

A Study on Bio-inspired and Physical SWARM-BOT Design

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Abstract

Throughout history, scientists and engineers have looked to nature for inspiration and dreams in order to solve problems in real-world situations. The emergence of 'swarm intelligence notions' has been based on observations of the performance of swarms of bees and ants working together. The construction of self-independent and self-intelligence swarm robots is one of the most intriguing and fresh explore areas of recent decades towards the outstanding challenge of robotics. This notion might be critical for robots operating in environments that are amorphous or difficult to access for a single operator, such as a twisted structure, the deep sea, or the surface of another planet. The underlying bio-inspirations of swarms and their physical configurations, such as reconfigurability, replication, and self-assembly, are studied in this research. Swarm-bot, which focuses on miniaturisation with robustness, adaptability, and scalability, is used to introduce the swarm ideas. The numerous swarm-bot intelligence, self-assembly, and self-reconfigurability among the most significant key capabilities as well as usefulness of swarm robots are discussed in this work.

Keywords: *Bio-Inspiration, Environments, Flexibility, Physical configurations, Swarm-bot*

INTRODUCTION

Swarm-bot is an intelligent design that combines multiple very small mobile

robots to provide the needed functions and can self-assemble into a huge individual identity. A swarm-bot entity [13] is a

physical organisation of numerous (2 to 35 swarm-bots) single robots. Each swarm-bot is a completely autonomous [2] mobile robot capable of performing fundamental tasks such as autonomous direction-finding and vision to grab items in its environment.

The swarm-unique bot's characteristic is its ability to create high-density connection mechanism devices that can be patched into multiple places depending on the surroundings.

Several bio-insects [1] exploit the swarming bots, which give a collective robots inter-action with all are frequently that implicit environment. Insects include ants, bees, and flies [19], which have six legs and a split body.

SOURCES OF INSPIRATION

Many scientific disciplines are focusing on robotics, with self-organizing systems [3] serving as inspiration for swarms. The swarm's first and most important function is self-organization learning, which is described as "a process in which a pattern at the global level of an organisation arises entirely through multiple linkages among the organization's lower-level systems." Swarm-bots may be thought of as the

growth and functionality of self-organization in a physical form in this way.

The balance of positive and negative feedback of connections among people is necessary for self-organization in biological systems, according to studies [1], [3]. Some social insects [19] spend the most of their time searching for food, such as ants and bees. Honey bee colonies have a decentralised system for collecting food, and they may fine-tune their seeking tactics to improve the system's collection.

Figure 1 shows how bees estimate the distance from the hive to food sources by assessing the amount of energy used while flying, as well as the direction and quality of the food source. The construction of swarm bots [13] is inspired by such phenomena as decentralisation, searching, and arriving at the optimal path.

MOTIVATIONS FOR SWARM INSPIRATIONS

- a) Robustness necessitates that the swarm robotic organisation [1] be able to continue operating, although at a lesser level, despite individual failures or environmental problems.
- b) Flexibility necessitates the capacity of the swarm robot organisation to

develop modularized solutions to various jobs. Take part in a variety of duties, including as foraging, prey retrieval, and chain configuration, as adequately identified by ants. [6]

- c) Scalability necessitates the capacity of a swarm robotic organisation to function across a wide range of group sizes.

- d) Low-cost robots can possibly reduce total costs by producing several copies of a single type modulus.

So, with this economy of scale, one set of modules saves money by reusing and producing the system. Figures were taken from swarmbot.org.



Figure 1 . Foraging Swarm

Figure 2. Flocking Fish



Figure 3. Foraging behaviour of ants [Source: swarmbot.org]

Swarm Robot Features:

- Collected many individuals
- Individuals are maximum homogeneous structure
- Individuals are relatively incapable
- The interactions among the individuals are based on the behavior rules that exploit only local in sequence (communication)
- The overall behavior from self-inspiration process coordinated exploration.

