SWARM ROBOTICS - SURVEILLANCE AND MONITORING OF DAMAGES CAUSED BY MOTOR ACCIDENTS

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Abstract: In this paper we shall focus on effective management of accident response protocols with the inclusion of swarm bots (surveillance bots) that could enhance the immediate response time to any unexpected traffic ambiguity including accidents and non-routed traffic. In case of an untoward event like an accident, bots can replace standard policing and manual data collection practices that are both time consuming and ineffectual. This paper explores the probability of software integration to provide live feeds of an incident, environment image capture and data interpretation. Swarm bots can divide tasks among themselves[12] effectively as they mimic the behavior of fire ants that are renowned for their magnanimous collective ability.

Keywords – swarm robot, robotics, accident management, surveillance, modular robot

I. INTRODUCTION

We live in a world that is getting denser exponentially and have come to the point that it would be very tiresome to rely on humans to carry out every task. Humans in any field are a limited resource and thus must be put to the most optimum use. It is in such a situation that we explore using modular robots (or swarm robots) to effectively carry out those tasks that would either consume too much of time for a human to do or poses safety hazards.

An epitomic example of a limited resource is police in any major dense city. As one must have observed the population keeps increasing at a very large rate and the number of people that are employed to enforce the rules grow much slowly. We also see that policemen have a range of duties, from something trivial as ticketing improperly parked cars to capturing hardened criminals who aren't shy to commit murder. According to the Pareto Principle, 20% of the work that is done will have the majority of the effect on the environment. Thus in this situation we could say that catching criminals is more important than going around looking for improperly parked cars. And so to save man power we should try and allocate these menial jobs to robots.

Swarm robots fit perfectly with respect to finding out about accidents. They are light, can travel quickly and can quickly capture images of the area. Thus the proposed idea is to use swarm bots to record and report accident sites. In this process, when an accident takes place, either a by stander or the one involved can call a number which acts as a reporting call.

A swarm bot will reply to this by getting to that location. Once there it will scan the incident with its camera and try and take as many perspectives as possible. It would be using image processing to determine the level of damage. If it feels that the damage is serious, it could relay a communication to other bots nearby that could come rushing to the scene.

These other bots, in themselves, could be more specialized than the original scout bot. One of the other bots could be equipped with medical facilities to help anyone in immediate danger and also these robots could relay a signal to the nearest hospital or ambulance stating that there is an emergency.

What this does that it helps us on two fronts. At one end, the time taken by police officers to reach at the spot is often too long and if it is a serious situation there is a possibility of irreversible damage taking place even before they get there. On the other end, if it is a minor accident then it makes no sense to waste the police officer's time with such situations when there are evidently much more important things to be done to maintain peace in a city.

II. THE SWARM BOT CONCEPT

A *SWARM-BOT* entity is composed of many (2 to35) single robots (*s-bots*) physically interconnected. Each s-bot is a fully autonomous mobile robot capable of performing basic tasks such as autonomous navigation, perception of the environment and grasping of objects[1]. In addition to these features, an s-bot is able to communicate with other s-bots and physically connect to them in flexible ways, thus forming a SWARM-BOT[13]. The SWARM-BOTis able to perform exploration, navigation and transport of heavy objects in very rough terrain, where a single s-both as major problems to achieve the task. This hardware structure is combined with a distributed adaptive control architecture (general approach [2], applied to swarm bots [3]) inspired upon ant colony behaviors[8]. Figure 1 shows some views of an s-bot prototype.

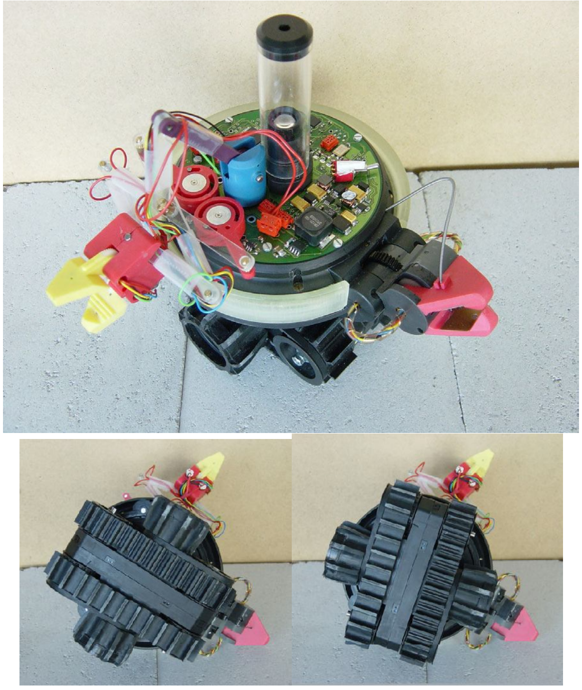

Fig. 1. Top and bottom view of the s-bot prototype. The bottom view shows the treels©drive mechanism rotating in respect to the main body.

