Evis Plaku: RESEARCH STATEMENT
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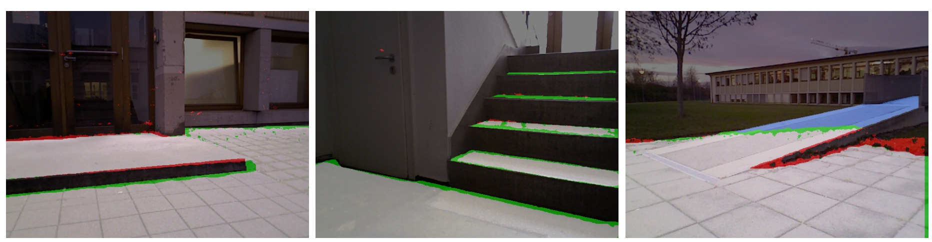
My research goal is to develop algorithms that enable robots to become more autonomous and more efficient. My research is focused in machine learning based robotics and navigation for single or multi-agent robotic systems. The main objective is to design learning algorithms which are able to deal with new scenarios by learning from past observations. A crucial issue that needs to be tackled is the uncertainty that arises from different factors such as noisy actuation and sensing, modeling errors, and unpredictability of dynamic environments. It needs to be addressed in a principled manner in order to facilitate the successful deployment of robots in the real world.

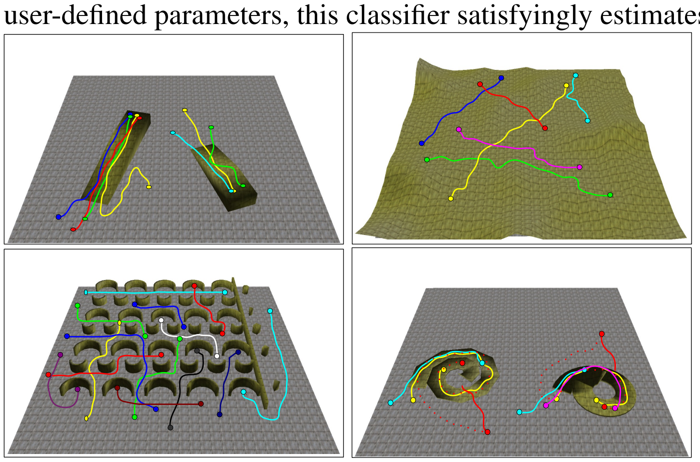
1 Machine Learning Based Robotics

The objective of machine learning is to develop algorithms that improve their performance through experience. As such, machine learning is a powerful tool for dealing with domains where there are many observations, but poor models exist for making sense of these observations. Machine learning algorithms have been applied to such diverse fields as bioinformatics, robotics, economics, medical diagnostics, as well as some of my application areas including traversability analysis of the terrain and navigation.

The key motivation for my interest in machine learning is that it provides a sound mathematical framework for dealing with uncertainty in sensing and actuation in a principled manner. It also provides a strong theoretical basis for explaining huge amounts of sensor data, and for defining actions that take into consideration uncertainty. I developed machine learning approaches that tackle the problem of estimating the traversability of the terrain and also the problem of autonomously navigating in various environments. In my work, I usually acquire sensor data from a Kinect camera and have worked with a variety of robots such as TurtleBot, PR2, and a robotic wheelchair.


Estimation of terrain traversability. White/black denote traversable/non-traversable environments correctly classified as such. Green/red denotes false positives/negatives.

The traversability of a terrain is a complex function jointly determined by the terrain's characteristics and the robot's capabilities, which makes it difficult to characterize a priori. I developed a supervised learning approach to learn the traversability of the terrain by learning models of terrain from a set of image data manually labeled by a human supervisor. Without relying on user-defined parameters, this classifier satisfyingly estimates the traversability of the terrain it encounters.

