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Swarm Robots

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Abstract

Famous inventor, Leonardo da Vinci's contributed the nose of the bullet train that was inspired from the beak of the kingfisher, resulting in more speed, energy efficiency and less noise as it passed through the tunnels; all of this summing up to a term coined as Biomimicry.Running parallel to the same, swarm intelligence emerged, promoting collective behavior of decentralized, self-organized systems, natural or artificial.Drawing reference, swarm robotics is a field of multi-robotics in which large number of robots are coordinated in a distributed and decentralized way. It is based on the use of local rules, and simple robots compared to the complexity of the task to achieve.Large number of simple robots can perform complex tasks in a more efficient way than a single robot using the transmission and reception modules of communication in electronics.Swarm intelligence claims historical underpinnings from both biology and engineering.Within a year, Beni had coined and popularized the term "swarm intelligence" in relation to robotics. He later identified a vague definition of the term swarm intelligence: "a property of systems of non-intelligent robots exhibiting collectively intelligent behavior".Reviewing the genesis and subsequent development of swarm intelligence research therefore requires approaching the subject from both entomology and robotics.Further looking up to this, it provides user friendly communication for personal assistance for the disabled and the young ones and creates bonding in fields where audience gets engaged with stage dramatics, theatre education and sci-fi based movies.The swarm robots comprises of, an obstacle avoider master robot and a blind slave robot.Master robots senses the environment and changes it direction; as this also poses a threat to the slave, it gets an alert to change the direction.Future could include: Swarmanoid, a heterogeneous swarm robotic system capable of operating in a fully 3-dimensional environment; Alice, a micro robot swarm.These cubical swarm robots form a bit huge army of 90 robots working together; Kilobots, self-assemble in a thousand-robot swarm.But if it was to argue about it's application in military defense, then it would be-"The fiercest serpent may be overcome by a swarm of ants."

Keywords: Swarm Robotics,Future prospectus, Biomimicry, Swarm intelligence,Applications

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1. Introduction

Origins of Swarm-Based Robotics

In order to fully trace the intellectual heritage of swarm-based robotics, one must begin in the early 1970s. At that time, coordination and interaction of multiple agents were being studied in the field of distributed artificial intelligence (DAI), but investigations were limited to problems involving software agents. This tendency persisted until the late 1980s, when the robotics research community began to explore cooperative robotic systems. The earliest forays into cooperative robotics related to cellular (or reconfigurable) robotic systems, cyclic swarms, multi-robot motion planning, and primitive architectures for multi-robot cooperation. The first two of these topics eventually merged into the current field of swarm intelligence. Cellular robotic systems, such as CEBOT (CEllular roBOTs), were initially explored by Fukuda et al. CEBOT drew direct inspiration from biological organisms to generate an architecture based on decentralized hierarchies of robotic cells. Gerardo Beni started working on the same topic from a more theoretical perspective in 1988. Within a year, Beni had coined and popularized the term “swarm intelligence” in relation to robotics. He later identified a vague definition of the term swarm intelligence: “a property of systems of non-intelligent robots exhibiting collectively intelligent behavior”. The most precise definition provided by Beni was not a written verbal definition, but a mathematical construct is presented graphically in Figure 1. Note that the generalized definition (on the right) is less strict than the original, as it allows for systems to be termed swarm-intelligent by completing effective work, W, more efficiently than a non-cooperative group. Beni’s definition requires that the useful work in a given task can only be performed by N interacting agents, and only for N greater than a critical number, Nc.

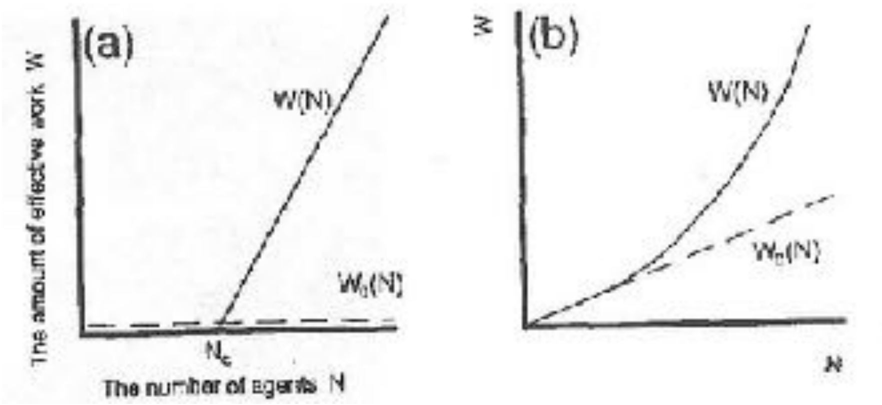


Figure 1. (a) Beni's definition of swarm intelligence (b) the generalized definition. W(N) denotes the amount of work achieved by N interacting agents, and W0(N) denotes the work achieved by N

