysis and an exploratory factor analysis will be conducted on the questionnaire data. In the next phase of research, I will use the results of the first study to create specific game mechanics designed to increase mind wandering and lead to more time in the default network and then validate that these designs were successful in a comparative lab study. The expected contribution(s) of this work will help understand the link between gameplay and the brain and help to inform the methodology of game design.

Determining Features for Technology for People with Mild Cognitive Impairment at Work

Karan Shastri

Work is an integral part of most people's life. Changes in cognition caused by MCI/dementia (MCI/dem) can profoundly impact workplace performance and role in the workplace. There is little research on how MCI/dem can affect a person's activities and tasks in a vocational situation.

Through my thesis work I am exploring four key research questions: 1) What are the needs and tasks of people living with MCI/dem at work? 2) What technologies/tools/artifacts do people with MCI/dem currently use at work? 3) What features, and design do people with MCI/dem want in a digital tool, and 4) How can we co-design a digital tool in a meaningful and engaging way? Involving vulnerable users of technology, like people living with MCI/dem is crucial in designing technology, yet detailed descriptions and critical reflections on the process, techniques and methods of co-design with people with MCI/dem are rare.

My research is structured in two key stages: 1) Scoping stage: to explore the experiences of working while living with cognitive impairment from the perspectives of people living with MCI/dem and their care-partners. 2) Participatory design workshops: to identify the functionalities and design features preferred by people living with MCI/dem in a digital tool through persona design and low-fidelity prototyping. The scoping stage involves semi-structured focus groups with people with MCI/dem. I combine two different analytic techniques to analyze the data from the scoping stage – thematic analysis and cognitive task analysis (CTA). Thematic analysis is used to inform our participatory design workshops and persona design. The CTA is leveraged to understand people with MCI/dem's macrocognitive activities and capture what strategies people with MCI/dem use to make decisions at work. The analyzed CTA data is then used to derive design recommendations for a digital tool using decision-centered design (DCD). In doing so, I approach the data from both an ecological (top-down) and cognitivist (bottom-up) perspective.

There currently are no digital tools or assistive technology specifically designed to support people with MCI/dem at work. For my thesis, I am piloting a new CTA-DCD model to systematically elicit the self-initiated strategies, artifacts used and understand the needs of people with MCI/dem from a macrocognitive perspective. With this data I structure participatory workshops to explore required functionality and metaphors for co-creating a digital tool that might be useful to adopt for people with MCI/dem. Through my research, we may better understand the barriers in context of work coupled with making participatory design sessions meaningful and engaging for people with MCI/dem. We can then use these results to guide the design of technology to better support people with MCI/dem at their workplace with their role-planning and task completion.

Using Design And Artificial Intelligence To Augment An Electronic Medical Record System

Harjot Singh Parmar

Traditionally electronic medical records have been maintained by medical coder/nurses at the hospitals. Medical coders are expected to gather information from different sources such as patient history logs, test results from different labs etc. and enter them into the EMR system. Due to unstructured nature of the task, data entry is susceptible to errors. Our research work focuses on improving the interface of one such system called Dialysis Management and Reporting (DMAR). DMAR is a renal disease patient record management system being used at Sunnybrook Health Sciences Centre, Kidney Care Centre at CNIB. The existing system allows doctors to review patient files and communicate back the errors to the coders for required changes. Our research explores interface redesign as an effective way to reduce these error rates and improve workflow. The first phase of the research focused on user research by conducting user interviews, generating user stories and analyzing the workflow for both coders and physicians. New interface designs were proposed based on these analyses. Logical checks were created in the data entry forms to reduce common data mismatches such as start dates and end dates of medical intervention. Further a new chat feature was designed to allow easier and faster communication between the physician and the coders. In the second phase of the research, we will work on creating a more efficient interface for an AI based error detection system. This AI engine is being developed in collaboration with students at the Applied Health Sciences(AHS) department at the University of Waterloo. The AHS team is researching the use of different machine learning and natural language processing techniques to be trained on the historic communication logs of the physician coders' messages of the DMAR system. The system is expected to detect patterns in the errors and automatically flag them. Our research is to augment the suggestions from this system and visually present them in a more interpretable manner to the physicians, which would make the recommendation more transparent and help build trust in the system.

Predicting Peritoneal Dialysis Catheter Insertion Related Outcomes using Machine Learning Methods

Sujan Subendran

Peritoneal dialysis (PD) is one of the common treatment methods for End Stage Renal Disease. In comparison to other treatment methods such as hemodialysis, PD supports greater patient independence, improved quality of life and reduces healthcare costs. The use of PD continues to grow as government funding and incentives further promote this treatment method. However, complications and variability with performance have been increasingly observed as PD becomes more commonly used. The objective of this study is to identify patients who are at risk of PD failure and to understand the associated factors.

Machine Learning (ML) models are explored for this binary classification task to predict PD success or failure. The ML algorithms that were considered are decision tree, random forest, SVM, kNN and neural networks (multi-layer perceptions). The models were tested using 10-fold cross validation and assessed using accuracy, precision, recall, specificity and AUC. The preliminary analysis was conducted using data collected from a single-center renal dialysis program which focused on the classification of voluntary dialysis withdrawal [1]. This analysis has shown that gradient boosting with decision tree as the base learner performed the best with accuracy of 88.8%. The preliminary analysis provides insight on the dialysis domain and sets the foundation for further analysis using data from multicenter renal dialysis programs.

[1] *Hammad Qazi (2018). Factors Associated with Dialysis Withdrawal in Chronic Dialysis Patients. UWSpace. <http://hdl.handle.net/10012/13571>*

Enhancing the Detection of Steady State Visual Evoked Potential Based Brain Computer Interfaces (SSVEP BCI)

Aravind Ravi

Non-invasive Brain Computer Interfaces (BCIs) based on electroencephalogram (EEG) enable users to interact and control external devices by modulating their neuronal activity. The most-widely used BCI is based on steady state visual evoked potential (SSVEP) responses. These responses are elicited in the visual cortex when the user gazes at an object flickering at a certain frequency. The object with the user's engagement can be detected by analysing the dominant frequency in the EEG. In this study, we investigate different BCI system design parameters for enhancing the detection of SSVEP. These include studying the interface with competing stimuli, EEG channel selection methods and detection algorithms. Firstly, we propose a simple user-customized channel selection method that enhances the decoding accuracy of the SSVEP BCI under the influence of competing stimuli. The results of user-specific channels show a significant improvement in accuracy of over 5% and reduction in variation of 55% compared to the classical 3 channels set and 6 channels set. Next, we propose a convolutional neural network (CNN) based classification for SSVEP detection for both user-dependent and user-independent training scenarios. The results show a significant improvement in accuracy of over 10% when compared to the state-of-the-art method based on canonical correlation analysis (CCA). The methods are robust to changes in inter-stimulus distance for SSVEP detection and provides increased flexibility for user interface design of SSVEP BCIs for commercial applications.

