Analysis and Identification of an Intraocular Pressure Waveform
Margaret Walter
Mentors: Hyuck Choo, Jeong Lee, and Taeyong Kim

Certain ocular diseases such as glaucoma cause an increase in the internal pressure of the eye, damaging nerves. An implantable pressure sensor would give patients the ability to monitor their own intraocular pressure and then consult a physician if necessary. One device to do this has been developed using a microscopic Fabry-Perot interferometer with the plates implanted between the intraocular membranes, and Raman spectroscopy measurements taken to determine the distance between the plates and thus the pressure in the eye. However the signal produced is difficult for a machine to recognize and link to the pressure environment of the sensor. To analyze the signals and convert their differences into numerical quantities, various signal processing techniques were investigated, such as using Fourier transforms, polynomial fit, and simple peak matching. A program combining these techniques to compare frequency shift across pressures and angles is currently being tested for consistency over samples at the same pressure.

Magnetic Manipulation of Microglia and Magnetic Repulsion of Superparamagnetic Beads
Torkom Pailevanian
Mentor: Ali Hajimiri

Immunotherapy uses the body’s own immune system to seek out and kill cancer, unlike the drugs that chemically do the same task. Past experiments have shown that macrophages loaded with specific synthetic DNA molecules have the ability to eradicate brain tumors. When these cells are loaded with micron sized superparamagnetic beads, they are susceptible to magnetic manipulations. Circuitry has been designed to generate small localized magnetic fields is being used to test loaded macrophages in vitro. Experiments have been conducted to show that standalone beads can be moved to desired locations by generating a magnetic field with a specific distribution. Viability experiments have determined the maximum non-toxic magnetic loading of macrophages to use in manipulation experiments. Current experiments have not been successful in replicating an ideal cell environment which is an area of ongoing research. In addition a potential method of magnetic repulsion using high frequency circuitry is being developed.

Development of Characterization Tools for Integrated Electro-Optical Devices
Andy Zhou
Mentors: Ali Hajimiri and Behrooz Abiri

Advances in silicon photonics processes have opened up many new opportunities and allowed for novel approaches to solving various problems in circuit design and data communication. The ability to fabricate optical and electronic devices in the same chip fabrication process allows for fully integrated electro-optical systems. A feed-forward equalizer (FFE) for optical communications and a frequency-modulated continuous wave coherent camera were implemented in the OpSIS/IME silicon on insulator process, which is mainly developed for optical devices. Several transistors were also fabricated in the same process to be tested and possibly be used in conjunction with optical devices. This project involves developing the methods and tools for testing and characterizing these devices. We designed boards to interface with the equalizer and the coherent camera to couple input signals, to generate and provide supply voltages, and to process the outputs. We also wrote a script to control test equipment to automatically measure and generate the current-voltage characteristics for the batch of transistors. Preliminary measurements show that the OpSIS/IME transistors are functional. Furthermore, tests on the FFE show that it can be successfully controlled to equalize a bandwidth-limited communications channel.

Investigation of Feedback Methods for Directing Wireless Power Transfer
Ajay Mandlekar
Mentors: Ali Hajimiri and Florian Bohn

Directing wireless power via adaptive feedback over short-range distances has many potential applications. The purpose of this project is to implement methods to send radio-frequency waves to desired locations in space over short to medium ranges by adjusting phases and amplitudes of element transmitters to maximize the received power at a nearby receiver. For this project, various hardware and software components had to be developed to implement a closed-loop feedback system involving the transmitter and the receiver. In particular, embedded system software on the transmitting side controls the amplitude and phases of the element transmitters while
receiving feedback data from the receiver over a wireless communication channel. On the receiver side, hardware and software interfaces for commercial tablets and phones running the Android operating system have been developed. These together form the feedback control loop to maximize the wireless power transfer from the transmitter to the receiver. Future work will focus on implementing more sophisticated communication between the transmitter and the receivers as well as different control algorithms.

**Pose Detection for Pedestrians in the Wild**  
Ingrid Fiedler  
*Mentors: Pietro Perona and David Hall*

Automatic pose detection has applications in fields from behavioral psychology to biometrics. However many pose detection systems require extensive cooperation of the subject and are limited to very controlled environments. This project seeks to detect the pose of pedestrians the wild, i.e. without special clothing, backgrounds or equipment beyond a camera to make the task easier. The pose detection system is based on a robust cascade pose regression system originally designed to detect the pose of a face, mouse or fish, objects with much less relative movement and self-occlusion than the human body. Applying the pose estimator to people entailed constructing a pedestrian model, assembling a sufficient training set—which needs to be quite large in order to handle the frequent occlusion of limbs—and investigating parameters of the detector. This work will contribute to the labeling of pose ground truth for the publication of the Caltech Rose Bowl dataset.