A. MOBILITY

The mobility of the system is ensured by a combination of tracks and wheels. We call this type of structure *Differential Treels©Drive*[1]. Each side of the treels© (one track and one wheel) is controlled by a motor so that the s-bot can freely move in the environment and easily rotate on the spot. This structure enables a very good mobility thanks to the position of the wheel and their diameter larger than the tracks height. The treels© driving system allow each s-bot to move in moderately rough terrain, with more complex situations being addressed by SWARM-BOT configurations. This kind of modularity and flexibility to pass large obstacles is very similar to the one developed by self-reconfigurable robots[9]. The main difference consists in the fact that the SWARM-BOT has less 3D capabilities than self-reconfigurable robots, an s-bot being able to lift only one s-bot. This aspect is compensated by exploiting the mobility of each module, which is not present in self-reconfigurable robots.

The treels© base can rotate with respect to the main body by means of a motorized axis, as illustrated in figure 1 (for more description on the hardware see [4]).

B. SENSORS

Each s-bot is a fully autonomous mobile robot and is equipped with all the sensors necessary for navigation, such as a gray scale camera, 16 lateral and 4 bottom infra-red proximity sensors, 24 light sensors, a 3 axis accelerometer, two humidity sensors as well as incremental encoders and torque sensors on each of the nine degree of freedom[7]. In addition to these basic features, each robot is equipped with sensors and communication devices to detect and communicate with other s-bots. Typical devices implementing these features are again the omnidirectional camera combined with 24 color LEDs all around the robot (inside the transparent T-shaped ring, to express “state” of the robot) and in the grippers, 8 local color detectors all around the body and inside the grippers as well as one speaker and three microphones.

Despite the availability on the robot of a wireless LAN, images and sound will be the only communication channels between s-bots used in our experiments. Radio LAN will be used exclusively for debugging and monitoring of experiments. In addition to multiple perception modes implemented by several sensors, we made a careful differentiation on range of perception. Research on collective insects shows that collective behaviors are often based on multi-range and multi-modal sensing in order to perceive and exchange signals at multiple levels and in several circumstances. For this reason, as well as for more practical reasons of interferences, infra-red proximity (active) sensors have been limited to a very short range. Sound covers a much longer range and the camera is used both for long and short range sensing, depending on the features extracted from the image.

Placing an autonomous robot as basic component for the modular system is a radically different choice than in self-reconfigurable robots, where the basic element includes only one or two degrees of freedom and very few sensors.

This different choice is motivated by the clear goal of distributed autonomous control in the SWARM-BOTS project. In most self-reconfigurable robots the control is implemented in a centralized way or by remote control. Only a few groups working on self-reconfigurable robots have presented experiments on distributed control[10] [11].

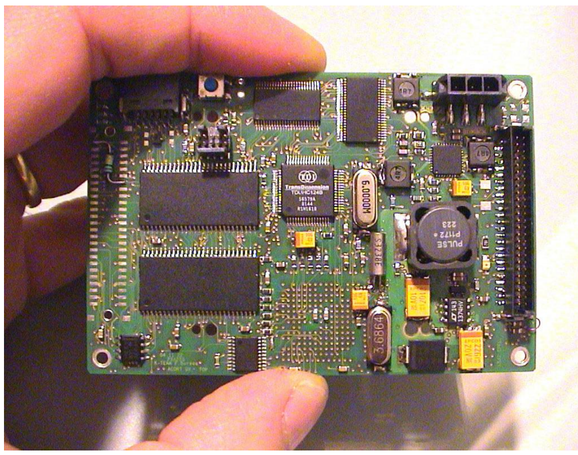

Fig. 2.Main ARM board prototype running LINUX. The processor can run at 400MHz, has 64M of RAM and 32M of FLASH, USB, I2C, RS232 and two CompactFlash slots. The power consumption is 500mW at 100MHz and 700mW at 400MHz.

