AUTONOMOUS SWARM ROBOTIC SYSTEM.

Meet Patel

Abstract— Paper gives overview of swarm robotics, how it works, requirement, advantages, limitations, and implementation. This system helps to automate most of the works. The basic principle of operation is simple and it uses simple programming knowledge and helps to coordinate group of robots. In today's technology driven industry, many a times a same task needs to be carried out at multiple places at once. For completion of such a task a large amount of man-force or machinery are required which are many a time not economical. As a solution to this, I designed and fabricated a swarm robotics system which works autonomously as a line following robot system, the only difference being that the slave robots are controlled not by the operator but by the master robot via a RF transmitter and receiver. This concept can help make many complicated tasks simple as these robots can do seemingly tough tasks with high precision and co-ordination. The computer program used to control both the robots is a Hexadecimal Program and the robots are operated by 5v DC Batteries.

Index Terms— Autonomous Robots, Nubots, Particle Swarm Optimization, Quasi-identical members, Swarm Robotics.

◆

1. Introduction

1.1 Field of Invention

Swarm robotics is the study of how to coordinate large groups of relatively simple robots through the use of local rules. It takes its inspiration from societies of insects that can perform tasks that are beyond the capabilities of the individuals. Benin describes this kind of robots' coordination as follows:

The group of robots is not just a group. It has some special characteristics, which are found in swarms of insects, that is, decentralized control, lack of synchronization, simple and (quasi) identical members.

1.2 Background of Invention

The expression swarm intelligence was first conceived by Beni to denote a class of cellular robotic systems in 1980s. these works used many simple agents occupy one-or two-dimensional environment to generate patterns and self-organize their nearest neighbor interactions. At that time, the definition swarm intelligence only marginally covers works on cellular robotic systems, which does not take the inspiration from social insect behavior. Recently, the expression "swarm intelligence" moved on to cover a wide range of researches from optimization to social insect studies, losing its robotics context in the meantime. Nowadays, the term SR has started to be used as the application of swarm intelligence to multi-robot systems. is concern was first explicitly started by Sahin in 2005.

As previously mentioned before, an SRS must have three functional properties at the system level that are observed in natural swarms:

Robustness is the ability to operate despite disturbances resulting from the malfunctioning of its individuals. For instance, lost individuals can be immediately replaced by others, with the operation will continuing smoothly. is is seen as the key advantage of the SRS approach.

Flexibility is the ability of an SRS to generate modularized solutions to various tasks, meaning that an SRS must be able to adapt their behaviors to different environments. Scalability is the ability of an SRS to operate with a wide range of group sizes and support a large number of individuals.

2 Swarm Robotics

2.1Brief Description of Swarm Robotics

Swarm robotics is currently one of the most important application areas for swarm intelligence. Swarms provide the possibility of enhanced task performance, high reliability (fault tolerance), low unit complexity and decreased cost over traditional robotic systems. They can accomplish some tasks that would be impossible for a single robot to achieve. Swarm robots can be applied to many fields, such as flexible manufacturing systems, space crafts, inspection/maintenance, construction, agriculture and medicine work.

Swarm-bots are a collection of mobile robots able to self-assemble and to self-organize in order to solve problems that cannot be solved by a single robot. These robots combine the power of swarm intelligence with the flexibility of self-reconfiguration as aggregate swarm-bots can dynamically change their structure to match environmental variations.

2.2 What is “swarm”?

As robots become more and more useful, multiple robots working together on a single task will become common place. Many of the most useful applications of robots are particularly well suited to this “swarm” approach. Groups of robots can perform these tasks more efficiently, and can perform them in fundamentally difficult to program and co-ordinate.

Swarm robots are more than just networks of independent agents they are potentially reconfigurable networks of communicating agents capable of coordinated sensing and interaction with the environment.