Stimulus Design

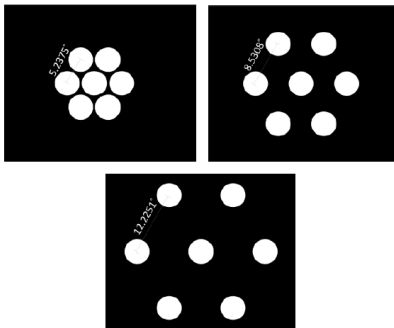


Figure 1. Stimulus Configurations

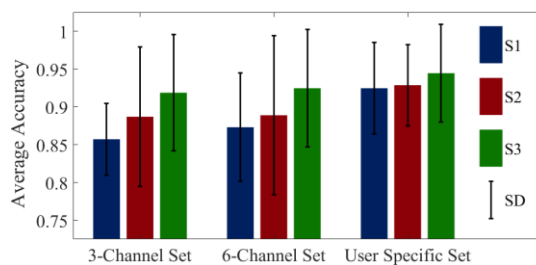


Figure 3. Average classification accuracies across all participants for each channel set and stimulus configuration

Convolutional Neural Network Results

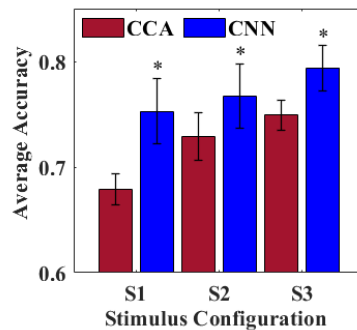


Figure 2. Offline average classification accuracies across all participants for each stimulus configuration (* $p < 0.05$) with a data length of 1s

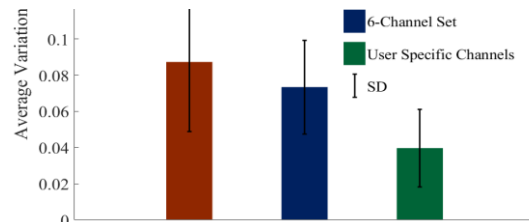


Figure 4. Average variation in performance across all participants for each channel set

Feedback-Based Interface Design to Reduce Driver Impatience at Traffic Intersections

Sardar Elias

Impatience among drivers during traffic delays and time gaps at red lights and left turns at intersections can affect their decision-making, leading to increased risks of poor maneuver, red-light violations and accidents. The purpose behind this research project is to study sensation-seeking behavior, time-perception and impatience of drivers at traffic intersections; design a feedback-based interface to alter drivers' time-perception and reduce their impatience by providing them with some sort of minimal visual, auditory or other forms of interaction during the intersection delay; and finally observe and evaluate the effect of the interface on driving behavior of young adults (aged 18-24) in a between-subjects' simulator-based study. The primary goal of this research study is to determine whether drivers who receive feedback are more likely to opt for a safer decision-making process, in terms of their anticipation and mitigation abilities; and consequently, increase driver awareness and road safety at intersections. The interface will be implemented in a driving simulator that will consist of control and test scenarios based on real-world traffic conditions; an eye tracker will be used to collect eye movement data of drivers. Participants for the user study experiment will be recruited through advertisements on social media and posters, flyers and bulletin boards throughout the UW campus; and will be compensated with monetary remuneration. Experimental data may include driver reaction time, traffic conditions, signal delay, time gaps, relative vehicle speed, signs of impatience near the final phase of a red light, "close-call" left-turn maneuvers in absence of a signal, red-light violations, etc., over a period of traffic signal cycles. Information obtained from the study and feedback from participants will be used for testing, evaluating, refining and making further advancements to the interface design.

Radiometric Compensation of nonlinear Projector-Camera Systems for the Human Visual System

Matthew Post

Radiometric compensation is the process of adjusting the luminance and colour output of images on a display to compensate for non-uniformity of the display. In the case of projector-camera systems, this non-uniformity can be a product of both the light source and of the projection surface. Conventional radiometric compensation techniques have been demonstrated to compensate the output of a projector to appear correct to a camera, but a camera does not possess the colour sensitivity and response of a human. By correctly modelling the interaction between a projector stimulus and camera and human colour responses, radiometric compensation can be performed for a human tristimulus colour model rather than that of the camera. The result is a colour gamut which is seen to be correct for a human viewer but not necessarily the camera. In this seminar, a novel radiometric compensation method for projector-camera systems and textured surfaces is introduced based on the human visual system (HVS) colour response. The proposed method for modelling human colour response can extend established compensation methods to produce colours which are human-perceived to be correct (egocentric modelling). As a result, this method performs radiometric compensation which is not only consistent and precise, but also produces images which are visually accurate to an external colour reference.

Additionally, conventional radiometric compensation relies on a solution of a linear system for the colour response of each pixel in an image, but this is insufficient for modelling systems containing a nonlinear projector or camera. In the proposed method, nonlinear projector output or camera response has been modelled in a separable fashion to allow for the linear system solution for the human visual space to be applied to nonlinear projector-camera systems. The performance of the system is evaluated by comparison with conventional solutions in terms of computational speed, memory requirements, and accuracy of the colour compensation. Studies include the qualitative and quantitative assessment of the proposed compensation method on a variety of adverse surfaces, with varying colour and specular reflectance which demonstrate the colour accuracy of the proposed method. By using a spectroradiometer outside of the calibration loop, this method is shown to produce generally the lowest average radiometric compensation error when compared to compensation performed using only the response of a camera, demonstrated through quantitative analysis of compensated colours and supported by qualitative results.

