

## **Swarm Robotics Software and Theory**

### **Introduction**

Swarm robotics is a developing approach to the control of multirobot systems [1]. Its applications include education through robotics and cooperative robotic vehicles to be used for search and rescue missions to find missing aircraft [2]. This paper reviews commercially available software for swarm robotics and the decentralized control algorithms that can be its foundation.

### **Commercial Applications**

#### *Kilobot*

Harvard's Kilobot swarm [3] consists of 1024 cooperative robotic vehicles, each with a 33 mm diameter. The swarm's purpose is to research collective artificial intelligence and better understand theories that connect minimal robot capabilities to the overarching goal of achieving efficient swarm behavior. Via the Kilobot Controller's software, KiloGUI [4], users can upload programs to test these theories by performing swarm operations. This software is available for free download online and a pack of 10 Kilobots costs \$1109.99, distributed in Central America by RoadNarrows LLC and K-Team Corporation [3].

#### *Decentralized Control Algorithm*

The Massachusetts Institute of Technology (MIT) [5] has developed a new decentralized control algorithm to implement cooperative robotics, arguing decentralized algorithms are superior to centralized algorithms because they will not immediately fail if the central controller is disconnected. Another advantage of decentralized control algorithms is their ability to handle communication throughout a swarm, despite unpredictable patterns. Centralized algorithms require a single controller to process all data and arrive at a solution. Decentralized algorithms give each robot partial data concerning its environment and surrounding robots. MIT's proposed application for this technology is decentralized drone swarms travelling in a formation for mapping or surveillance. This algorithm has been tested on two of Kuka's Youbots by successfully making them carry a single object together. Since the robots communicate near

each other without obstacles, the decentralized algorithm reduces bandwidth and computational cost.

## **Technology**

### *Kilobot Software*

Kilobots are programmed to communicate in KiloGUI [4] by dedicating one bot as the speaker and the other as the listener. To send a message through the speaker, the programmer must first declare a message of type `message_t`, then create the callback function `message_tx()` to return the declared message's address. The callback function will interrupt the main method every time a message is ready to be sent. Similarly, to receive the message through the listener the programmer must declare a `rcvd_message` variable that will be assigned to the received messages and create a callback function, `message_rx()`, to perform this assignment. This callback function will interrupt the main method when a message is ready to be received.

### *Graph Theory*

One of the most notable implementations of decentralized algorithms is graph-based multi-agent control, which can be implemented through the rendezvous problem [6]. In the rendezvous problem, a collection of robots communicates to meet at the same unspecified location. This problem assumes each robot only knows its position relative to its neighboring robots. To have all robots meet at a common location, each robot moves to the centroid of its neighboring set of robots, creating a static centroid that all robots move towards asymptotically.

## **Future Developments**

Currently, MIT [5] has only tested decentralized algorithms on simulated drones and physical robots like the Kilobots [3]. Future developments in this software technology include testing on full-sized vehicles and drones to perform similar swarm applications [5]. According to MIT researcher, Javier Alonso-Mora, drone implementation is far in the future and decentralized algorithms are still in the research phase.

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