- Simple behaviors based on odor and wind detection
- Communication can help to increase the efficiency

Pheromone Robotics

- Robot dispersion
- Shortest path
- Pheromone diffusion

Chaining

- Limited sensing range
- Signaling of colors
- (directional chains)

Environmental Monitoring

- Swarm of mobile robots for localizing an odor source

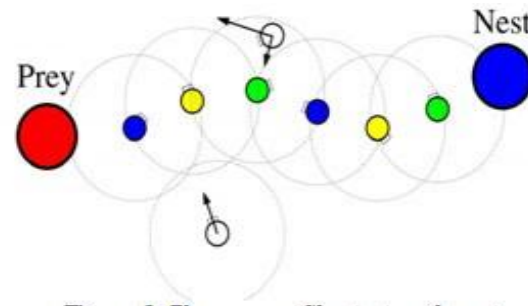
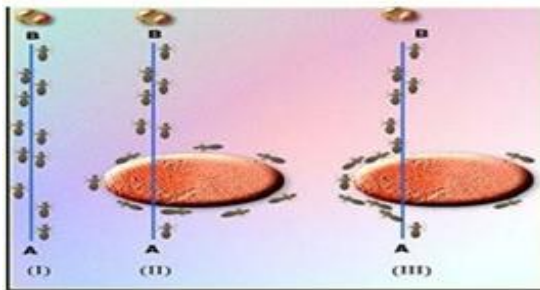


Figure 4 Ant pheromone shortest path route **Figure 5. Pheromone Shortest path route**



Figure 6. Chaining

PROBLEM IDENTIFICATION

Many scholars in the field of self-reconfigurable robots have previously developed the problem of interconnection between existing modular robots. Certain module robots, such as MTRAN and Polybot [4],[5],[6],[15],[16], show some user-friendly connections in the MTRAN design [2], which is based on the permanent magnet technique and non-linear springs for disassembly. The latching mechanism grips the polybot connection between the plates, which is

made up of four groove pins that match four holes or opposing plates. Both have a mechanical locking mechanism in place. The CONRO modules [10],[16] feature a pin-based connection, although this module is not neutral, as seen in figure 7. The system includes two types of modules: I-cubes and molecular module robots. One module focuses on structure, while the other focuses on connectivity (connecting complex shapes only possible).

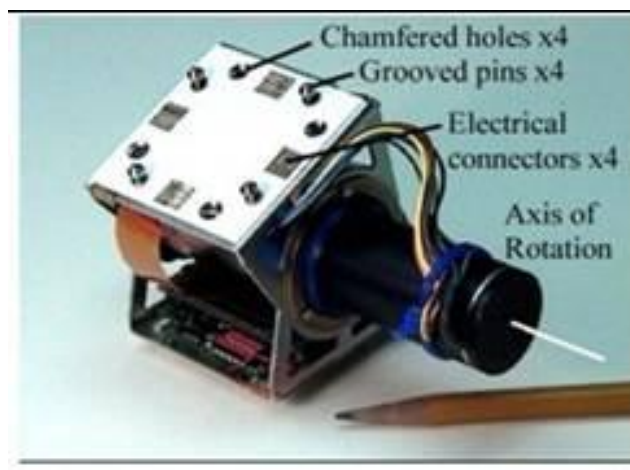


Figure 7. Polybot module[5]

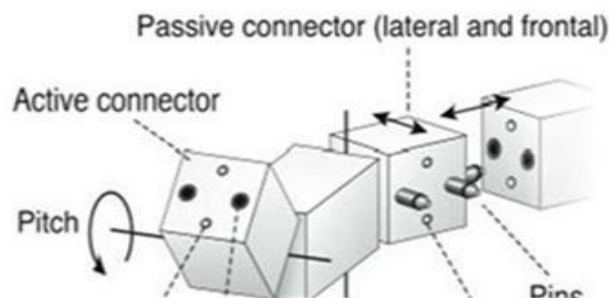


Figure 8. Polybot module linking mechanism [5]

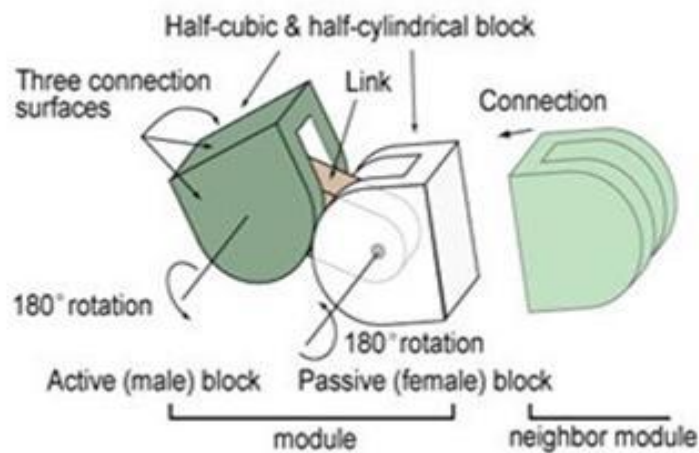


Figure 9. MTRAN Module [2]