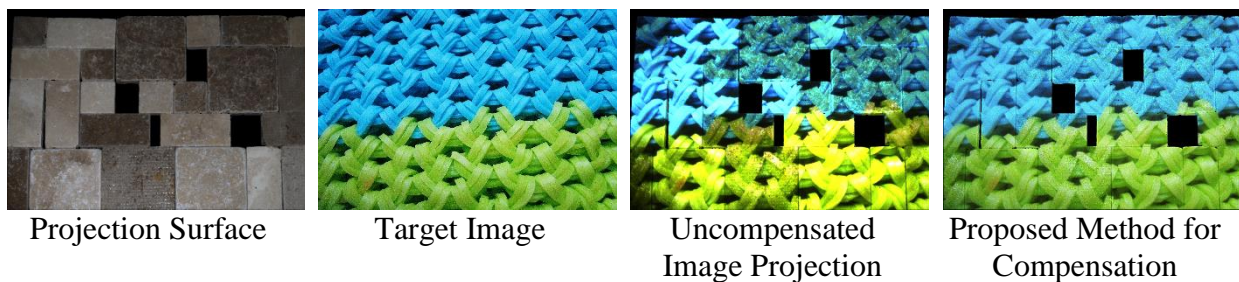


Figure 1: Qualitative results of the proposed scheme, showing a target image projected on a stonework wall with a nonlinear projector, before and after radiometric compensation using the human colour response. This background is particularly challenging due to the extreme colouration, geometry changes, regions of specular reflectance and regions that are black.

Anomaly Detection in Textured Surfaces

Manpreet Singh Minhas

Texture is a powerful visual cue and a way of characterizing objects or regions of interest in images. It is present in images ranging from multispectral satellite data to microscopic images of tissue samples. Methods of modelling textures have ranged from statistical moments to neural networks. An anomaly is defined as something that deviates from what is standard, normal or expected. Anomaly detection is the task of finding patterns in data that deviate from the expected appearance. For example, a crack in an image of a roadway would be an anomaly. Visual defect assessment which is a form of anomaly detection finds application in industrial settings such as in the manufacturing process to ensure that the final product is free from defects. The task is extremely challenging since the appearance of anomalies, such as cracks, dents, smudges and impurities, varies in terms of pixel intensities, geometrical constraints and visual appearances. Two of the major challenges in anomaly detection are the lack of labelled training data and the low availability of anomaly instances. This research focusses on being able to use loosely labelled data and few instances for training texture anomaly detection models. Another goal is to make the results explainable by analysing how the texture representation is being encoded by the filters learnt by the convolutional neural networks (CNNs) leading to the detection. At least two different approaches are considered. One is a patch-based and the other is pixel level segmentation to detect the anomalies. These have been applied to the real-world task of road crack detection. Patch based model created by training on a new road crack dataset created from images provided by the Ontario Ministry of Transportation (MTO), achieves a classification accuracy of 96%. Training data used to develop the model is sparse and loosely labelled. We are exploring various ways of dealing with loosely labelled training data. We are exploring Generative Adversarial Networks to learn the underlying distribution of the normal instances. Deviation from this distribution is the anomaly score and the anomalous instances are classified based on a threshold. A segmentation-based model trained on the “Crack Forest” dataset is adapted using transfer learning to work on the target road crack dataset. Preliminary results obtained look promising. Work is being conducted on analysing the effect of choosing different loss functions such as mean squared error, binary cross entropy etc. on the segmentation model performance. To make the approach interpretable, we are conducting further analysis and testing to try to understand and explain why the approach is working and how the texture is being encoded in the CNN filters and anomalies being detected. We are investigating the filters and activations of the intermediate layers of the network to better understand what computational measures of textures and defects are being learned. Gradient ascent is used to find input patterns that maximize the output of the learnt filters thereby giving valuable insights into the working of the CNNs.

Resolution-enhanced Digital Epiluminescence Microscopy Using Deep Computational Optics

Dino Kabiljagic

Skin cancer is the most common type of cancer, where one in three cancers diagnosed is a skin cancer. However, the survival rate increases with early detection, and it is an imperative for dermatologists and healthcare practitioners to become knowledgeable about and hence spot the skin cancer.

The standard practice employed by dermatologists for examining skin lesions is dermoscopy, where an epiluminescence microscope (ELM) is used to examine the skin chrominance and micro-structural characteristics for anomalies. Conventional ELM instruments are being replaced by digital ELM instruments that enable dermatologists and other health care practitioners to digitally capture, archive, and analyze skin lesions using computer-aided diagnosis (CAD) software.

One of the limiting factors of digital ELM is the fundamental trade-off between spatial resolution and field-of-view (FOV), where a larger FOV (which is needed to allow for larger skin lesions to be examined in their entirety) can be achieved by reducing magnification at the cost of spatial resolution (leading to a loss of fine details that can be indicative of malignancy and disease).

This thesis introduces deep computational optics (DCO) for the purpose of resolution-enhanced digital ELM to improve the balance between spatial resolution and FOV. More specifically, the multitude of parameters of a deep computational models for numerically magnifying digital ELM images are learned through a wealth of low-resolution and high-resolution digital ELM image pairs.

The proposed DCO approaches were experimentally validated, demonstrating improvements in the spatial resolution of the resolution-enhanced digital ELM by two-fold while maintaining FOV. Furthermore, these computational models are compared and analyzed based on their structure, size, complexity, speed, and efficiency.

A Unified Formulation for Visual Odometry

Georges Younes

Visual Odometry (VO) is the process of inferring camera motion from consecutive images. State of the art VO systems formulate the camera pose as an optimization of an objective function and can be broadly categorized as being either Direct or Indirect. While Indirect systems generate an alternative image representation by extracting salient features with associated descriptors to compute a geometric objective function, Direct methods process the image pixels directly to compute a photometric objective function. Both paradigms have dissimilar but often complementary traits, where the shortcomings of one are mitigated in the other. This work discusses the complementary properties of both paradigms and explores ways of exploiting their advantages within a hybrid approach while diminishing their shortcomings.

A loose integration between Direct and Indirect systems is first suggested, which is referred to as Feature-assisted Direct Monocular Odometry (FDMO). While FDMO shows promising improvement over state of the art, it opens up the possibility for an even more efficient tight integration of both systems; as such a Unified Formulation for Visual Odometry (UFVO) is then presented that efficiently exploits the advantages of both paradigms in a single formulation as shown in figure 1.

