UB Robot Swarm System: Design and Implementation

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Abstract

In this poster we described the hardware architecture of an inexpensive, heterogeneous, mobile robot swarm, designed and developed at RISC lab, University of Bridgeport. Each UB robot swarm is equipped with sensors, actuators, control and communication units, power supply, and interconnection mechanism. Robot swarms have become a new research paradigm in the last ten years offering novel approaches, such as self-reconfigurability, self-assembly, self-replication and self-learning. Developing a multi-agent robot system with heterogeneity and larger behavioral repertoire is a great challenge. This robot swarm is capable of performing user defined tasks such as wall painting, mapping, human rescue operations, task allocation, obstacle avoidance, and object transportation.

Introduction

Swarm robotics is inspired from the animals that behave in a group such as insects, ants and bees. Till date, most existing swarm robot systems have been designed and implemented with homogeneous hardware. Only a few of them have heterogeneous robots, but those swarm system were limited physically and behaviorally. Due to the lack of methods and tools, swarm robot designers cannot achieve the complexity required for the real world applications. The complexity of designing and physically implementing the heterogeneous robot swarm is greater when compared to the homogeneous robot swarms. There are several aspects involved in the development of robot swarm hardware, such as locomotion, actuation, navigation, size, appropriate sensors, cost, and communication. One of the challenges for robot swarm is its autonomy, as the robot must be aware of its battery life, self localization etc.

After reviewing existing swarm systems and studying the limitations, we decided to design and built our own robot swarm system. In this design we have considered some important factors such as its size, cost, autonomy, flexibility, robustness, power consumption, weight, etc. The main goal of our research is to build a heterogeneous robot swarm system in which each robot has a distinct type of hardware compared to other robots. The proposed architecture is an autonomous, modular, heterogeneous robot swarm with self-configurability, self-assembly, and self-learning capabilities. Nowadays electronic products are cheaper, smaller, lighter in weight and easily available, which makes robot swarms more cost efficient, lighter in weight, and compact in size .

Hardware Design

The hardware design for any swarm is an interactive and an important phase; as all components and/or parts are assembled to build one robot swarm. Swarm robots developed so far are aimed to provide a research platform and not intended for real-world applications or vise versa. In this section, we explain the hardware architecture of the UB robot swarm. This swarm of heterogeneous robots is designed for real physical world applications in order to perceive their environmental physical properties through sensors and do the manipulation and localization using actuators. UB swarm robots can be used for real life applications as well as for research purpose. This modular hardware architecture consists of independent sensory unit, actuator modules, and communication unit, that make swarm system scalable and flexible such that more sensors and/or actuators can be added without modifying the overall architecture. The fig. 1 shows an overview of the hardware design implementation.