2.3 Social insects motivation and inspiration

The collective behaviors of social insects, such as the honey- bee’s dance, the wasp’s nest-building, the construction of the termite mound, or the trail following of ants, were considered for a long time strange and mysterious aspects of biology. Researchers have demonstrated in recent decades that individuals do not need any representation or sophisticated knowledge to produce such complex behaviors. In social insects, the individuals are not informed about the global status of the colony. There exists no leader that guides all the other individuals in order to accomplish their goals. The knowledge of the swarm is distributed throughout all the agents, where an individual is not able to accomplish its task without the rest of the swarm.

Social insects are able to exchange information, and for instance, communicate the location of a food source, a favorable foraging zone or the presence of danger to their mates. This interaction between the individuals is based on the concept of locality, where there is no knowledge about the overall situation. The implicit communication through changes made in the environment is called stigmergy. Insects modify their behaviors because of the previous experiences.

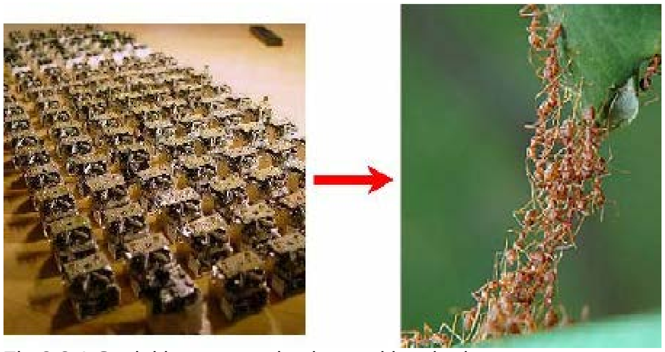

Fig 2.3.1 Social insects motivation and inspiration.

3. Working of Swarm

3.1 Swarm Intelligence:

Swarm intelligence describes the way that complex behaviors can arise from large numbers of individual agents each following very simple rules. For example, ants use the approach to find the most efficient route to the food source. Individual ants do nothing more than follow the strongest pheromone trail left by other ants. But, by repeated process of trial and error by many ants, the best route to the food is quickly revealed.

3.2. Software from insects

Local interactions between nearby robots are being used to produce large scale group behaviors from the entire swarm. Ants, bees and termites are beautifully engineered examples of this kind of software in use. These insects do not use centralized communication; there is no strict hierarchy, and no one in charge.

However, developing swarm software from the “top down”, i.e., by starting with the group application and trying to determine the individual behaviors that it arises from, is very difficult. Instead a “group behavior building blocks” that can be combined to form larger, more complex applications are being developed. The robots use these behaviors to communicate, cooperate, and move relative to each other. Some behaviors are simple, like following, dispersing, and counting. Some are more complex, like dynamic task assignment, temporal synchronization, and gradient tree navigation. There are

ISSN 2229-5518

currently about forty of these behaviors. They are designed to produce predictable outcomes when used individually, are when combined with other library behaviors, allowing group applications to be constructed much more easily.

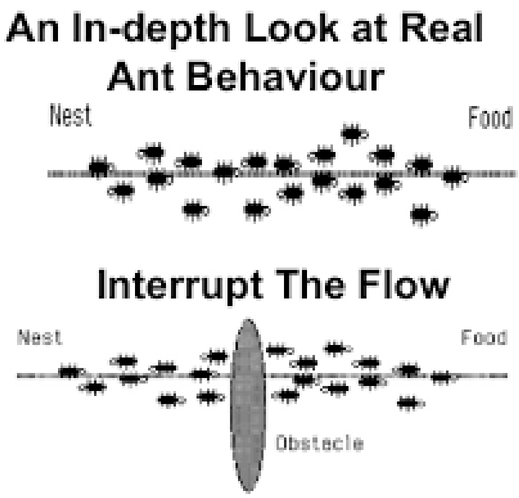

Fig. 3.2.1(a)