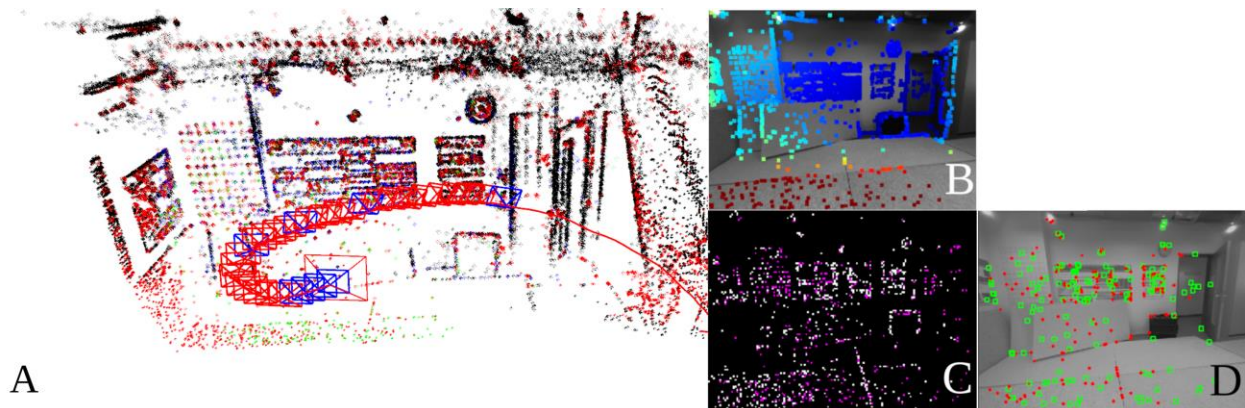


Figure 2: UFVO: A- shows the 3D recovered map and the different types of points used: green points contribute to both geometric and photometric residuals, red points geometric residuals only, blue points photometric residuals only and black points are marginalized (do not contribute any residuals). B- shows the projected color coded depth map of all active points (red for near points and blue far points). C- shows the occupancy grid used to ensure a homogeneously distributed map point sampling process. The white squares correspond to the projected map points while the magenta squares represent newly extracted features from the newest keyframe. Finally D- shows the inlier geometric features (active in green and marginalized in red) used during tracking.

The key contributions underlying UFVO are (1) a tight coupling of both paradigms within a joint multi-objective optimization for camera tracking, (2) the integration of prior knowledge on the behavior of the two paradigms within the optimization, (3) descriptor sharing, where features can have more than one type of descriptor and its different descriptors are used either tracking or mapping, (4) the depth estimation of both corner features and pixels within the same map using an inverse depth parametrization and (5) a corner and pixel selection strategy that extracts both types of information while promoting a uniform distribution over the image domain.

Experiments show that the proposed unified formulation is inherently robust to poorly textured environments, can handle large inter-frame motions, inherits the sub-pixel accuracy of direct methods, can run efficiently in real-time on a CPU and generate a global map representation at a marginal computational cost when compared to state of the art Indirect methods.

Analysis of the Automatic Classification of Algae using Computational Multispectral Microscopy

Jason Deglint

Under the impact of global climate changes and human activities, harmful algae blooms (HABs) in surface waters have become a growing concern due to negative impacts on water related industries, such as tourism, fishing and safe water supply. Many jurisdictions have introduced specific water quality regulations to protect public health and safety. Therefore, reliable and cost effective methods of quantifying the type and concentration of threshold levels of algae cells has become critical for ensuring successful water management.

In the proposed thesis research, it is hypothesized that classification of different types of algae can be achieved by using computational multispectral fluorescence microscopy and deep learning. To test this hypothesis a novel artificial intelligence-driven computational imaging system called SAMSON (Spectral Absorption-fluorescence Microscopy System for ON-site-imaging) was developed to automatically classify multiple types of algae from different phyla groups based on both morphological and spectral characteristics. Two sets of experiments were conducted to test the performance of SAMSON.

In the first experiment SAMSON was configured to image six algae types at six different fluorescence excitation wavelengths. To isolate the different organisms in a water sample automated data processing and segmentation was performed. Different morphological and spectral fluorescence features were then extracted and three different neural network classification models were trained and tested. The first was trained on morphological features (53.0%), the second trained on fluorescence-based spectral features (95.7%), and the third trained on fluorescence-based spectral-morphological features (96.1%). In the second experiment SAMSON was configured to image six different algae types at two fluorescent wavelengths and seven absorption wavelengths. Investigation of the possibility and effectiveness of automatic classification was done by using a deep residual convolutional neural network that was able to learn to the optimal combination of spectral and morphological features. The final classification accuracy of this classifier was 95%.

This research demonstrates that, when coupled with computational fluorescence multispectral microscopy, deep learning algorithms can be used as a robust and cost-effective tool for identifying algae cells. Furthermore, this research is the first step to create a monitoring system that can be used by scientists and researchers to observe, study, and characterize harmful algae blooms. This device can be used in Canada and around the world to collect data and build reliable bloom behavioural and forecasting models. By better understanding the intricate relationship between different organisms and environmental factors we can preserve our ecosystems and foster sustainability.

Convolutional Neural Networks Regularized by Correlated Noise

Shamak Dutta

Convolutional Neural Networks (CNN) trained for object recognition tasks are similar to the visual cortex in many ways. Early CNN layers show Gabor-like receptive fields similar to V1 in the cortex, later layers are highly predictive of V4 and inferior temporal cortex responses. However, there are also many differences between CNNs and the visual cortex. For example, neurons in the cortex are correlated in their variability. The presence of correlation impacts cortical processing because the noise cannot be averaged out over many neurons. In an effort to understand the functional purpose of correlated variability, specific forms of correlated noise models are implemented and samples from these models are used as a regularization technique in CNNs. Inspired by the cortex, the correlation is defined as a function of the distance between units in a CNN feature map and the corresponding weight parameters. It is shown how to sample from high-dimensional correlated distributions in a differentiable way so that back-propagation can proceed as usual. The correlations induced by current data augmentation techniques such as Mixup are compared to the aforementioned model to understand if data augmentation in input space has a relation to adding correlated noise in the intermediate feature space of a CNN. This method of noise regularization is different from existing techniques because the noise structure is parameter-dependent. The impact of correlated variability is evaluated on the classification of occluded and non-occluded images with and without the presence of other regularization techniques, such as Dropout. In ten out of the twelve cases we studied, the best performance on occluded images was obtained from a model with correlated noise.