C. CONTROLLER

We aim at controlling a group of s-bots in fully autonomous manner in such a way that they locate, approach and connect directly with an object that acts as a seed or with other *s-bots* already connected to the seed.

Algorithm1 Theassemblymodule

```
1:activatesensingmodules

2:repeat
3:  (i1,i2)←featureExtraction(camera)
4:  (i3,i4)←sensorReadings(proximity)
5:  (o1,o2,o3)←neuralnetwork(i1,i2,i3,i4)
6:
7:      if(o3  >0.5)∧(capturingrequirementsfulfilled)
then

8:      compare
9:      ifsuccessfullycompared then
10:         activate signals
11:         haltuntiltimeoutreached
12:     else
13:         move forward
14:                 repeat
15:     endif
16:   endif
17:   apply(o1,o2)totracks
```

17:**until** starting point = ending point

Algorithm 1 is a modified version of an existing algorithm[6]that has been modified to controlimage capturing. The main part is given by a reactive neural network (line 5) that maps sensory inputs to motor commands. The network takes as input the binary values *i*1 and *i*2 from the robot's vision system (line 3) and the values *i*3 and *i*4 from the left-front and right-front robot's proximity sensors (line 4). The network's output (*o*1, *o*2, *o*3) is used to control the speed of the left and the right wheels (line 16) and the connection mechanism (lines 7 to 15). By default, the tuple (*i*1, *i*2) is assigned (0, 0). Any other assignment indicates the presence of objects (in the front, or to the left or right side) who's pictures need to be taken. If an obstacle (a blue object) is present in between, *i*1 and *i*2 are set to zero. The network's weights have been shaped by artificial evolution in the context of a cooperative transport task in simulation.

Algorithm2 Swarm Positioning

Let S be the number of particles in the swarm, each having a position $\mathbf{x}_i \in \mathbb{R}^n$ in the search-space and a velocity $\mathbf{v}_i \in \mathbb{R}^n$. Let $\mathbf{p}_i$ be the best known position of particle i and let $\mathbf{g}$ be the best known position of the entire swarm. A basic PSO algorithm is then:

- For each particle i = 1, ..., S do:
  - Initialize the particle's position with a uniformly distributed random vector: $\mathbf{x}_i \sim U(\mathbf{b}_{lo}, \mathbf{b}_{up})$, where $\mathbf{b}_{lo}$ and $\mathbf{b}_{up}$ are the lower and upper boundaries of the search-space.
  - Initialize the particle's best known position to its initial position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
  - If $(f(\mathbf{p}_i) < f(\mathbf{g}))$ update the swarm's best known position: $\mathbf{g} \leftarrow \mathbf{p}_i$
  - Initialize the particle's velocity: $\mathbf{v}_i \sim U(-|\mathbf{b}_{up}-\mathbf{b}_{lo}|, |\mathbf{b}_{up}-\mathbf{b}_{lo}|)$
- Until a termination criterion is met (e.g. number of iterations performed, or a solution with adequate objective function value is found), repeat:
- For each particle i = 1, ..., S do:
- Pick random numbers: $r_p, r_g \sim U(0,1)$
- For each dimension d = 1, ..., n do:
- Update the particle's velocity: $\mathbf{v}_{i,d} \leftarrow \omega\, \mathbf{v}_{i,d} + \varphi_p\, r_p\, (\mathbf{p}_{i,d}-\mathbf{x}_{i,d}) + \varphi_g\, r_g\, (\mathbf{g}_d-\mathbf{x}_{i,d})$
- Update the particle's position: $\mathbf{x}_i \leftarrow \mathbf{x}_i + \mathbf{v}_i$
- If $(f(\mathbf{x}_i) < f(\mathbf{p}_i))$ do:
- Update the particle's best known position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
- If $(f(\mathbf{p}_i) < f(\mathbf{g}))$ update the swarm's best known position: $\mathbf{g} \leftarrow \mathbf{p}_i$
- Now $\mathbf{g}$ holds the best found solution.

Algorithm 2[14] is used to help swarm bots find each others. Since co-operation is the fundamental principle on which the swarm bots work it is essential for them to know each other's positions and the way to get to them. This algorithm effectively lets a swarm bot find and get to another swarm bot.