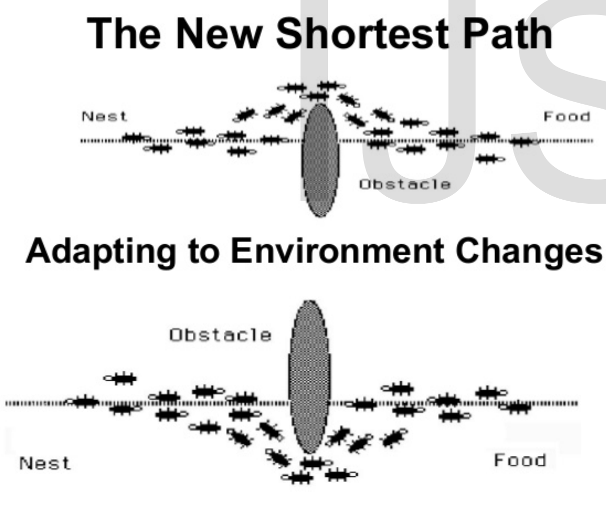

Fig. 3.2.1(b)

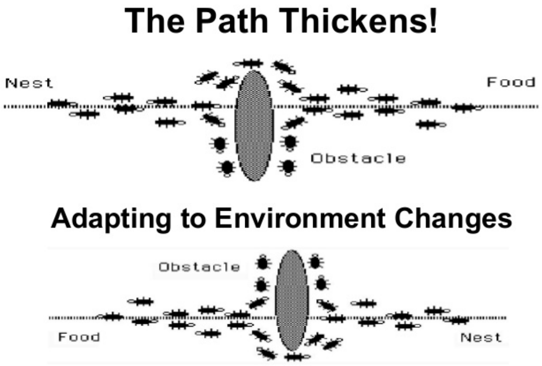

Fig. 3.2.1(c)

3.3. Particle swarm Optimization:

Particle swarm optimization or PSO is a global optimization algorithm for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space. Hypotheses are plotted in this space and seeded with an initial velocity, as well as a communication channel between the particles. Particles then move through the solution space, and are evaluated according to some fitness criterion after each time step. Over time, particles are accelerated towards those particles within their communication grouping which have better fitness values. The main advantage of such an approach over other global minimization strategies such as simulated annealing is that the large numbers of members that make up the particle swarm make the technique impressively resilient to the problem of local minima.

In near future, it may be possible to produce and deploy large numbers of inexpensive, disposable, meso-scale robots. Although limited in individual capability, such robots deployed in large numbers can represent a strong cumulative force similar to a colony of ants or swarm of bees.

4. Types of swarm

4.1. **Modular Robots:**

A module is essentially a small, relatively simple robot or piece of a robot. Modular robots are made of lots of these small, identical modules. A modular robot can consist of a few modules or many, depending on the robot's design and the task it needs to perform. Some modular robots currently exist only as computer simulations; others are still in the early stages of development. But they all operate on the same basic principle- lots of little robots can combine to create one big one.

Modules can't do much by themselves. A reconfiguring system also has to have:

•Connections between the modules

•Systems that govern how the modules move in relation to one another.

Most modular, reconfiguring robots fit into one of the three categories: chain, lattice and modular configuration.