Biologically Plausible Model of Spatial Cognition

Brent Komer

The ability to represent and reason about space is important for any cognitive agent interacting with the world. I am interested in how humans and other animals are able to construct representations of the space around them and navigate toward their goals. In particular I am working on models of spatial cognition that can be realized by a spiking neural network.

I present a novel method for constructing neurally implementable spatial representations. This method represents continuous (i.e. real-valued) spaces using neurons, and identifies a set of operations for manipulating these representations. This is accomplished through “fractional binding” to produce “spatial semantic pointers” that can be used within a larger neural model to be able to store spatial information in memory along with semantic information. These representations can be transformed to answer queries about the location and identities of objects, move the relative or global position of items, and answer queries about regions of space, among other things. I demonstrate through experiments that the neural representation in spiking networks has similar accuracy to the mathematical ideal. In addition to spatial queries, I perform two experiments with this representation relating to navigation.

The first experiment involves training a policy that can navigate multiple maze layouts to arbitrary goal locations. Using a spatial semantic pointer representation for locations, supervised learning is able to quickly train a network to accomplish this task. Other representations such as random encoding, one-hot encoding, or using the 2D coordinates directly, fail at this task.

The second experiment uses spatial semantic pointers as a basis for path integration. A recurrent network using LSTMs was trained to estimate position given a sequence of velocity commands.

The network is able to learn how to path integrate correctly. Furthermore, when analyzing the activity of the neurons in the LSTM, patterns that resemble grid cells can be found.

Spatial semantic pointers show much potential both in terms of modeling biological neural systems and for use with artificial cognitive agents.

Learning Methods for Robotic Grasping

Youssef Zaky

Unstructured robotic grasping presents many challenges in perception, planning and control. A general-purpose grasping system must adapt its strategies to a wide variety of object shapes, sizes, orientations, materials and to the scene context and task requirements. While primates accomplish this with ease, robotic systems have typically been confined to special-purpose, structured settings. Recent learning methods however aim to expand robotic grasping capabilities by mimicking some aspects of how primates learn such behaviors. Impressive progress has been made in handling a large number of objects in cluttered settings, and in learning such behaviours autonomously. We discuss some of these deep and reinforcement learning methods while pointing out their shortcomings. Amongst the latter are reductions in degrees of freedom, a dependence on precise sensors, 3D object models, or large amounts of data and robots. We present initial work that tackles some of these challenges. Our system has two components: a) a neural representation that resembles how infants learn about the visual world, and b) a reinforcement learning agent that uses this representation to learn to grasp. We show that this representation can efficiently encode properties of the scene along with object positions, shapes and orientations from RGB images only. This can help alleviate the dependence on additional sensors, provide a representation suitable for grasping, and enhance the data-efficiency of the learning process. Our reinforcement learning agent, which adapts a state-of-the-art method to grasping, can efficiently represent a grasping policy and explore the grasp action-space. The latter avoids some difficulties found in previous grasping systems such as heuristic grasp sampling procedures or costly action optimizations during learning. We present initial promising experiments with our system in a simulated environment, and discuss future work and improvements. Finally, we briefly overview the correspondence of our system components with structures of the primate brain that are responsible for visual-motor processing for grasping.

Applications of Deep Learning for the Classification of Novel Hand Gestures for Prosthetic Control

Erik Lloyd

Modern prosthetic arms are controlled using electric signals generated by the muscles at the residual limb of an amputees arm. Such signals, when recorded at the skin surface is called surface electromyography (sEMG). The studies that use machine learning to classify EMG signal patterns have focused largely on the classification of discrete isometric hand gestures. While this type of method of classifying discrete gestures has demonstrated high performance in predicting the users movement intentions from sEMG signals, these types of architectures have significant limitations, in that these systems can only classify gestures that the system has been previously trained with.

The topic for my research focuses on various methods, including Feed Forward Neural Networks, Convolution Neural Networks and Stacked Sparse Autoencoders, that can be applied to discriminate gestures that these algorithms have been trained with, as well as new gestures that the methods was naïve about (not in the training set). Twenty different combinations of training and novel gestures are being tested from a set of 14 isometric hand gestures. In testing these various gesture combinations, the purpose is to evaluate whether certain gesture combinations perform better than others for predicting the finger positions in untrained gestures. The method has involved collecting surface EMG data from 10 healthy participants performing 14 different isometric hand gestures. A subset of this raw data is used to train the different types of algorithms, and another subset is used to test the algorithms, which includes gestures that the algorithms are completely naïve about.

The testing is currently ongoing, however initial results for the performance of the CNN in classifying untrained gestures have generate some interesting results. Overall the algorithm was able to classify new data from trained gestures with accuracies about 95%. For certain gestures combinations and subjects the algorithm was able to classify certain novel gesture with accuracies between 50-93% accuracy. However, the algorithm did not classify all finger positions for many novel gestures correctly and therefore further improvements are being made to the CNN to improve the algorithms ability to generalize the common signal patterns for individual finger movements between different gestures.

The long-term goal for this type of system is to develop prosthetic control systems that require training on only a limited number of gestures, and can automatically extrapolate to a much larger repository of possible gestures or movements intentions of a user.

Multi-Lane Adaptive Cruise Control for Autonomous Driving using Deep Reinforcement Learning

Saeedeh Lohrasbi

Advanced Driver Assistance Systems (ADAS) aim to reduce road crashes by either providing a warning signal to human drivers or initiating certain control tasks in the vehicle. Multi-Lane Adaptive Cruise Control (MLACC), one of these systems, maintains the speed of the car as close as possible to the maximum desirable speed while keeping a safe distance from surrounding vehicles. This controller considers all available lanes in the road to change the vehicle driving lane when the preceding vehicle is traveling at lower speeds. Therefore, both longitudinal and lateral motions of the vehicle are under control of MLACC, and as a result, weather conditions (such as slippery roads in winters) have a significant effect on this controller's performance. In this research, an MLACC is designed based on Deep Reinforcement Learning (DRL) method. The environment, which consists of a five-lane highway road and surrounding vehicles, is simulated in PreScan, a powerful vehicle dynamics modeling and simulation software package, to integrate the realistic vehicle dynamics. Different DRL architectures, including Deep Q-Network (DQN), Double DQN, and Dueling DQN, are used to train the controller, and their performances are compared at the end. Diagram 1 illustrates the training process for the DRL-based MLACC controller.