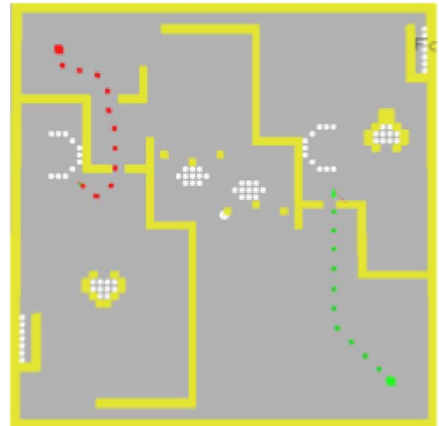

The curved lines denote the trajectories taken by the robot

Building upon this research, I also developed an inverse reinforcement learning approach that enables a mobile robot to successfully navigate in a variety of environments without providing a manually generated cost or reward function in the planner. This approach allows for learning navigation actions from a set of trajectories demonstrated by a human supervisor. Given observed, optimal behavior, a reward function is recovered that best explains the demonstrated behavior. The TurtleBot robot used in simulations is able to learn a policy that guides it towards the goal destination, while avoiding collision with obstacles.

2 Path Planning for a Multi-Agent System

Autonomous robots rely heavily on their ability to plan actions quickly, under massive uncertainty and with a large number of factors that affect execution. Recently, multi-agent systems have been gaining increasing attention, especially to carry out tasks that can be done more efficiently and effectively with a team of agents such as search and rescue tasks. I focus on the path planning problem for a simple multi-agent system.

Path planning among multiple agents in environments that contain various obstacles is a challenging problem. Not only should each agent plan its own motion, but it must as well find a (possibly optimal) way to cooperate with the other agents to solve the specified tasks. We equip our agents with a simple system of communication, which they use to carry out their tasks more efficiently, since communication bottlenecks between agents pose potentially serious drawbacks in coordinated behavior.



Multiple agents collaborate to find a more efficient way to “collect” some objects and bring them back to a predefined location by following a quasi shortest path.

3 Obstacle Detection using a new Time-of-Flight Sensor for Automotive Applications

In recent years complex mobile robotic systems have been developed for autonomous navigation in various environments. The more complex a robot’s working place gets the more sophisticated its obstacle detection and avoidance facilities need to be. First of all, sensor equipment must be appropriate for the requirements of given scenarios. In most cases such sensors have a limited field of vision and therefore cannot cover the complete area around the robot.

In this project, together with my colleagues, we develop an obstacle detection software which acquires sensor data from a new time-of-flight sensor mounted on Audi cars. The problem of detecting obstacles lying into the path of a driving car poses difficult challenges. Since the car drives at considerable speeds, one needs to deal with uncertainty and measurements errors in a principled way. To better evaluate the efficiency of this new sensor in providing reliable and informative data we compare its performance with the performance of a velodyne sensor.

We develop a software that, given sensor information acquired from a new time-of-flight sensor, is able to detect dangerous objects lying in the road while driving at considerable speeds, and if necessary, perform an emergency brake, even though the driver might not choose to do so.

4 Future Research Directions

Ultimately, my research aims to enable autonomous robots to operate successfully in the real world in the face of uncertainty. Dealing with uncertainty in a principled fashion has the potential to address problems not only in my areas of interest such as machine learning based robotics and navigation, but also influence other fundamental research areas.

I plan to continue research in machine learning based robotics by devising algorithms that expand the capabilities of robotic systems using principled methods. It is my objective to develop algorithms that tackle important problems in the field of robotics and bridge the gap between theoretical analysis and real-world applications.

I have a keen interest in navigation and path planning. A fundamental issue with the operation of robots in real world environments is that sensors do not provide exact geometry but rather noisy point clouds, and approaches typically attempt to reconstruct the geometry from these. Representation of this geometric uncertainty and its implications on planning are still largely unexplored topics. Thus, I aim to to develop algorithms that address the path planning problem in real world environments.

Furthermore, I am interested to investigate into combining motion planning with navigation approaches based on machine learning. Using a policy learned from a set of demonstrated trajectories by a human supervisor to expand the tree and then use motion planning techniques to find a path to the goal can further improve the performance of a planner both in terms of efficiency and computation time.