Advancements in Multi-Robot Systems

By: Alice Min, Robayet Hossain, Hammad Izhar, Narek Harutyunyan
Automatic Coordination of Teams Lab, Department of Computer Science and Engineering, Brown University

Creating Drone Art

Introduction

An interest in multi-robot technology and artistic expression has led to a project in designing and optimizing a custom-built drone for controlled paint application on canvas. Fine-tuning the drone's firmware prompted a dynamic LED dance performance that responds to sound frequencies. Through sound analysis, this project explores changes in LED colors with music pitch, creating captivating visual effects during choreographed movements.

Hello

Methodology

The meticulous design used Fusion 360 for specialized mechanical components, including the paint canister and propeller guards. After integrating these components with after-market brushless motors and a carbon fiber body, iterative testing refined their functionality, ensuring that the guards would protect the motors' capabilities and that the paint canister was capable of a constant dispersion of paint. The drone's firmware was carefully fine-tuned to ensure smooth paint application on canvas. Sophisticated audio analysis algorithms synchronized the drone's movements with the music's pitch, allowing for creating visually stunning effects.

Figure 1: Custom-built Drone Framework

Results/Discussion

Challenges, such as system calibration and synchronization accuracy, were addressed throughout the iterative design process, which led to its successful realization. The experimental focus centered on flight tests of the custom-built drone to ensure successful takeoff and stable flight during the controlled paint application. The main limitation encountered was the drone's inability to achieve stable flight due to the lack of tuning of the PID (Proportional-Integral-Derivative) control system. As a result, the drone faced challenges in maintaining its position and stability during flight, hindering the execution of the paint dispersion process. The drone has also not been significantly tested in flight with the paint canister in use yet, as stable flight remains the first challenge to be addressed.

Enhancing the Crazyflie Platform

Introduction

ACT Lab conducts research in the area of coordinated multi-robot systems. Central to this endeavor is the planning and enhancement of the Crazyswarm system. Leveraging ROS (Robot Operating System), planning algorithms, and VICON motion capture, the project accomplishes two major tasks: (1) enabling Crazyswarm flight with MAPF (Multi-Agent Path Finding) and (2) spontaneous and dynamic replanning.

Methodology

(1) Crazyflie positional data was synchronized with configurations at various time steps. The discretized paths coordinated the swarm for a mission involving Crazyswarm commands for takeoff, waypoint navigation, and landing. The system distinguished drones with unique LED colors.
(2) The system's core control component governs Crazyflie flight by subscribing to ROS topics that publish VICON camera system information. The A* algorithm is employed to derive the optimal path from the current position to the goal. The planned path is communicated through a ROS topic, allowing the drone to execute autonomous navigation, adjusting its trajectory based on dynamically changing goal positions.

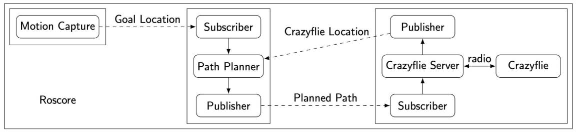

Figure 2: Crazyflie Replanning System Architecture

Results/Discussion

(1) A series of long-duration experiments were conducted, with the largest involving 31 drones. All Crazyflie crashes could be attributed to radio delays, VICON tracking, or proximity. (2) Successful experiments were conducted with a single Crazyflie drone alongside a dynamic human subject, where premature landings were attributed to tracking issues. Improvements for both systems include enhancing object tracking, vision-based tracking, radio communication, and trajectory smoothness.

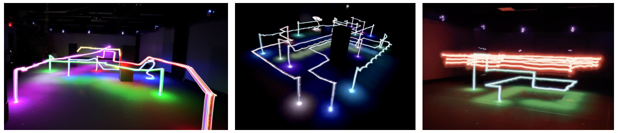

Figure 3: Crazyswarm Mission Long-Exposure Photos

Integrating JARVIS

Introduction

Recent interest in the convergence of AI and robotics has birthed JARVIS, an AI-driven chatbot JARVIS that integrates with ACT Lab's drone swarm to optimize movements and efficiency. Using advanced natural language processing and Meta AI's Llama 2 model, JARVIS executes precise drone operations via voice commands and controls drone positions, hues, and predefined flight paths in real-time.

Methodology

The system utilized a 7 billion parameter Llama 2 model on the NVIDIA GeForce RTX 4070 Ti GPU, and to improve consistency, it adopted a fine-tuned 7B-Chat model with function calling support, although post-processing modifications were required. For audio tasks, integrating Microsoft's speecht5_tts was planned, but it requires careful management of concurrent model loading due to hardware constraints. To enable real-time communication, the system utilized a local WebSocket connection. Current features include changing LED colors, issuing go-to commands, and creating predefined flight paths during drone operations.

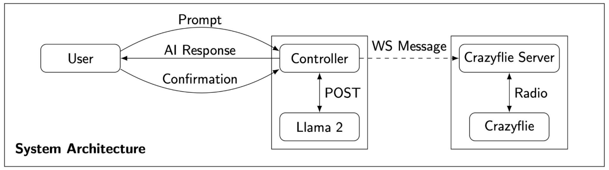

Figure 4: JARVIS System Architecture

Results/Discussion

While the system initially integrated OpenAI's GPT-3.5 Turbo's API, it switched to new models to preserve user privacy. JARVIS has successfully obtained real-time control of up to four Crazyflies, with LED color changes, go-to commands, and the formation of regular polygons. It also executes tasks like generating YAML files and launching RViz. Current limitations such as understanding prompts could be improved by loading larger models, but fine-tuning remains a challenge. Additionally, the WebSocket server operates locally, requiring users to connect to the same machine for interface communication. Future plans include hierarchical control for dynamic adaptations and relative trajectories such as orbits.