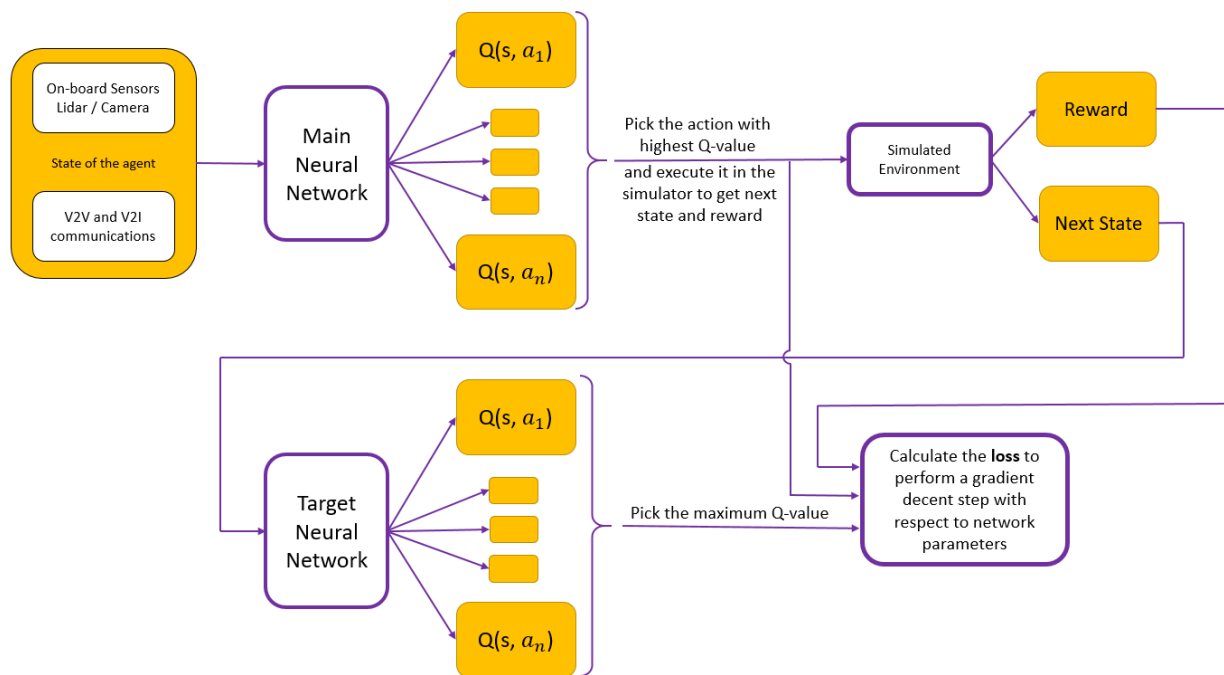


Diagram 1: Training process for DRL-based MLACC controller

A Safe Model of Path Planning in Dynamic Highway Environments Using Harmonic Functions

Steven Daetong Lee

Path planning is the stage of an autonomous vehicle that decides where the vehicle should go and defines how to get there. The path planning stage breaks down into three sub segments: prediction, behaviour, and trajectory generation. In this research thesis we show how a trajectory generation method in the path planning stack can be used in an autonomous vehicle to perform lane changes on a multi-agent highway environment in a safe and timely manner.

Our framework of safety is driven by a model described as Responsibility Sensitive Safety (RSS)¹. The model proposes a transparent mathematical model for safety assurance by formulating definitions of autonomous mobility safety like safe distance. By using the definitions described in the model and identifying the associated parameters of the definitions, we wrap a safety framework around our path planning method to navigate lane changes in our experimentation.

The trajectory generation method we employ performs gradient descent along harmonic functions, the solution to Laplace's equation, to create a smooth path that minimizes the hitting probability within a 2D bounded grid. We use a nascent modification of the harmonic function method² that improves on previous iterations in two areas. The first is performing computations in a log-space which solves the numerical precision problem of harmonic functions and the second integrates the use of a graphics processing unit to accelerate the speed of computations.

This research thesis uses an industry recognized open-source autonomous driving simulator, Carla, as the platform of our experimentation. Our experimentation is conducted in the simulation to present how our solution performs with respect to varying environmental factors including amount of congestion on the road and relative speeds between vehicles. The major contributions of this research are in identifying the parameters that would make for safe interaction of the autonomous vehicle with other cars based on the safety definitions described in the RSS model, and evaluating the performance of the harmonic function path planner in a real-time highway simulation under different dynamic conditions.

¹ Shalev-Shwartz, Shai, Shaked Shammah, and Amnon Shashua. "On a formal model of safe and scalable self-driving cars." *arXiv preprint arXiv:1708.06374* (2017).

² Wray, Kyle Hollins, et al. "Log-space harmonic function path planning." 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2016.

Nonlinear Model Predictive Control of Quadrotors for Real-time Applications

Hadi Mohammadi Daniali - MASc candidate

Quadrotor (or quadcopter) is a type of Unmanned Aerial Vehicles (UAVs). Due to the capabilities of quadrotors to hover, vertical take-off, and landing, they have become popular platforms and are applied to civilian and military duties. In recent years, a lot of research activities have been dedicated to finding more efficient methods to control this kind of UAVs. In this research, a nonlinear model predictive controller (NMPC) for an unmanned quadcopter has been proposed as a high-level controller. Since the quadrotor's equations of motion are highly nonlinear, a fast scheme is required to solve the NMPC's optimization problem for real-time applications. For this purpose, Hamiltonian's equations of the system have been derived and the Newton/GMRES method has been employed to solve them online.