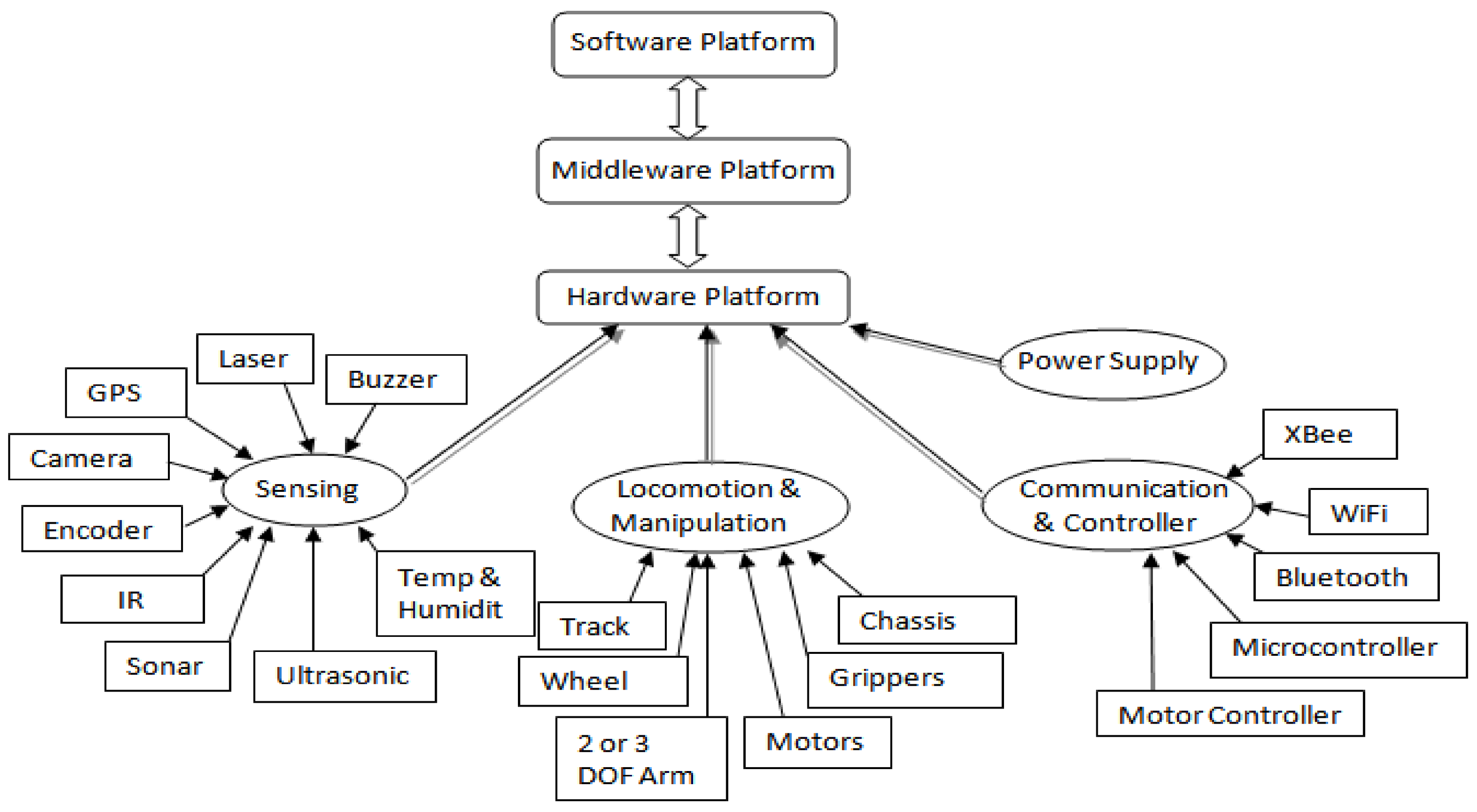

Figure 1: Hardware Architecture Design

Design Goals

There are many things that have to be considered while designing and implementing the hardware platform for the heterogeneous robots. Following are the design goals for UB swarm of heterogeneous robots, such as:

• Each robot should be easily modifiable and compatible with a high performance microcontroller.
• Should consume less power.
• Should provide user friendly mobile, modular, and flexible platforms.
• They should be reconfigurable and provide easy support for the software as well as for the middleware.
• They should provide low cost wireless communication for indoor as well as outdoor applications
• They should have enough future expansion space for sensory units and actuators.
• The robot should be relatively of different size and shape with light weight, so that it can allow ease of movement and maneuverability.
• Each robot should be fully functional, and continuously coordinate and communicate with other robots.

UB Robot Swarm

We have designed and built five UB swarm robots and performed several experiments to demonstrate the system's feasibility (video clips are available on the Web). The fig. 2-5 shows the images of UB robot swarm after implementing and mounting all the sensors and actuators. The hardware architecture of UB robot swarm is reconfigurable and can be reassembled at any time. Also the hardware architecture is very flexible; we can connect any type of sensors without doing any modification to it. This robot swarm was tested for a set of different experiments such as object avoidance, object transportation, human rescue, wall painting and mapping.