ISSN 2229-5518

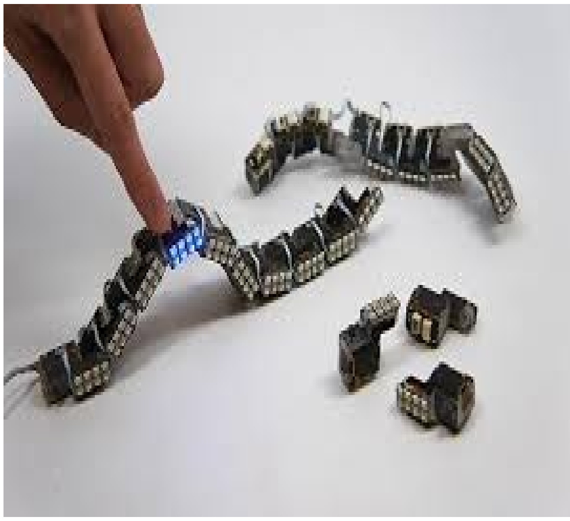

Fig 4.1 Modular robots

4.2. Chain robots:

Chain robots are long chains that can connect to one another at specific points. Depending on the number of chains and where they connect, these robots can resemble snakes or spiders. They can also become rolling loops or bipedal, walking robots. A set of modular chains could navigate an obstacle course by crawling through a tunnel as a snake, crossing rocky terrain as a spider and riding a tricycle across a bridge as a biped. Examples of chain robots are Palo Alto Research Center's (PARC) Polybot and Polypod and NASA's snakebot. Most need a human or, in theory, another robot, to manually secure the connections with screws.

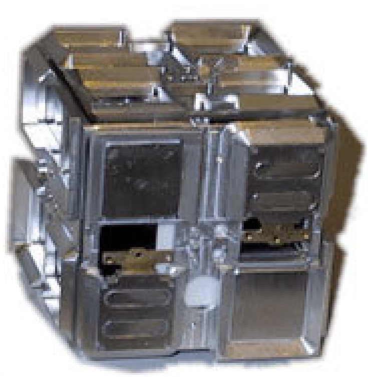

Fig4.2.1 A Telecube G2 module fully contracted.

Fig 4.2.2 NASA's Snakebot

The basic idea of a lattice robot is that swarms of small, identical modules that can combine to form a larger robot. Several prototype lattice robots already exist, but some models exist only as computer simulations. Lattice robots move by crawling over one another, attaching to and detaching from connection points on neighboring robots. It's like the way the tiles move in a sliding tile puzzle. This method of movement is called substrate reconfiguration – the robots can move only along points within the lattice of robots. Lattice modules can either have self-contained power sources, or they can share power sources through their connections to other modules.

Lattice robots can move over difficult terrain by climbing over one another, following the shape of the terrain, or they can form a solid, stable surface to support other structures. Enough lattice robots can create just about any shape. The modules can combine to make flat surfaces, ladders, movable appendages and virtually any other imaginable shape. So a lattice robot is more like a Terminator T-1000 than a Transformer.

Like lattice robots mobile reconfiguration robots are small, identical modules that can combine to form bigger robots. However, they don't need their neighbors' help to get from place to place- they can move around on their own. Mobile configuration robots are a lot like cartoon depictions of schools of fish or flocks of birds that combine to create a tool or structure. They move independently until they need to come together to accomplish a specific task. Even though these swarm-bots look very different from one another, they have many similarities in how they move and operate.

4.3 Asteroid eaters: Robots to hunt space rocks protect Earth.

The best way to stop an asteroid from wiping out earth is to lob a few nuclear missiles at the rocky beast or blow it apart from the inside with megaton bombs. But the more efficient weapon can be a swarm of nuclear powered robots that could drill into asteroid and hurl chunks of it into space with enough force to gradually push it into non-Earth impacting course.

4.4. A MADMEN swarm:

Since each MADMEN robot could only give a small push to an asteroid over time, SEI researchers envision sending an entire fleet of them to a potential Earth impactor. The key, is said to have a lander on each face of an asteroid working together autonomously to push the space rock in one direction as it tumbles through space, each lander "firing" as it comes into position.

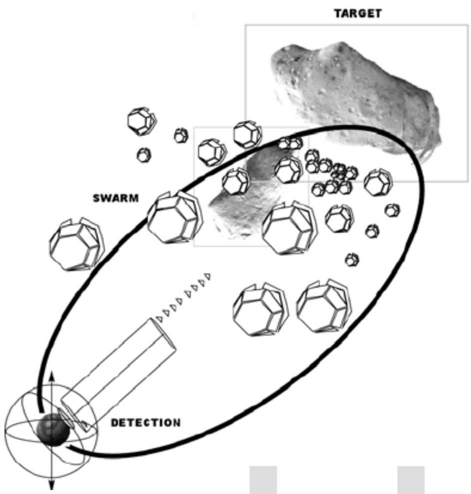

Fig. 4.4.1 This is a concept for madmen swarm.