MATLAB/Simulink has been used to simulate the NMPC's performance and the results obtained by the designed NMPC have been compared with the results attained by a proportional controller. Furthermore, this method has been tested on a commercial quadrotor called AR.Drone 2.0. Also, a set of off-board cameras (a VICON system) and an onboard IMU has been used to track the quadcopter's position. It is demonstrated that by employing this method, the NMPC's complex problem can be solved in real-time. Moreover, another advantage of this method is that it can solve the obstacle avoidance problem by only adding a constraint in the NMPC's optimization problem.



Figure 3. AR.Drone 2.0

Optimal Control of Connected and Automated Plug-in Hybrid Electric Vehicles at Roundabouts

Sina Alighanbari

Connectivity and automation provide a spectacular opportunity to improve traffic flow, safety, and efficiency due to their capability to exchange critical driving data and information. On the other hand, plug-in hybrid electric vehicles (PHEVs) have been a topic of extensive research in the past and it has been demonstrated that it is a good solution for improving fuel economy and ecological features. PHEV performances enhance with the addition of connectivity and automation. Coordination of vehicles at an urban area like roundabouts is a demanding problem especially by knowing that the chance of both lateral and longitudinal collision exists.

In this research, the main goal is to solve the coordination problem of connected and automated PHEVs (CA-PHEVs) at roundabouts. We assume that each of the vehicles are equipped with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems and can get informed about the states of surrounding traffic vehicles. When a vehicle enters the control zone (light orange zone in Figure 5), it gets information about other vehicles. The problem is to calculate and provide best control inputs to the vehicle so that when the vehicle enters merging zone (light blue zone in Figure 5), it will be the only vehicle in the merging zone.

To achieve this goal, we proposed an approach for solving nonlinear multi-objective optimal control problem of decentralized coordination of CA-PHEVs at roundabouts with consideration of fuel economy. It was found that the proposed decentralized controller could calculate priorities based on a navigation function and provide a safe gap between vehicles. Also, the addition of energy cost to the performance index improved the fuel consumption of the vehicle. By investigating the controller through hardware-in-the-loop tests, the controller proved to be real-time implementable. Finally, to consider the effect of disturbances and uncertainties caused by different sources, a robust tube-based controller was proposed and it was shown that it improves the performance in the presence of bounded additive disturbances.

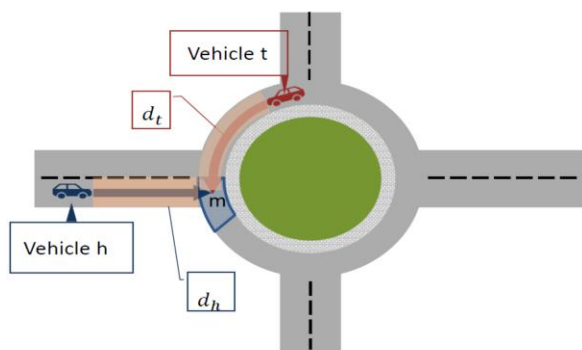


Figure 5: Single lane roundabout with four entrances. Red vehicle is traffic vehicle (t) and blue vehicle is host vehicle (h). The light blue zone is called merging zone and light orange zone is control zone.

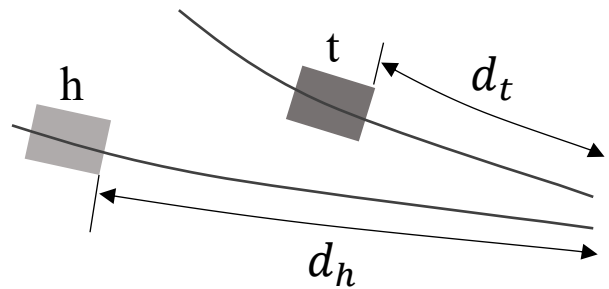


Figure 4: Schematic of distance of host vehicle (h) and traffic vehicle (t) to merging zone.

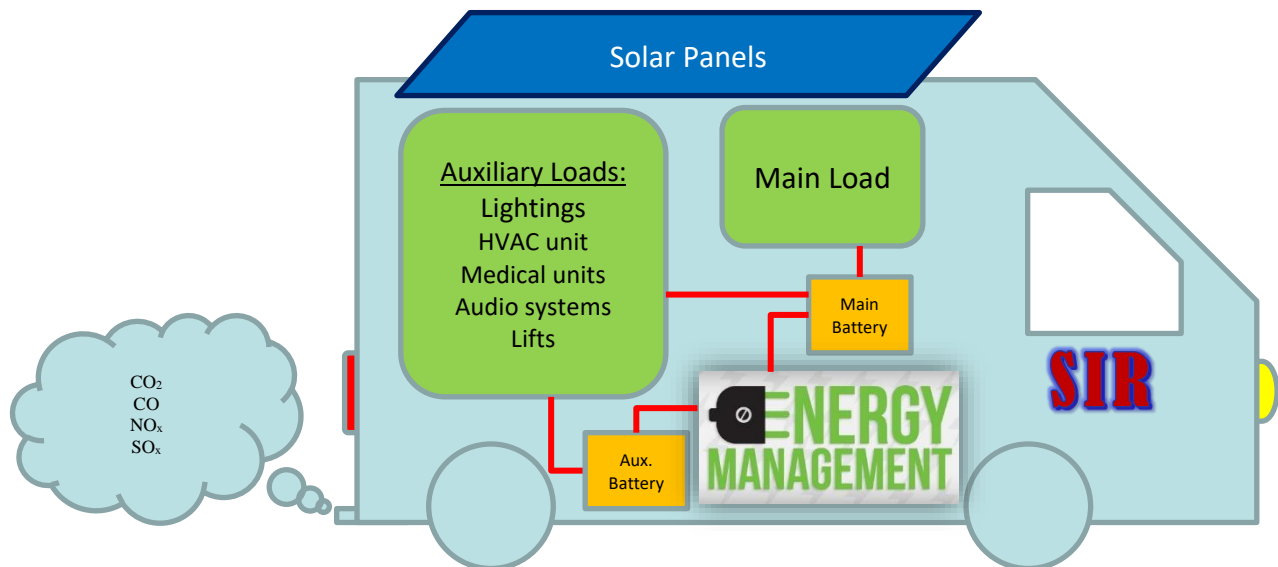
Designing Intelligent Energy Management and Cost-effective Data Acquisition System for Vehicular Solar Idle Reduction Systems

Seyed Mohammad Hosseini

In this study, an innovative energy management system (EMS) employing the promising reinforcement learning (RL) approach is developed. The EMS intelligently manages the power stream between the vehicle engine and its solar-powered auxiliary battery which is used for vehicle idle time reduction via providing energy for auxiliary loads which force the engine to be running, although the service vehicle is stopped. RL, as an elegant artificial intelligence technique, is expected to provide sub-optimal performance for this EMS problem compared to the really time consuming Dynamic Programming approach, which determines the optimal solution through exhaustive search.

