Research Statement

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I would characterize myself as a researcher eager to 1) invent new algorithmic and mathematical techniques and 2) design novel AI and robotic systems with interesting properties, with the hope that these techniques and properties are enablers of novel applications that could make a great impact on society. Therefore, one way to look at my work is from a **system perspective** and focus on the properties of the AI and robotic systems my students and I developed:

1. **High Throughput:**
   (a) A set of mobile conveyors can form a **dynamic robot chain** that can achieve a much higher throughput when transferring many objects simultaneously. We studied how to deploy dynamic robot chain networks in foraging tasks in which robots search for resources and bring them back to a collection zone [28, 43, 45]
   (b) We designed a new robotic system called **mobile workstation robots** in which a mobile robot can perform some operations on the objects it is carrying on the move. The key to unlocking the power of this system is a better scheduling algorithm for overlapping production time and delivery time [29, 37].
   (c) Autonomous intersection management is an intersection control protocol for autonomous vehicles that can achieve a near-zero traffic delay at intersections. I generalized AIM to **autonomous traffic management** and studied how to maximize the throughput of transportation systems [17, 18, 20, 23, 24, 25, 27].
2. **High Agility:**
   (a) In autonomous parking lots, a group of vehicles can be asked to move to another location when they block another vehicle. I devised a dynamic programming approach for **formation planning** that minimizes the makespan of moving multiple vehicles from one location to another safely [46].
   (b) We built and programed fully autonomous drones for **autonomous drone racing**. These drones can fly in cluttered environments as fast as possible while delivering an object to a target location [38].
3. **High Responsiveness:**
   (a) There are many practical planning situations in which planners acquire information from external sources during the planning process, but the information may change or expire during the planning process. We devised a reactive planning framework for handling **volatile external information** [3, 7, 12].
   (b) In drone light shows, a group of drones displays a sequence of light patterns in the sky. We consider using drone light shows for **drone-swarm-based games** and devise planning algorithms that provide a real-time guarantee for displaying pixels in animations and a fast response to user inputs [47].

4. **High Safety Guarantee:**
   (a) Autonomous intersection management cannot tolerate mechanical failures that cause vehicles to deviate from their trajectories. We proposed a preemptive approach that pre-computes **evasion plans** for several common mechanical failures before vehicles enter an intersection [15, 21].
   (b) A robotic system is fail-safe if the robot can steer the system to a safe state after an error occurs. We described a neural network model that can be used to speed up the generation of **backup paths** for robots in emergency situations in cooperative transportation tasks [35].
5. **High Degree of Cooperation:**
   In multiagent systems, self-interested agents need to resolve conflicts before they can cooperate with each other. Existing strategies, such as Tit-For-Tat for **Iterated Prisoner's Dilemma**, perform poorly in the presence of noise. We proposed a **noise detection technique** that is very effective in many non-zero-sum games [6, 8, 10, 11].
6. **High Density:**
   High-density parking increases the capacity of parking lots by allowing vehicles to block each other but making way for departing vehicles by driving autonomously upon request. We proposed **autonomous parking lots**, which employ different parking strategies to increase the car density of parking lots [41, 46].
7. **High Availability:**
   Drones have a fairly short range due to their limited battery life. We propose an adaptive exploration technique to **extend the range of delivery drones** by taking advantage of physical structures such as tall buildings and trees in urban environments [33, 40].
8. **High Accuracy:**
   A fast algorithm for checking whether a vehicle can arrive at a position at a given **arrival time and velocity** is the key to autonomous intersection management. We presented a complete set of closed-form equations that fully describe the set of all reachable arrival configurations in **longitudinal motion planning** [22, 34, 39].
9. **High Security:**
   Goal recognition design (GRD) is the task of modifying environments to aid observers in recognizing the objectives of agents during online observations. We presented a new GRD framework called **extended goal recognition design** for goal recognition that involves multiple goals [44].

Most of my work fits very well into multiagent systems, specifically multirobot systems [32]. My work spans across many application domains: intelligent transportation systems [17, 19, 42], logistics systems [45], security systems [44], drone-swarm-based entertainment systems [47], drone delivery systems [40], disaster management systems [36], smart warehouses [31], smart factories [30], mixed reality systems [16], and web applications [4]. I am most interested in studying the mathematical properties of these systems (e.g., [17] and [39]) and devising new algorithms to provide these properties (e.g., [11] and [46]). The techniques that I often use are planning techniques such as motion planning [26] and domain-independent planning [2, 5, 14]. I particularly like to use search algorithms [44] and dynamic programming [9, 46] for combinatorial optimization. I like to put multiagent systems in game theoretical settings [8] and study the best strategies for the agents [13]. Sometimes, I use logic [9, 44] and case-based reasoning [1] to specify certain properties in a system. Recently, I have started looking into deep learning and reinforcement learning for controlling multiple robots. For more information about my work, please visit my homepage at `https://chiuau.github.io`.

In the last decade, artificial intelligence has enjoyed a renaissance, and roboticists have made tremendous progress in autonomous robots. We can foresee a future in which fully autonomous robots are roaming around us, and this future is not too distant from our time. I hope my work can contribute to the technological and scientific advancement of AI and robotics for the benefit of humankind.

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