4.5. Nubot:

Nubot is an abbreviation for “Nucleic Acid Robots.” Nubots are synthetic robotics devices at the nanoscale. Representative nubots include several DNA walkers.

4.6. The water skater:

A bug like robot inspired by insects that skate across water has been engineered. The machine provides deeper insight into how these long legged bugs known as water striders or pond skaters move.

The machine is over 7 centimeters long, and looks and moves very like a real insect. It has six legs: two fronts, two back and two out to the side, which row back and forth to propel it forward. Made of a light weight metal, the robot weighs only 0.6 grams. But the lightness alone is not what keeps it walking on water.

Tiny hairs on the ends of its legs that repel water keep the actual insect afloat. These machines are made buoyant by dipping the legs in a water resistant Teflon solution.

Fig 4.6.1 This robot has water-resistant legs to make sure it floats in water

Three flexible joint-like connections called actuators, one on the body and one where each side leg attaches to the body, give the robot the flexibility it needs to move.

5. Case Study

5.1 Introduction

This project involves development of autonomous swarm robots enabled with master-slave communication. The master robot controls the slave robot while performing its own task and the slave robot functions based on the signal received from the master robot (both being autonomous).

5.2 Working

The master robot is designed to be able to follow a black line on the ground without getting off the line too much. The robot has two sensors installed underneath the front part of the body, and two DC motors drive wheels moving forward. A circuit inside takes an input signal from two sensors and controls the speed of wheels’ rotation. The control is done in such a way that when a sensor senses a black line, the motor slows down or even stops. Then the difference of rotation speed makes it possible to make turns. For instance, in the figure on the right, if the sensor somehow senses a black line, the wheel on that side slows down and the robot will make a right turn.

The master bot is equipped with line following capabilities and has a 4-bit RF transmitter while the slave bot has a similar 4-bit RF receiver. The master bot follows the line marked by black insulating tape with help of IR proximity sensors and it also transmits the motion of it’s rear wheels via the previously described transmitter. The slave robot now receives this transmitted signal and processes the digital input in AT89S52 micro controller.

5.3 Programming Used

The Programming of master and slave in this project was made in hexadecimal format in notepad and was then converted to machine language using Kein and the by using Progisp it was then flashed onto the development board using a USBasp.
The program for Master Line Following Robot is as given below:

```
#include<reg52.h>
#include<stdio.h>
#define lt 0x06;
#define rt 0x09;
#define st 0x0a;
#define stop 0x0f;
#define rev 0x05;
unsigned int a;
void delay(unsigned int t)
{
int i,j;
for(i=0;i<t;i++)
{
for(j=0;j<1275;j++);
}
}
void main()
{
while(1)
{
a=P1&0x03;
if(a==0x01)
{
P2=rev;
P0=rev;
delay(100);
P2=stop;
P0=stop;
delay(100);
P2=lt;
P0=lt;
delay(100);
}
if(a==0x02)
{
P2=rev;
P0=rev;
delay(100);
P2=stop;
P0=stop;
delay(100);
P2=rt;
P0=rt;
delay(100);
}if(a==0x03)
{
P2=rev;
P0=rev;
delay(100);
}
if(a==0x00)
{
P2=st;
P0=st;
delay(100);
}
}
}
```

The programming for slave robot is as follow :

```
#include<reg52.h>
#include<stdio.h>
#define lt 0x06;
#define rt 0x09;
#define st 0x0a;
#define stop 0x0f;
#define rev 0x05;
unsigned int a;
void main()
{
while(1)
{
a=P0&0x0f;if(a==0x06)
{
P2=lt;
}
if(a==0x09)
{
P2=rt;
}
if(a==0x0a)
{
P2=st;
}
if(a==0x05)
{
P2=rev;
}
if(a==0x0f)
{
P2=stop;
}
}
}
```