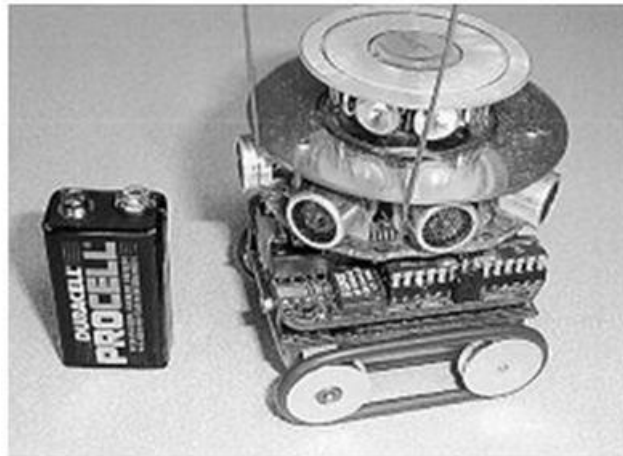


Figure 10. Millibot model [9]

As demonstrated in picture 9, MTRAN modules [6] have just flat contact surfaces for higher misalignment tolerance. Mechanical parts that use friction do not endure any lateral forces. Millibots are any two modules that are interconnected [6], [8],[10] in the absence of a structure. They have a more intricate pattern. Millibot design [9] is based on a simple pin-hole concept for mechanical stability, but it is difficult to perform the task and requires

more sensors in the joints, as shown in figure 10.

When assigned the task of creating a robotic system, the researchers' primary concerns are the hardware architecture and control system architecture. The outcomes of the swarm-bots project have been given in this debate. The swarm bots project [13] was primarily concerned with evaluating two different robotic system design

options. We chose to implement a system made up of many autonomous robots [2] with the unique ability to attach to (and detach from) one another for the hardware.

So that larger, physically linked structures may be formed[11] and this system can be controlled using the information supplied. These choices were motivated by the desire to make our robotic system the swarm-bot robust and versatile (By saying that a robot is versatile we mean to say that it is capable of dynamically changing shape and control functionality depending on the situation it faces], as well as

allowing it to navigate on rough terrain.

MECHANICAL CONCEPT AND IMPLEMENTATION

The connection between the bots in a swarm-bots setup is based on the aforementioned two-dimensional form matching without penetration. The link mechanism is a gripper that resembles the form of a ring on the robot's main body. Two linked swarm-bots with the detail of gripper and ring form matching. A robot may hold another robot all around its body using this principle.

