

TinyRobo: A Platform for Tabletop Swarm Research

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Abstract—Previous platforms for swarm robotics have relied on custom-manufactured mechanical assemblies for their mobility. Because these assemblies are usually hand-made in limited numbers, they restrict the availability of swarm robots to organizations with large budgets. Recent attempts to avoid this problem, such as the Harvard Kilobots [Rubenstein et al., 2014] have reduced sensing and processing ability in order to remain small in size. This paper presents a hardware platform and a proposed software infrastructure to sidestep both problems, resulting in a swarm platform that is cheap and easy for researchers to duplicate. The platform permits heterogeneous mobility solutions and flexible visualization of sensing and inter-robot networking.

I. INTRODUCTION

Swarm robots are generally small. The reason to keep swarm robots small is at least three-fold. First, larger robots consume more materials per unit, and so cost more money. As a result, for a given number of swarm units, larger robots will result in a higher cost swarm. Second, each robot requires some amount of space to move around in. To keep the ratio of free space to robots constant, the area of space used by the robots grows as the robots do. If the ratio isn't kept constant, the robots will crowd each other, and so large robots will require either a very large space, or become overly crowded. The challenge of construction of swarm robot hardware, then, is to put all of the same parts as non-swarm mobile robots: a mobility platform, a power supply, a processor, some sensors, and a communication system, into a small package.

The robots used in most swarm work are of a sufficiently small size that many of them can fit in a room. The lower bound on the size swarm robots is generally dictated by fabrication technology, with smaller robots becoming increasingly difficult to assemble. As a result of these bounds, swarm robots are mostly between 1cm^3 and 0.3m^3 . This scale range divides fairly evenly into robots that can operate in large swarms on a table, and those that can operate in swarms within a room, albeit possibly a large room. Room-scale swarms, being composed of larger robots, can be equipped with significant on-board processing power. However, for the purposes of this work, only tabletop swarms are considered.

II. OVERVIEW OF PREVIOUS SWARM HARDWARE

Tabletop swarm robots generally occupy the size range from 1cm^3 to 15cm^3 . Many impressive designs for small swarm robot platforms have been proposed and constructed

as part of research in swarm robotics. At the low end, in terms of scale, the I-SWARM Project was intended to create a $2\times 2\times 1\text{mm}$ robot that moved by stick-slip locomotion actuated by piezo levers [Seyfried et al., 2005]. Other techniques have been developed to use magnetic fields to apply force to small magnetic objects, resulting in controlled motion of the objects [Floyd et al., 2008], [Pelrine et al., 2012]. Alice [Caprari et al., 1998] combined a PIC16F84 processor, motors, RF and IR networking, and enough battery power for 10 hours of autonomy into a robot measuring under 2.5cm^3 . The AmIR robot was similar to Alice in size and capability, but with a more modern processor [Arvin et al., 2009]. The Jasmine swarm robots were possibly the closest approach to a commercially-available successor to Alice [Kernbach, 2011]. Jasmine measured $26\times 26\times 20\text{mm}$, and included an ATmega processor, IR close range communication and obstacle detection, two motor skid steering, and li-po batteries. InsBot was a small robot, measuring $41\times 30\times 19\text{mm}$, that was designed to interact with cockroaches [Colot et al., 2004]. It used two processors, one to run higher level behaviors and one to interface with a suite of sensors that included 12 IR sensors and a linear camera.

None of the previously listed robots are currently commercially available, and many of them never were. Even when they are commercially available, most existing swarm robots are too expensive to build a large swarm. The Eepuck from EPFL costs approximately 800 Swiss francs (\$810 USD) per unit, so the cost of maintaining a large swarm can become daunting quickly. Jasmine robots cost about 100 Euro (\$111 USD) when they were available. Even the Kilobots [Rubenstein et al., 2014] cost 1100 Swiss francs for a 10-pack, or about \$112 (US) per robot.

One way to reduce the cost of swarm robots is to use commercial, off-the-shelf (COTS) hardware in the construction of the robot. Reusing existing hardware leverages the economies of scale that reduce the price of commercial hardware, as well as eliminating the need to design or build the COTS parts. Use of COTS parts in research robotics has led to at least two platforms referred to as COTSBots [Bergbreiter and Pister, 2003], [Soule and Heckendorn, 2011]. The first COTSBots used mote hardware for the communications link and sensing, plus a motor control add-on board [Bergbreiter and Pister, 2003]. The mobility platform is a modified toy, in particular, a specific brand of high-quality micro RC car. At the time of this writing, the car used in COTSBots is moderately expensive for a toy car, costing a little over \$100USD per unit.

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A. TinyRobo Hardware

In order to avoid the sensitivity to the work surface exhibited by the Kilobots and, to a lesser extent, the Epucks, TinyRobo uses children's toys as mobility platforms. The TinyRobo controller module was designed to be used as a replacement for the control electronics of children's toys, similar to the Spider-Bots developed by Laird, Price, and Raptis or Bergbreiter's COTSBots [Laird et al., 2014], [Bergbreiter and Pister, 2003]. However, unlike the Spider-Bots and COTSBots, TinyRobo does not specify a particular toy chassis to use for mobility. TinyRobos are intended to be heterogeneous, partly because of the advantages of heterogeneity in a swarm, and partly because toy supplies are unreliable. While toys in the general case are expected to remain available, a particular line of toys might be discontinued or a modified version released. The software framework in development to support TinyRobos is based on ROS, and so will allow modular replacement of the control algorithms used to convert desired motion of the robot into drive signals for the motors.

Modified toys are an adequate substitute for custom mechanical assemblies, and permit easy experimentation with heterogeneous swarms. Most children's toys use either one motor with a mechanical linkage to cause the toy to turn when the motor is reversed, or two motors. Two-motor toys frequently use either differential steering or have one motor supply drive power and the other provide steering. All of these toys can be controlled by the hardware described in this work.

The ESP-8266 wifi module for wireless communication and as a micro controller. The ESP-8266 costs approximately \$3-5, and contains both a wireless interface and a micro controller that can be programmed from a variety of programming environments and languages, including Lua and the Arduino variant of C/C++. The ESP-8266 is available in several form factors, each designated by a different suffix. The version selected is the ESP-8266-03, which offers more GPIO pins than most other versions, and includes an internal antenna, which some versions lack.

The robot described in this work is intended to occupy a theoretical "sweet spot" at the high end of the tabletop swarms or the low end of the room-scale swarms, depending on how large of a mobility platform is used. As a result, if it is configured for tabletop operation, the system can be used with a minimum of available space. If, on the other hand, it is configured for room-scale operations, the system can be tested in natural or naturalistic human environments.

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