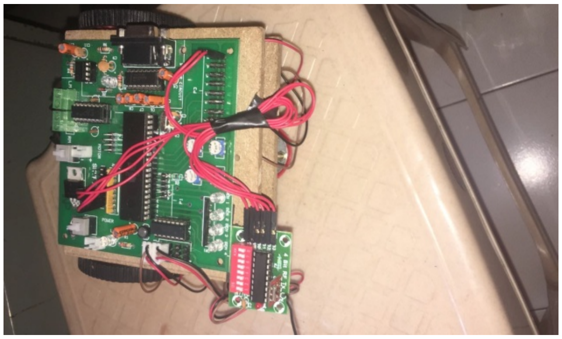

Fig.5.3.1 Master

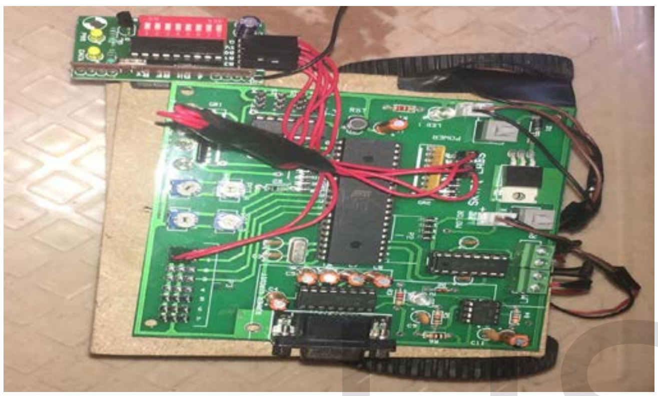

Fig.5.3.2 Slave

Fig.5.3.3 IR sensor

Fig.5.3.4 USBAP

Fig.5.3.5 Receiver

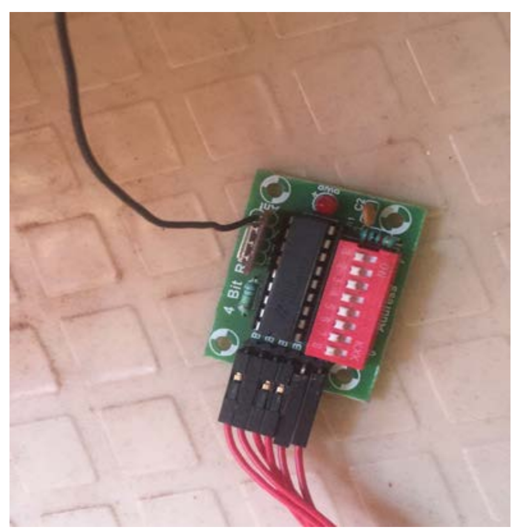

Fig.5.3.6 Transmitter

6. Towards Real World Applications

In recent times, many interesting and promising properties of swarm robotics have been enlightened. Nevertheless, currently there exist no real commercial applications. The reasons for it are varied. Sahin and Wineld [64] enumerate three of them as follows.

Algorithm Design. Swarm robotics must design both the physical robots and the behaviours of the individual robots, so the global collective behaviour emerges from their interactions. At the moment, no general method exists to go from the individuals to the group behaviour.

Implementation and Test. The use of many real robots needs of good laboratory infrastructure to be able to perform experiments.

Analysis and Modelling. Swarm-robotic systems are usually stochastic, nonlinear, so building mathematical models for validation and optimization is hard. These models might be necessary for creating safety real world applications.

Wineld et al. discuss the concept of swarm engineering, studying the dependability of swarm-robotic systems through a case of study. According to them, some of the future work needed from a dependability point of view is the following.

(i) Mathematical modeling of swarm-robotic systems.
(ii) Work on safety analysis at robot and swarm level.
(iii) Develop an approach to the design of emergence.
(iv) Develop methodologies and practices for the testing of swarm systems.