III. EXPERIMENTAL SETUP

In our experimental setup, we use six samples of different levels of car damages generally found. These levels are shown in figure 3. Initially, the robot is preloaded with the sample images. The robot then runs a high pass filter through the images and replaces them with the original image. The high pass filter allows the robot to identify the damage done to the car more specifically. Then, the robot is triggered towards the car by sensing DTMF signals sent to it. A person with a mobile phone can locate the nearest robot by switching on the Bluetooth and pairing with the first robot found. Then, the robot can be made to travel towards the damaged car. Now, the robot moves slowly around the car, taking pictures at regular intervals. It runs a high pass filter through the captured images and compares them with the preloaded images. The nearest matching image depicts the level of the damage. The robot can then decide on what action to take next based on the algorithms.

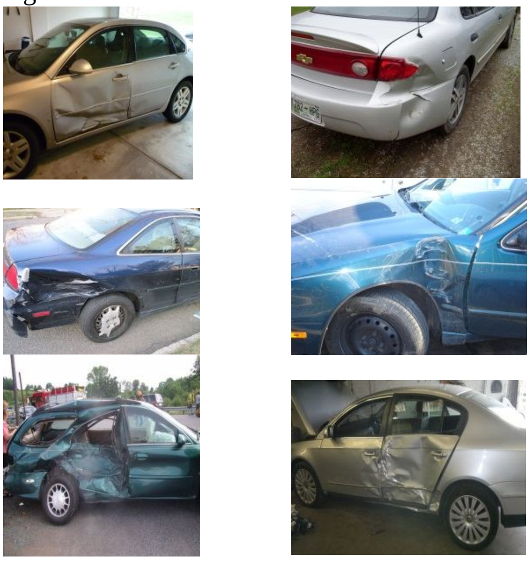

Fig. 3.Six levels of damages done to cars. These images are preloaded into the robots controller.

IV. RESULTS

For our setup, we have used the Twodee simulator[5]. The simulator helps us to simulate real world scenarios virtually. It also helps us monitor the test results and enhance our algorithms. For the experimental setup, we have carried out 96 tests on the simulator. Out of these 96 tests, 92 have shown favorable outcomes, with the rest 4 missing out by just.

We continuously fed the robot with different images of car damages very different from the ones it has been preloaded with. The robot ran a high pass filter through them and compared. The level of the image closely matching the histogram of the captured image was determined to be the level of the robot.

V. FUTURE SCOPE

The robot would be capable to fly autonomous, recognize and locate target object, and perform navigation. A model helicopter is used as the airframe of the robot, which has various flight modes such as hovering, forward/backward flight, sideward flight, vertical climb/descent, etc. This gives the helicopter an unparalleled maneuverability to achieve the task. To develop a suitable control scheme for autonomous flying, a simulation program of the helicopter will be developed. The helicopter dynamics will be simulated based on the models developed in [15] and [16].

Computer vision system for the aerial robot is under development to perform object recognition and navigation. We are also exploring the possibilities in combining control with vision directly for visual serving and path planning. For control, in order to obtain information about position, orientation, velocities and accelerations in both angular and translational directions, a Kalman filter will be employed for sensor fusion with the outputs of inertial sensors and GPS. In the future, this project would become the tested for Multi-Agent Systems and Intelligence Augmentation of Human Centered Systems.

Opportunities and Challenges with Autonomous Micro Aerial Vehicles. In International Symposium on Robotics Research. Flagstaff, AZ, September. (H. Christensen and O. Khatib, Eds.). (BibTeX)

Future implementation of autonomous bots can include laser technology as cited [S. Shen, N. Michael and V. Kumar (2011)] to involve more complex analysis of disaster situations and motor accidents. The replacement of rotors instead of wheels will make the swarms even more diligent and at the same time more effective.

The current edition of the bots that has been implemented can be evolved into the above mentioned aerial bot using rotor physics as cited in [Vijay Kumar and Nathan Michael (2011) **Opportunities and Challenges with Autonomous Micro Aerial Vehicles**].

The swarm optimization and image capturing algorithms remain the same.

CONCLUSION

As a first of its kind, we have been able to establish a prototype for a model wherein the need for human inputs in minimized. We have been able to successfully implement a prototype to make a bot take specific actions based on the level of the damage done to a car, so that manpower is utilized only when needed. We have been able to accomplish this by using the concept of swarm robotics.

As the experimental setup, we performed 96 tests on a computer simulation of the real world model, and have been able to gain success in 92 of those tests. This explains the robustness of the prototype. This model can now be further expanded to be implemented in real world. This model could actually prove to be the right substitute of traffic monitors/traffic police.

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