A service vehicle is modeled in the Matlab/Simulink environment. Different parts of the model are described in detail, and the dynamics of the considered vehicle are discussed. The simulation results show a better performance compared to an existing rule-based controller, making the devised RL-based EMS an effective strategy for applications in vehicular solar idle reduction (SIR) systems. Double Deep Q-Network is also utilized to come up with the continuous observation space. The results are showing that Deep RL can be a promising method in control tasks like the EMS of vehicular systems. Moreover, a model predictive based controller (MPC) for the energy management task is developed and compared with our intelligent EMS.

Furthermore, a cost-effective and efficient data acquisition system is designed, tested, and implemented using the renowned Raspberry Pi board, and some sensors to collect voltage, current, and temperature data. The required electrical enclosures are also designed to keep the whole package safe. The validation of the system results is done and the process is discussed in detail. This data acquisition system can be employed to read the required information from vehicle and its loads, in order that the intelligent EMS system can wisely decide which action to take in a real time manner.

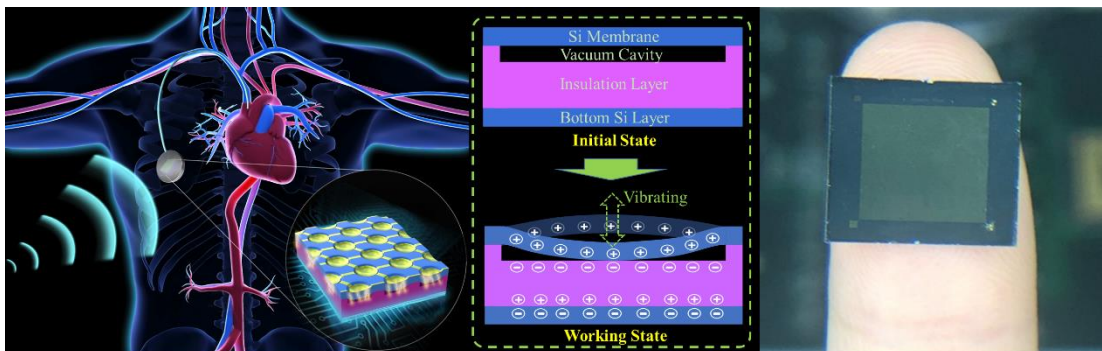


A Novel MEMS Triboelectric Energy Harvester

Chen Chen

Limited by lifespan of battery, remotely charging and harvesting energy from environment are becoming two trends of powering miniaturized electronics. Triboelectric nanogenerator (TENG) is an emerging technology to convert mechanical energy to electricity by the coupling of triboelectrification and electrostatic induction. It has been widely applied to fields of sensing and energy generation due to the simple device configurations and high output voltage. Although there is a “nano” in the name, current TENGs still suffer from the large device size, typically in the scale of centimeters.

This research focuses on the development of novel micro triboelectric energy harvester (μ TEH) for wireless energy transfer and communication via an ultrasound link. A μ TEH with circular membrane was designed by both analytical calculation and finite element method (FEM) simulation. For the first time, μ TEH was fabricated by Micro-Electro-Mechanical Systems (MEMS) technologies in batch process, giving a better IC compatibility and easier array construction. We demonstrated a prototyped ultrasound link, functioning to power implanted devices. The demonstrated acoustic energy transfer system can generate 243 nW power on load resistor ($\sim 360 \Omega$) under the safety regulation of the Food and Drug Administration (FDA). Benefited from the high signal-to-noise ratio (SNR), the μ TEH also exhibits promising potential for data communication by modulating the incident ultrasound. Finally, optimization methods are proposed to further improve the output power of the μ TEH in the future.



Electrostatic Micro Arch Tweezers

Ayman Alneamy

Micro/Nano Electro-Mechanical manipulation and assembly systems are widely used in many engineering and science fields for handling and characterizing objects such as biological cells, DNA strands, etc. These objects require small, compatible and controllable tweezers or grippers. Miniaturizing tweezers allows engineers and physicians to target a specific object in a narrow region. This research offers a simple design of compact MEMS/NEMS tweezers with two rigid arms mounted to a bistable initially curved beam (arch). The tweezers are actuated electrostatically via a stationary electrode. Electrostatic micro arches exhibit a snap-through buckling instability, resulting in bistable equilibria, in addition to the pull-in instability common to electrostatically actuated systems. The MEMS tweezers will use the snap-through instability as a gripping mechanism to close the distance between the rigid arms allowing for manipulation of a large range of object sizes.

The gripping mechanism is designed to offer further controllability via electrostatic actuation which results in two gripping stages. As the voltage is increased between the arch beam and a stationary electrode, the beam first snaps to close the tweezers arms around larger objects, 10-14 μm in diameter. Further motion towards the stationary electrode increases pressure on those objects or allow for manipulation of smaller objects, less than 6 μm in diameter. The tweezers will then be moved using a coarse positioner to the desired position. Once there, voltage will be dropped to release the object.

The tweezers are currently being fabricated at the Quantim-Nano Fab. It uses a p-type Silicon on Insulator (SOI) wafer with a device Si layer of 30 μm thick, buried silicon oxide (SiO_2) layer with a thickness of 1 μm , and a 550 μm thick handle Si layer. The two-mask fabrication process starts with RCA cleaning followed by a metallization layer deposited using sputtering and then photoresist deposition. The first mask patterns the photoresist to create the anchors. The whole wafer is then immersed into a developer to remove the exposed photoresist. Metallization layers are patterned using wet chemical etching and then the remaining photoresist is striped. Another layer of photoresist is deposited and patterned using the second mask to create the device. After that, the silicon crystal layer is etched all the way to the buried silicon dioxide using Deep Reactive Ion Etching. In the final step, the device is released using HF to etch the oxide layer.