**Efficient Video Annotation Using a Tracker and a Detector**  
Jeong Park  
*Mentors: Pietro Perona and Steve Branson*

In contrary to the ease of obtaining videos, annotation of the video datasets has been extremely costly. We describe an active-learning based approach to semi-automate the annotation process. Given a sparse set of annotated keyframes, a detector is trained with the frames near the keyframes. A tracker, then, interpolates the non-key frames by tracking both forward and backward from the keyframes. The detector, which showed above 90% recall rate on the specific dataset that contains the keyframes, not only updates and validates the tracking results to reduce drifting, but also provides room for annotating appearance of objects that are not caught in the keyframes. To ensure the accuracy of bootstrapping, we either query unmatched detections to oracle or set them as "ignore" windows to avoid wrong negative sampling. We demonstrate our approach by annotating challenging pedestrian video datasets with less than 10% of the human effort that would have otherwise been necessary for naive frame-by-frame human annotation.

**Generating Smart Region Proposals Using Interpolation and New Neural Networks**  
Michael Feldman  
*Mentors: Pietro Perona and Steve Branson*

To locate and classify objects in large and complicated images, detection algorithms and neural networks are often used to extract and then score region proposals. Our algorithms use regression and other interpolation techniques to estimate the true locations of objects, this allows for a reduction in the number of regions that must be extracted and scored. Given data that contains the center coordinates of region proposals and the corresponding scores, we use radial basis function interpolation. We then find the maximums on the interpolation surface, which correspond to the rough locations of objects. Then, we use the Nelder-Mead downhill simplex method to obtain better estimates of the objects' locations. New neural network layers were trained to score optimal bounding boxes highly. In the future, we plan on combining these algorithms with a standard detector.

**Monitoring Animal Behavior With the Intel 3D Camera**  
Esther Du  
*Mentors: Pietro Perona and Louise Naud*

Tracking animals and monitoring their behavior accurately is a very important part of behavioral research. Currently, the method used to track the animal movements is to use standard video cameras to videotape the movements and then have someone sit there and annotate the movements and behaviors of the animals. This process is not only tedious but can also be highly subjective as different people may interpret the same movements in different ways. Therefore, attempts have been made to replace this tedious task with an automatic visual recognition system. Using depth data from the Intel Interactive Gesture Camera along with two other standard grey-scale video cameras, we are able to develop 3D models that can replace the current method used to monitor animal behavior in the laboratory. In this project, a software application has been created that will allow researchers to stream and record video and change settings for all three cameras at once. Researchers can then use this application to easily obtain the data necessary to automate the process of monitoring animal behavior.
**Transmission Enhancement of Epidermal Metasurfaces**
Brynan Qiu  
Mentors: Ada Poon, John Ho, and Azita Emami

The integration of wireless technology with miniaturized implantable bioelectronics could enable new classes of diagnostics and treatments. However, the large mismatch in electromagnetic properties between air and biological tissue severely limits the efficiency of wireless transmission. By structuring the surface of the skin on a subwavelength scale, flat electromagnetic devices known as metasurfaces could potentially improve transmission by several orders of magnitude. Such surfaces can modify the radiation wavefront, enabling momentum mismatch to be overcome, but existing metasurfaces themselves exhibit low transmission. Two approaches for transmission enhancement of a candidate metasurface structure have been theorized and applied. Simulations of an improved metasurface design demonstrate a 10.4 dB increase in power transmission efficiency with improved beam steering. This enhancement in transmission allows for the practical development of conformal metasurfaces for wave focusing, steering, and other applications.

**Alternative Methods of Recording Neural Activity**
Bryan D. He  
Mentors: Lakshminarayan Srinivasan and David Rutledge

Current methods of recording neural activity include procedures such as electrocorticography (ECoG) and scalp electrodes. However, methods related to ECoG require highly invasive surgical procedures, and methods like scalp electrodes record weak signals. We explore methods of recording neural signals that are less invasive than normal surgical methods, but are able to record cleaner signals. The signal strength is evaluated for Visual Evoked Potentials (VEP), Steady-State Visual Evoked Potentials (SSVEP), and Steady-State Auditory Evoked Potentials (SSAEP). In addition, we seek to allow these methods to localize the source of a signal and detect frequencies that cannot be detected by scalp electrodes. We also found that cardiac activity measured by the electrodes is highly repeatable with low variation, so we also study how to filter out cardiac activity from the recorded signals.

**PID Controller Implementation for Digital Feedback in Optical Linear Chirps**
Oliver Chen  
Mentors: Amnon Yariv and Mark Harfouche

Wideband optical swept-frequency sources have found immediate applications in optical chirped radar as well as 3D biomedical imaging. Unfortunately, the inherent non-linearity of the optical sweeping mechanism limits the repetition rate and the dynamic range of the ranging systems. To correct for these non-linearities, an analog feedback system is used to adjust the chirp rate toward the desired setpoint. However, the current analog design is inflexible and making alterations to the system is cumbersome. In order to increase reconfigurability of the feedback mechanism without necessarily modifying hardware with every updated design, a digital system was used to replace the analog system. A proportional-integral-derivative (PID) controller on a field programmable gate array (FPGA) integrated chip was implemented in order to create a digital feedback system to linearize an optical lazed frequency chirp. The ability of the feedback hardware to control the injection current to a laser in real-time stems from the high-capacity computational ability of the FPGA chip. This digital feedback system can replace traditional analog feedback systems in optical applications due to inherent flexibility and reconfigurability of simulated hardware.