Lecture 7 (10/23) - Dr. Dinesh Manocha - Robot Navigation in Complex Indoor and Outdoor Environments

The speaker has been doing robotics since the late 80’. One of the biggest successes in the last 10 years or so has been in warehouse automation. Amazon, for example, deploys a lot of robots to assist in warehouse operations. One of the areas that has a lot of potential for growth is in robot navigation and movement. How do robots move in cluttered environments? An example of this is the automatic car which is nothing more than a robot moving through a cluttered environment. In the last seven or eight years machine learning has been integrated into robots to help assist them in navigation.

In the last decade most of the successes for robots have been in friendly, controlled environments. These environments have no humans (unpredictable movement), special sensors, and improved lighting conditions. When robots are put into unpredictable environments, such as automatic cars or inside a home, it becomes much more difficult for them to navigate. Homes, especially, have navigational challenges with small spaces, surfaces that reflect and give off varied lightning, and unpredictable obstacles like humans and pets. If some of these problems could be overcome then we could see delivery robots going down the sidewalk delivering Amazon packages.

The general algorithm for a robot for moving is Perception(Sense)->Planning (Plan)->Control/Action(Move). (Dr. Manocha slide) Within the last ten years machine learning has been deployed at each step. Now, we are going to look at several different challenging environments for navigation, indoor scenes, outdoor scenes, and autonomous excavator.

Let us start by considering indoor scenes where robots have to navigate through crowds. Robots are still limited by navigating in sparse crowds. To overcome this problem there have been studies done on how humans move and capturing data for training in machine learning. The idea is to move towards pedestrian motion prediction and make robots prediction around human movement as good as humans are at predicting human movements. The results were decent but there are problems in small congested spaces with unfriendly people. What do we mean by unfriendly? We mean people that go out of their way to step in front of the robot.There are some concerning problems with robot movement. Once such problem is when the robot freezes up when obstacles appear in front of it. The research to overcome this issue is looking into freezing zones for the robot and how to avoid these zones. A second problem is how to get the robot to detect transparent objects like glass panes.

Now we consider how a robot navigates outdoors. This is really challenging because the terrain is dynamic, uneven, and not really structured. Elevation changes, which can affect the robots stability, come into play. Contrast this with an indoor setting where the terrain is mostly flat and even. Even elevation changes indoors are fairly consistent since they are either stairs, a ramp, or an elevator. The environment also changes as the seasons change. The approach used, called TERP, looks complicated compared to the general algorithm described several paragraphs ago. Multiple different types of sensors are put on the robot to help them move outdoors. Legged navigation is a promising research area. Another outdoor navigation architecture was shown, AdVENTR, which is even more complicated than TERP. “The challenge is the more components that you have, how do you make it explainable?” (speaker quote) I think that quote summarizes the difficulties in putting these types of systems together.

The last project discussed was around an excavator. The excavator global market is huge, 44.12 billion USD in 2018 (slide). Excavators have unique problems. They work in all kinds of temperatures, in dusty environments, and the problem of elevation change exists, like in any outdoor environment. A good application of these robot excavators is when they are working with toxic materials that create dust.

Some of the takeaways are that (paraphrased from slide) developing autonomous robotic systems are hard. This is due to the challenges in trying to integrate the robot’s perception, planning, and control systems. At the same time, advances in sensor and AI technologies have allowed robots to advance as well. Finally, different navigation systems are continually being developed that allow for better robotic movement solutions in indoor and outdoor environments.