Higgins address the main security challenges that swarm-robotic systems should face in a future. They state that due to the simplicity of swarm-robotic architectures they have to deal with the following problems.

(i) Physical capture of the robots.
(ii) Identity and authentication, robot must know if it is interacting with a robot from its swarm or from an intruder robot.
(iii) Communication attacks, communications can be intercepted or disturbed by an attacker.

The possible real applications of swarm robotics will take special importance when robots get to be mass produced and the costs of building swarms of robots decrease. This is the objective of I-swarm project which aimed at building a swarm of micro robots. The development of technologies such as MEMS (Micro-Electro-Mechanical Systems) will allow to create small and cheap robots.

Swarm robots can perform tasks in which the main goal is to cover a wide region. The robots can disperse and perform monitoring tasks, for example, in forests, lakes, and so forth. It can be really useful for detecting hazardous events, like a leakage of a chemical substance. The main advantage over a sensor network is that the swarm can move and focus on the problem and even act to prevent the consequences of that problem.

In this way swarms of robots can be really useful for dangerous tasks. For example, for mining detection and cleaning. It can be more useful than a unique specialized robot, mainly because of the robustness of the swarm: if one robot fails and the mine explodes, the rest of the swarm continues working. In the case of a single robot this is not possible.

The number of possible applications is really promising, but still the technology must firstly be developed both in the algorithmic and modeling part, and also in the miniaturization technologies.

7. Advantages and Limitations

Advantages:

(i) Improved performance: if tasks can be decomposable then by using parallelism, groups can make tasks to be performed more efficiently.
(ii) Task enablement: groups of robots can do certain tasks that are impossible for a single robot.
(iii) Distributed sensing: the range of sensing of a group of robots is wider than the range of a single robot.

Disadvantages:

(i)Interference: robots in a group can interfere between them, due to collisions, occlusions, and so forth.
(ii)Uncertainty concerning other robots‟ intentions: coordination requires knowing what other robots are doing. If this is not clear robots can compete instead of cooperate.

8. Summary

The objective of this project is to design, develop, and implement an autonomous robot swarm in order to perform a line follower elated operation. The motivation for this endeavor is the cost, parallel-processing, and system redundancy benefits that are inherent within collective cooperative units. A set of similar tasks such as exploration and mapping or following a predefined path (in our case a line follower) of an unknown environment can be completed quicker and more reliably by a coordinated group of slaves and a master where all the slaves do not need to be programmed individually, but only a simple connection needs to be established by using transmitters and receivers. These swarm robots will be designed to be modular, small form-factor, low-cost, low-power consumption, and easily assembled.

9. References

[1] G. Caprari, K. O. Arras, R. Siegwart. The Autonomous Miniature Robot Alice: from Prototypes to Applications. Swiss Federal Institute of Technology Lausanne (EPFL).

[2] Evolutionary Swarm Robotics: a theoretical and methodological itinerary from individual neuro-

controllers to collective behaviours
Vito Trianni, Elio Tuci, Christos Ampatzis and Marco Dorigo LARAL-ISTC-CNR, Rome, Italy Dept. Computer Science, Aberystwyth University, UK ACT-ESA, ESTEC, Noordwijk, The Netherlands IRIDIA-CoDE-ULB, Brussels, Belgium

[3] J. Borenstein, H. R. Everett, L. Feng, D. Wehe. Mobile Robot Positioning – Sensors and Techniques. Journal of Robotic Systems, Vol. 14 No. 4.

[4] Robust Swarm Robotics System Using CMA-NeuroES with Incremental Evolution
Kazuhiro Ohkura1*, Tian Yu1, Toshiyuki Yasuda1, Yoshiyuki Matsumura2 and Masanori Goka3

[5] An Introduction to Swarm Robotics
Iñaki Navarro and Fernando Matía
ETSI Industriales, Universidad Politécnica de Madrid, c/José Gutiérrez Abascal, 2, 28006 Madrid, Spain