Over the years there has been one key thread connecting my academic interests: *Perception*. The breadth of my research has included themes like how haptics – the sense of touch – can be used as a learning tool for mechanism design and how latent structure in autonomous vehicle images can be used for object detection. The fundamental idea in both cases is extracting and permuting information from physical sensors. I am interested in identifying underlying structure in data for use in real-time systems. Although there are numerous application areas, my interests in the medical domain stress additional research into topics surrounding surgical robotics and hospital room automation.

Haptics and User Interaction: 2008 - 2010
Between sophomore and senior year at University at Buffalo my work in the Automation, Robotics, and Mechatronics (ARM) Lab under Dr. Venkat Krovi focused largely on haptic interaction. As part of an NSF Research Experience for Undergraduates I developed a system for haptic rendering of virtual mechanisms that was selected for presentation at the 2010 University at Buffalo Celebration of Academic Excellence and 2010 Honors College Research Symposium. The goal was to expand on current visual-based methods for teaching mechanism theory by adding a haptic component enabling individuals to feel workspace and manipulability constraints.

While creating these teaching simulations I quickly found limitations in using a Novint Falcon, a haptic device with only three degrees of freedom (DoF). The lack of rotational control severely limits the user's hand motions. In order to increase effectiveness and manipulability I created a prototype 5-DoF device and integrated it with an open source haptics platform. By developing a low cost, high manipulability solution it is possible to bring haptic training to a much broader audience. Limitations in the chosen haptic platform meant that software integration required adapting a current 3-DoF haptic renderer to create force and torque feedback and distribute it across two sets of actuators. This is in part where I learned my interests revolved more in computation and algorithms than mechanical design. Note that most of my ARMLab projects are documented on my website [1].

Unmanned Ground Vehicles: 2008 - 2011
As part of the undergraduate Robotics Club, my work on the Intelligent Ground Vehicle Competition (IGVC) was as a leader and researcher. The focus of this international contest is the creation of an outdoor robot that can autonomously navigate around objects and advance to specific GPS waypoints. My three-year tenure on this project includes work on sensor fusion where I implemented an Extending Kalman Filter, controls where I helped implement Proportional-Integral-Derivative feedback for our motors, and improved path planning. The project requires a significant amount of teamwork and dedication. Aside from helping develop the system, I assisted others on skills such as document writing, resource finding, and software development. We regularly spoke to high schoolers and other community members and in Spring of 2010 gave a keynote presentation at the Buffalo Public Library's "Robots and Remotes" community event.

At the 2010 IGVC competition I saw that our computer vision algorithm for lane detection was the critical weak point of our intelligence system. Thus, in conjunction with a graduate Statistical Vision class I audited, I developed a technique using multi-layered Markov Random Fields to accomplish lane detection and object recognition for our robot. Our previous methods were prone to noise coming from specular regions on the grass which hindered our detection phase. I also imple-

mented a Gaussian Mixture Model based pre-processing method which decreased color variation and noise. We saw great improvements over our prior work and consequently performed better at our most recent competition. The technical report was submitted to the International Conference on Intelligent Robots and Systems (IROS) 2011 [2].

3D Perception: 2010 - 2011

Under the leadership of Dr. Red Whittaker, director of the Field Robotics Center at Carnegie Melon, I focused on implementing and evaluating Structured Light and Stereo Vision techniques in rocky, unstructured environments such as those in mines and caves. Subterranean accidents are an ever-present concern and new techniques for enhanced mine safety are necessary for their prevention. Further research shows that this requires accurate geometric modeling of the underground tunnels making it is critical to identify what sensors are capable of generating sufficient maps. We collected data from a research mine and a local cave to evaluate a variety of camera- and laser-based sensors in a project recently published at IROS 2011 [3]. I have long been intrigued by computer vision, but it was my work implementing 3D vision algorithms at CMU where my passive curiosity turned into an active interest.

My endeavors senior year took two directions within computer vision: 2D object detection on a robot (discussed previously) and 3D perception. For my senior design project I formed a group to participate in the Solutions in Perception Challenge, a 3D object recognition and pose estimation competition. The task involved using an Xbox Kinect with ROS (Robotic Operating System) to extract household objects from a table and determine their locations in under 15 seconds. Our solution was to do recognition in image space and pose estimation in 3D. We used SIFT, a feature-based object recognition technique, together with Multi-Resolution Occupied Lists (MROL), a probabilistic localization technique developed in our lab. I worked on integrating these two methods with ROS and developed a plane-based object segmentation technique using Random Sample Consensus and Singular Value Decomposition to find items on top of a table. This was presented in a special session at IROS 2011 and the technical report is available online [1].

Looking Forward

My current one-year fellowship through Intuitive Surgical has enabled me to focus on my interests without additional obligations. In efforts to get involved right away I started a project that acquaints me with our CISST robotics libraries while developing a product that will be used by doctors for laparoscopic surgery. I have gained experience working with physicians and learned what types of visualization cues are actually useful during surgery. I recently started research on the project discussed in my proposal which continues in the direction of 3D perception but for activity recognition. Where my undergraduate experience provided me with a broad overview including a variety of general robotics topics, my doctoral studies will allow me to to delve further into the vision and machine learning associated with computer integrated medicine and automation.

[1] Technical reports and project descriptions: `http://www.colinlea.info`

[2] **Colin Lea**, Jason J. Corso. *Efficient Hierarchical Markov Random Fields for Object Detection on a Mobile Robot.* 2011. http://arxiv.org/abs/1111.1599.

[3] Uland Wong, Aaron Morris, **Colin Lea**, James Lee, Chuck Whittaker, Ben Garney, Red Whittaker. *Comparative evaluation of range sensing technologies for underground void modeling.* International Conference on Intelligent Robots and Systems. 2011.