**Social Navigation in Unconstrained Social Environments**

The rapid increase of robots in social environments is leading to a heavier need of social navigation in these environments. Most of these robots are meant to be for assisting people, assistive social robots need to understand social queues and environment structures in order to be successful. Recent Developments in the field of Human Robot Interaction (HRI) have provided several social navigation models for Robots to follow during a wide range of scenarios such as offices [5], malls [10] urban environments [2][6], airports[3] and labs[4]. The Social Force Model (SFM) [1] seems to be the leading algorithm for this application; which was developed in a psychological study observing the motion of pedestrians. Research by G. Ferrer et al, and X. Troung et al, provide advancements in the SFM and its application in Robotics. R. Triebel et al, expresses the view that it’s also possible to use machine learning techniques to solve these kinds of problems. Additionally, from the perspective of social interaction, there has been several studies performed looking at human-robot proxemics [7][8][11]. M. Walters’ et al, offers experimental results defining how far a robot should keep from a person and explains how different cultural biases can affect these distances [8]. While J. Mumm and B. Mutlu demonstrate how a person’s perception of a robot can affect the distancing and cooperation[7]. Combining both of these groups, proxemics and social navigation, we seek to navigate crowded environments where the goal is to communicate with a person (or people) in this same environment, such that the robot is able to become part of these social groups.

Currently the primary area of focus is socially-aware robot navigation. Hindell’s Social Force Model [1] has provides the basis for how people interact with one another in crosswalks, creating a numerical model that can be extended into the field of social robotics. However, this model fails to take into account how people would behave when there is an object of interest, or when they are interacting with one another. Therefore, X. Troung et al. provides a Social Reactive Control SRC model as an extra layer to the SFM [12]. One of the benefits provided by X. Troung’s research is that it provides a robust model on how a robot should behave in several scenarios in which there are multiple agents and objects of interest. However, all studies were performed in a heavily controlled, static lab space, which is not very similar to a real scenario. R. Triebel’s et al study shows that socially aware navigation in heavily crowded environments, an airport, is possible. The study looks into using a reinforcement learning to successfully approach a group of people and provide them with assistance; which is guidance to another point in the airport. The measure for success in the study is such that at least one person stays following the robot as it moves towards the desired destination. The study found there were several social norms that must be taken into account which can be affected by the layout of the airport, culture and other factors. The robot interaction with people was limited to approaching a single individual in a group rather than having an understanding of the gorup. In a more extensive study, X. Troung proposes a Proactive Social Motion Model, that is measured by a “human comfortable safety index” (HCSI) The study demonstrates method that takes into account people’s personal space in both static and dynamic environments. Through a simulation, they tested a crowded and dynamic environment where they measured the HCSI of the individuals in the simulation, where the model performed significantly better than the base SFM. However, this metric is solely developed by these researchers for the purpose of this research and has no out-of-simulation value. That said, further studies are still necessary to understand how people really feel in these crowded environments. G. Ferrer et al uses the SFM to navigate urban outdoor environment, using reinforcement learning to learn the SFM parameters for the robot. The study is successful at navigating crowded environments, where people are moving and navigating in several directions. This is a promising model because the study uses the robot as a companion to a human, giving it a social context, and navigates through several social contexts in a dynamic environment.

In the area of proxemics, studies show that among a given cultural group results are consistent. That said, proxemics cultural difference have a reasonable impact in the results of a study[8]. J. Mumm and B. Mutlu, have shown that a person’s perception of a robot heavily affects how they will interact with it. The study looked into distancing, gaze maintenance, and disclosure of information to the robot. This research is actually very important because when navigating in social environments, the robot must attempt to remain as likeable by everyone as possible. If someone has a negative perception of the robot, then it will affect how the interact with it which can lead to the robot becoming less assistive to an individual, and reducing its performance. R. Mead’s study [11] looks at how speech affects social robot interaction, and measure’s the distance between participants and robots. Although the study results in slightly different proxemics, it demonstrates that a speech can affect the distancing a person takes from the robot. Which correlates without how other people distance each other after 2 meters of distance. [3] was unable to study human-robot speech communication because airports are very crowded and it’s harder to perform appropriate filtering in this situation. However, since the main motivation is to create assistive robots, then successful speech processing and navigation are necessary for social environments.

The different areas of research in proxemics and socially aware navigation provide a solid ground for communicating with people in dynamic environments [7][8]. The studies provide an understanding on how people should be both avoided and approached, along with different models that allow for adaptability [3], or simple navigation ruled by social forces [1][2][6]. While [4][12] has provided a solid guideline of how a robot should perform in certain social scenarios.

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