Towards Agents That Exhibit Human-Like Autonomy in Complex Environments

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Abstract

Deploying intelligent, autonomous agents *e.g.* autonomous vehicles and robots, in the real world has been a longstanding goal in robotics and artificial intelligence (AI). We have already begun to witness the emergence of vacuum robots in our homes, service robots in warehouses, and even self-driving cars on our way to work. These environments are often dense, constrained, and unstructured, with heterogeneous agents, each with their own unique behaviors and objectives. While agents today are designed to navigate these environments safely, their overly conservative nature often leads to slow and jerky motion (frequent stopping and freezing), lack of social compliance (not giving way to other people, blocking doorways and intersection), and poor adaptability across diverse complex environments (failure due to sudden accidents *e.g.* liquid spills). In other words, these robots often fail to capture the essence of human-like autonomy, which involves the **ability to take calculated risks**, even in complex environments. In this talk, I will describe my vision for a paradigm shift in the way intelligent physical agents navigate highly dense, heterogeneous, constrained, and unstructured environments using human-like autonomy.

This talk surveys my research on risk-aware decision making for embodied agents that operate among people. The central AI goal is to enable agents to take calculated risks when beneficial, while remaining safe, socially compliant, and physically feasible. The work integrates perception and prediction, multi-agent planning and learning, and control, and is evaluated on real robots in domains such as traffic, buildings, hospitals, and campuses. I am an Assistant Professor of Computer Science at the University of Virginia and lead the CRAL lab. Before UVA, I was a postdoctoral fellow in Texas Robotics at UT Austin, advised by Joydeep Biswas and Peter Stone, and I received my PhD from the University of Maryland.

Part I of the talk covers my PhD work (Chandra 2022) on autonomous driving in dense, unstructured, and heterogeneous traffic. I will show how unsignaled intersection navigation can avoid collisions and deadlocks when the autonomous agent sometimes asserts right of way (Chandra and Manocha 2022). The approach reduces collisions and deadlocks relative to prior methods and demonstrates the value of reasoning about other drivers' incentives (Chandra et al. 2020a,b). This section also summarizes contributions in tracking (Chandra et al. 2019a, 2020c), trajectory prediction (Chandra et al. 2019b, 2020d, 2019c), and behavior modeling (Mavrogiannis, Chandra, and Manocha 2022) for unstructured traffic where rare events and atypical behaviors are common (Chandra et al. 2023c).

Part II of the talk transitions to a new definition of agent, from intelligent vehicles to social robots, during my postdoc. Here, the problem is crowd-conditioned mobility for indoor service robots. I will present methods that allow robots to pass through doorways and hallways without stopping and without collisions, using decentralized formulations that blend learning and control (Chandra et al. 2023b,a, 2025). I will discuss a line of work on safe, deadlock-free multi-robot navigation with control barrier functions and learned policies, and show how these methods retain safety while remaining minimally invasive to other agents (Chen and Chandra 2025; Gouru, Lakkoju, and Chandra 2024).

Part III of the talk focuses on systems, tools, and community artifacts that enabled broader progress. I will describe METEOR (Chandra et al. 2023c), a large-scale dataset of rare and atypical driving behaviors from unstructured traffic, designed to stress existing perception and prediction methods. I will also present SocialGym 2.0 (Sprague et al. 2023), a lightweight multi-agent social navigation simulator with a standard interface for benchmarking reinforcement learning and planning algorithms in doorways, corridors, and other conflict-prone layouts. Together, these resources help close the gap between benchmarks and the messy realities of human environments.

Part IV of the talk outlines my UVA research program, which treats risk as a design variable that couples three layers. First, perception and prediction infer human intent and group dynamics from multimodal observations. Second, planning and control generate decisive motion with safety certificates and structure. Third, social norms and infrastructure shape policies so that assertive actions remain acceptable and legible to people. This coupling differentiates the program from my mentors' work and targets deployment in hospitals, airports, and campuses in partnership with the UVA Link Lab community.

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