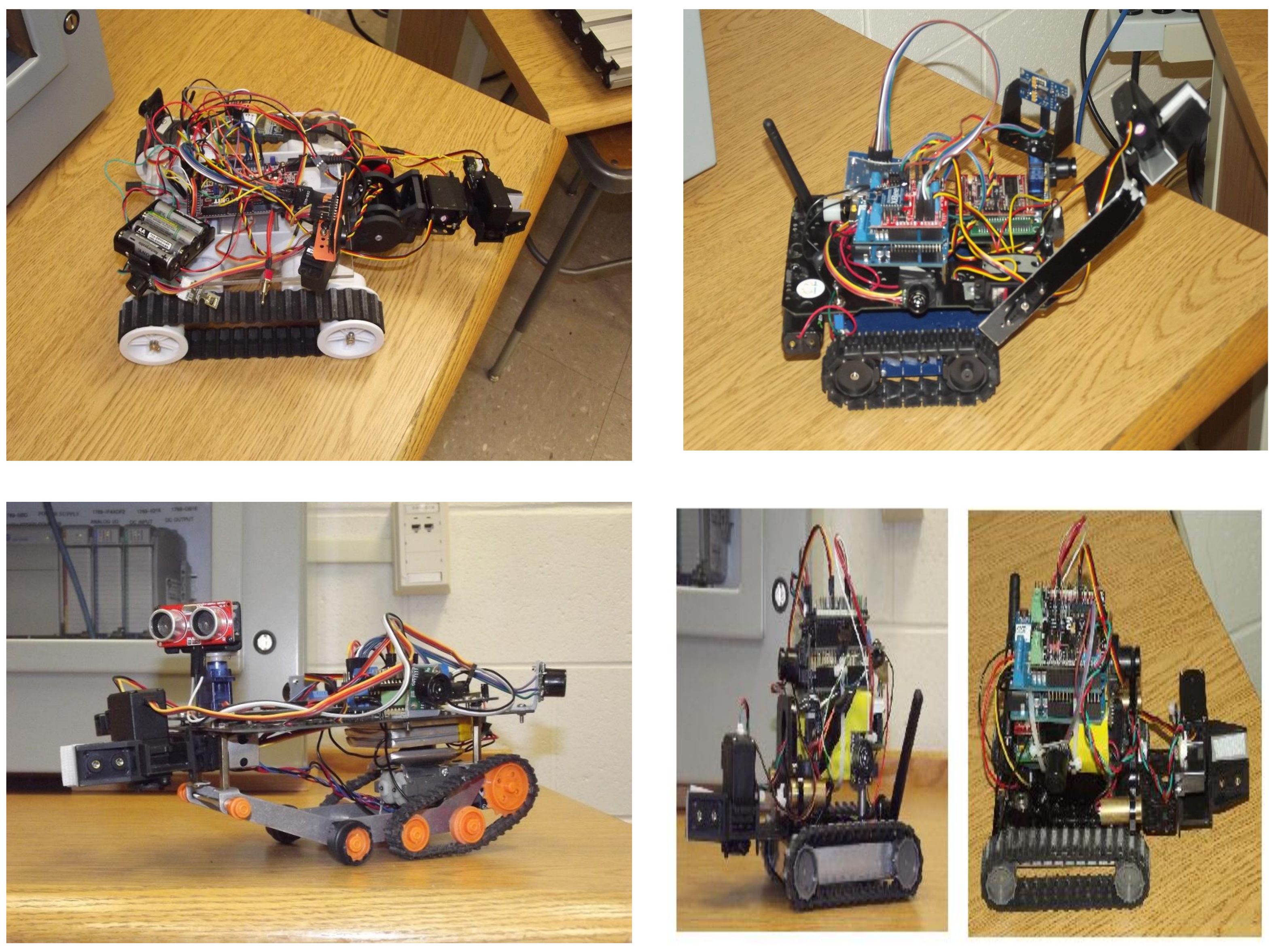

Figure 2-5: Images of UB Robot Swarm.

Human Rescue

Unstructured or unstable environment generated due to major accidents, natural disasters, and catastrophic events requires urgent intervention for rescuing humans. In such situations, the common operations are search, monitoring, rescue and transport. One of the tasks we tested using our robot swarm is to rescue a human. Our demonstrated example of search and rescue task shows the different integrated abilities of these heterogeneous robot swarm such as search, object detection, path planning and navigation, reconfigurability and rescue operation.