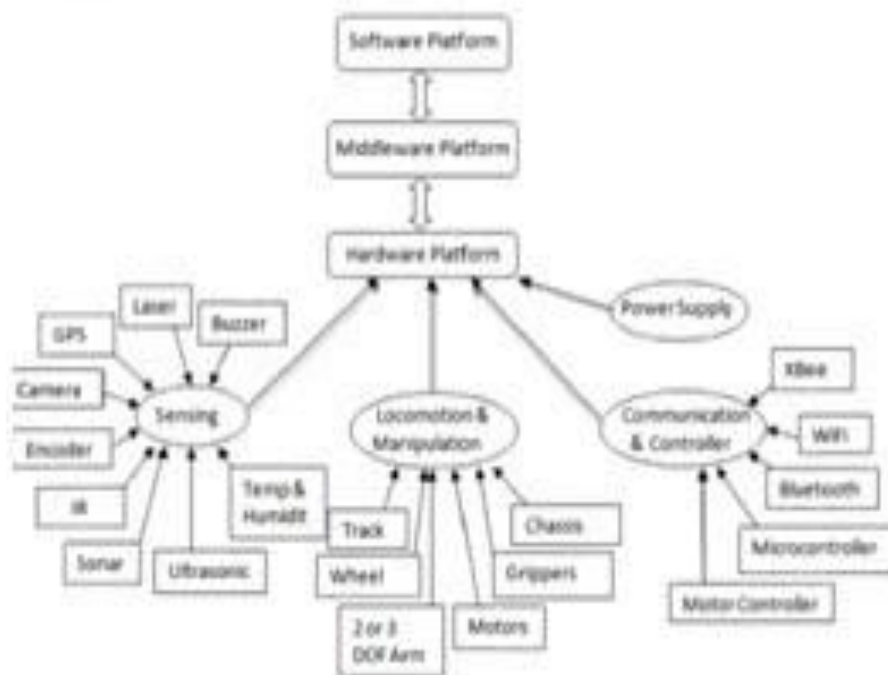


Figure 11. Hardware architecture of Swarm- Bot

ROBOT DESIGN

Swarm-Bot Size

The swarm-bot is about the size of a tiny ball, with a height and diameter of 19cm and 12cm, respectively. It also weights around 700g-800g. [1]. All-direction mobility treels drive mechanism (2DOF), rotation of the main body with respect to the motion base (1DOF), rigid arm with gripper (2DOF), flexible arm with gripper (4DOF), sensors, panoramic camera and microphones, and transparent ring with color LEDs Loudspeakers are among the main components. Two grippers are included with each Swarm -bot.

RIGID GRIPPER

A stiff structure with one degree of freedom (DOF) supports one. With one active degree of freedom on each inter-robot link, the stiff gripper enables for exceptionally stable multi-robot architectures.

FLEXIBLE GRIPPER

The second is attached to the end of a three-degree-of-freedom flexible arm. The flexible gripper enables for the development of a variety of different configurations on the terrain's surface. Because the flexible gripper can stretch all the way to the ground, it may be used to grasp things as well. In swarm-bot setups, the two grippers perform significantly diverse functions [12], [18]. In our assessment of Swarm-bot, we looked into mechanical robustness in autonomous operations [2]. It has fewer mechanical connections and locations that resemble a gripper, as depicted in Figure 12. The robot systems in this study are built on two-dimensional structures that harmonise without being dispersed. Mechanisms utilised by animals for this kind of work, such as mandibles, are discussed in this module. [It's as simple as jaws]



Figure 12 Gripper model[11]



Figure 13. Swarm collaborate to pass an obstacle[14]

MECHANICAL REPRESENTATION

A Swarm-bot [13] entity is a physical organization of numerous (2 to 35 swarm-bots) single robots. There is no dispersion in the Swarm-bot connection since the Swarm-bots have 2D form matching. The mechanism consists of a gripper that matches the location of a ring on the robot's main body. Figure 13 depicts two linked Swarm-bots with a position detail matching to the gripper and ring. A Swarm-bot can use this approach to snare another Swarm-bot all over its body.

MOBILITY

The system's movement is provided by a mix of rails and wheels. Differential treels drive is the name given to this sort of construction. Each side of the treels (one track and one wheel) is driven by a motor so that the Swarm-bot may freely travel in the surroundings and simply spin on the

spot. This arrangement offers a very excellent mobility, owing to the position of the wheel and their diameter bigger than the tracks height. The supply of motivation for a robot design is obtained from nature and is generated by ecological demands [19]. It presents diverse comprehension of the wide- reaching applications concerns needed to develop a robot for robotic swarm applications [12]. The premise of a swarm robot design plan is that it should be very simple and reasonably cheap to construct.

For example, if one robot would go misplaced or broken beyond repair during an assignment it would not matter much. Measure is the key to success in a robotic swarm to properly apply Swarm intelligence (SI) algorithms. A robot should be somewhat powerful, convenient to use, and valuable [3]. In robotic swarm

applications, there are a number of designs that meet these criteria. One instance of such a robot is the swarm-bot, [7],[13],[15],[19]. The Swarm-bot as the name suggest is developed for swarm applications and it's ideal for swarm functions.

SWARM APPLICATIONS

Tasks That Are Too Dangerous Cover An Area

As illustrated in figure 14, in numerous dangerous activities such as mine rescue and recovery, robots may be permanent once the task is over; consequently, it is more cost-effective to deploy swarm robotics with simple and low-cost persons rather than complex and costly robots.