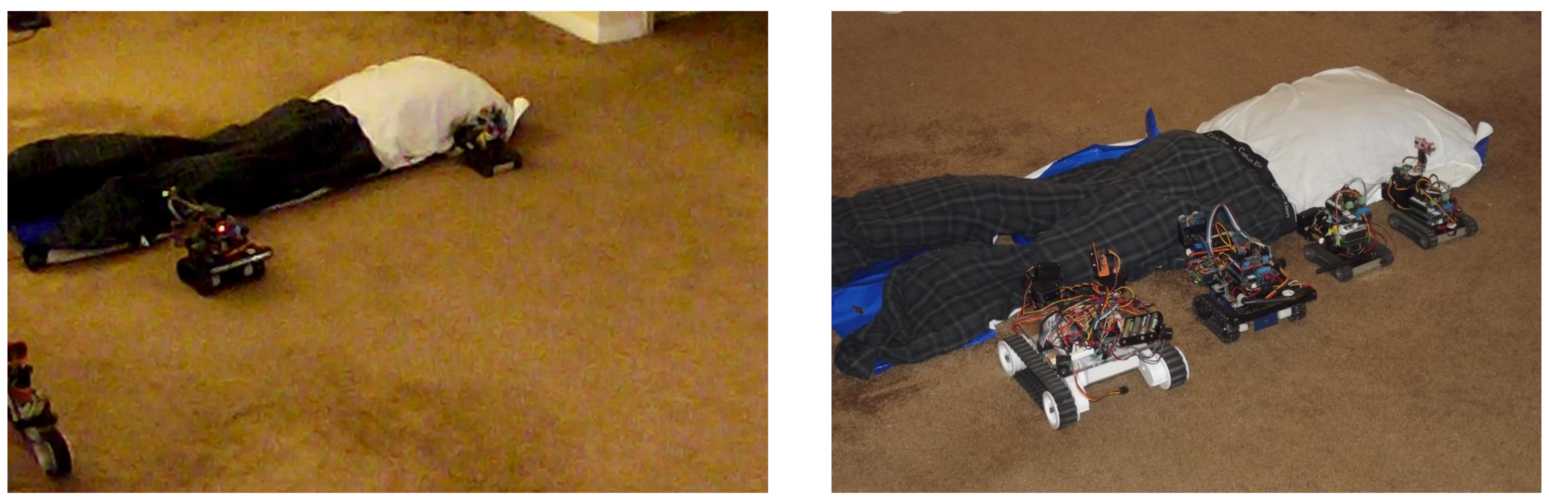

Figure 6-7: Human rescue using 2 and 4 robots of UB Swarm.

In this poster we describe a human rescue task and compare the results with increasing the number of robots in the swarm. To conduct this experiment we built small arena and initially robots placed randomly in the arena. A small web camera is mounted on the top of arena so that we can record the experiments. We created a dummy human lying on ground inside the arena and robot swarm tries to rescue that dummy human by pulling it to a safe location. Initially we deploy only two robots of UB swarm for this task and record the time required by them to finish the task. After that we add one more robot to do the same task and recorded the time required for them to complete it. We did the same experimental task by deploying four and five robots of UB swarm and then compare the time required by them to complete the task. The result of these experiment shows that the time required for five robots is very less and execution is more efficient than in the other scenarios. The fig. 6 and 7 shows human being rescued by using two and four robots of UB swarm respectively. Table **1** shows the result of the human rescue task using UB robot swarm.

No of Robots	Time required (Minute)	Distance travelled (feet)	Task accuracy (%)
2	20	89	48
3	17	129	54
4	14	176	63
5	10	210	72

Table 1: Experimental result of human rescue task

Conclusion

The UB robot swarm system is heterogeneous, and can achieves more robustness, flexibility, scalability by adding sensors such as chemical sensors, speech recognition sensor, more grippers, and robot arms. The proposed hardware architecture of heterogeneous robot swarm is designed, built and tested. We describe all the hardware components used to build UB robot swarm. The developed swarm robot approach uses decentralized control strategies within the swarm of heterogeneous robots. The robot-to-robot and robot-to-environment interaction provides the task oriented, simple collective swarm behavior.

This is an ongoing project and for more information please visit:– https://sites.google.com/site/madhavdpatil01