TASKS THAT REQUIRE IDLENESS

Swarm robots may also be used in instances where estimating the finances required to complete activities such as search and rescue, tracking, and cleaning

is difficult or impossible. In these situations, a scalable and adaptable solution is desired; hence, a robot swarm may be an enticing option: robots may be added or deleted at any moment without affecting performance, allowing the right number of resources to be provided while meeting the task's needs. When you look at a swarm, you'll see that it works as a group to fulfil a mission rather than as a single robot. A swarm can be thought of as a single enormous creature. A robotic swarm or multi-robot system is made up of several highly interconnected elements.

The physical linkages are utilised to build Swarm-bots, which can solve problems that a single robot cannot handle. By utilising load interaction among the Swarm-bots, Swarm-bot is capable of autonomously carrying out individual and collective behaviour [11-12]. As seen in figure 15, these bots are always looking for a desired site or drawing a path to there.



Figure 14. Rescue operation carried out by a group of swarm-bots. [14]

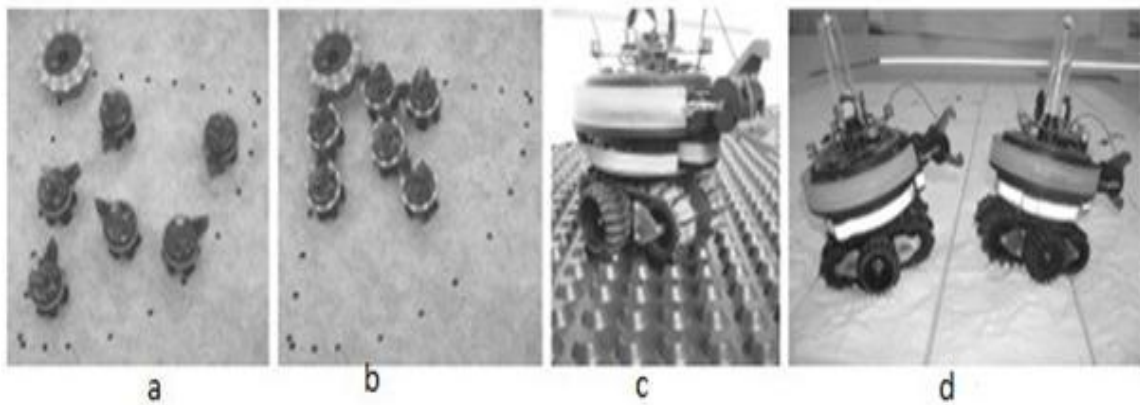


Figure 15.Initial (a) and final (b) configuration of six s-bots self-assembling with the prey on flat terrain. Types of rough terrain: the moderately rough terrain (c), and the very rough terrain (d).

COMPARISON OF SWARM BOT AND MRS ROBOTICS

Table 1. Comparison of Swarm Bot and MRS robotics

Characteristics	Swarm robots	MRS
Population Size	Variation in great range	Small
Control	Decentralized and autonomous	Centralized / remote
Homogeneity	Homogeneous	Heterogeneous
Flexibility	High	Low
Scalability	High	Low
Environment	Unknown	Known/Unknown
Motion	Yes	Yes

Our topic is divided into two categories: collaborative robotics (MRS) and self-reconfigurable robotics (SRR) [3-6],[8],[10]. Many of our decisions and tactics are bio-inspired, in the sense that they are based on natural processes or biological observations. We do not, however, attempt to perfectly mimic any natural system; instead, we draw

inspiration from natural processes and allow these principles drive our engineering decisions. Our research varies from that of collective robotics in that we are interested in the study of self-assembling structures and their application to challenges that need collaboration through physical connection.

We study robotic structures as swarm-bots that can change their shape as a function of the task they are performing, similar to self-reconfigurable robotics, except that the units that make up our self-reconfigurable robot are autonomous units that can perform tasks independently or cooperatively, depending on the task at hand.

CONCLUSION

We explored the research of the challenge of self-assembly in autonomous mobile robots in this work. With current technology, real-world applications for robotic swarms are restricted, where supervision, swarm interactions, and energy accumulators are major considerations. Through bio-inspired and communal robotics, this notion introduces several novel components, opening up new research paths in swarm robotics and distributed intelligence. Despite the physical connection between Swarm-bots, which makes them comparable to self-reconfigurable robots, some essential components of the swarm-bot method have demonstrated to be complimentary to self-reconfigurable robots.

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