Deneubourg, Theraulaz, and Beckers, who study swarm intelligence from an ethological perspective, define a swarm as "...a set of (mobile) agents which are liable to communicate directly or indirectly (by acting on their local environment) with each other, and which collectively carry out a distributed problem solving".These definitions conveniently avoid the problem of defining intelligence, although Deneubourg et al. imply that intelligence is somehow related to problem solving. The reader is referred to for a thorough discussion of robotic intelligence, the definition of which is debated philosophically as much as technically. Around the same time that cellular robotics research was taking shape, Rodney Brooks, from MIT's Artificial Intelligence Laboratory, published a groundbreaking paper in the still undeveloped field of cooperative robotics. In what has clearly become the most widely cited source in the swarm intelligence community, Brooks outlines a "robust layered control system for a mobile robot" known as subsumption architecture. Brooks' paper initiated the rapid progression of the behavior-based control movement. Combined with the inertia of cellular robotics and identified by Beni's terminology, swarm intelligence emerged in the early 1990s as a major component of mobile robotics research. Brooks and Beni provided the impetus for the emergence and rapid expansion of swarm intelligence as a research field. This is evidenced by the nearly omnipresent references to behavior-based control in the robotics literature. However, despite the rapid advance of swarm intelligence, a number of robot control architectures were developing simultaneously.Artificial intelligence is inspired from natural intelligence. It is abstracting natural intelligence continuously and implementing in machine artificially, example is robotics. Swarm robotics is a technique in which a group of Robots work in a synchronized and coordinated manner to complete a specific task in a team. Swarm Robotics is influenced by idea of swarm Intelligence and it implements the concept of natural swarms such as ant colonies, bee hives, flock of birds etc.The term “swarm” is used to refer a large group of locally interacting individuals with common goals”. Swarm robotics systems are characterized by simplicity of individuals, local sensing and communication capabilities, parallelism in task execution, robustness, scalability, heterogeneousness, flexibility and decentralized control. To analyze potential capabilities of robot swarms, swarm robotics has been studied in the context of producing different collective behaviors to solve tasks such as: aggregation, pattern formation, self-assembly and morphogenesis, object clustering, and assembling construction, collective search and exploration, coordinated motion, collective transportation, self-deployment, foraging and others(for detail tasks of robot read paper). The analysis of the results of these studies show that robot swarms are capable to solve these tasks satisfactory in controlled laboratory environments , at the same time there is no evidence of applying swarm robotics to solve real-life problems. Swarm robotics has large domain of applications. It plays a vital role in solving real world complexities in significant way. Through our recent studies it is recognized that it is able to solve the problems and becoming closer to human needs. Although, it offers several advantages for robotic applications such as scalability, and robustness due to redundancy, few issues are also present here. It has an analogy far similar to that of humans.IR sensors behave like the human eye.8 bit microcontroller acts as a processor to generate outputs via the IR sensor inputs.The DC motors act as the the actuators which are the limbs.Numerous Advantages: Parallelism, Robustness, scalability, heterogeneousness, flexibility, cheap Alternative, stability, economical benefits.Challenges include: redundancy, lack of central control, no gesture based communications, cannot behave dynamically and it leads to deadlock of the whole system, cheap but high maintenance, can’t respond to heterogeneous nature, identification and authentication, tracking, less proximity from the master, eavesdropping in communication.

2. Problem Statement

- To establish communication between multi(two) robot systems.
- To coordinate their movements on the arena(grids) with so as to make them perform a common task.
- To process the local interactions of the robot as well as the interactions of the robot with the environment.

3. Review of Literature

Kilobots

Today, most robots are designed to work by themselves, not as part of a team. Wyss researchers are developing robotic systems and algorithmic approaches to make artificial swarms of robots that collaboratively work together towards a common goal. In one licensed application of the technology, a collective of 1024 “Kilobots” (meaning “one thousand robots”) can be programmed to exhibit complex swarming behaviors, such as foraging and firefly-inspired synchronization, while a user can interact with the swarm as a whole (programming the robots, switching them on and off, etc.), no matter how many robots there are. Kilobot-inspired underwater swarming robots that use a novel vision system to coordinate movement like schools of fish are also being developed. The Kilobot technology has been licensed to K-Team Corporation for research and educational applications as a platform for collective swarm algorithms in hardware rather than merely computer simulations.Beyond this, a hive “operating system” could let a user program colonies of robots to perform complex tasks in natural environments such as land, air, and sea. Flying microrobots could be instructed to pollinate a field, or — inspired by mound-building termites — an autonomous robot construction team could be programmed to build 3D structures and traversable surfaces, to stack sandbags along vulnerable coastlines before a hurricane, or to lay out barriers around toxic chemical spills. Towards these goals, Wyss researchers have developed cutting-edge sensor technology, micro-actuators, and robust controllers allowing the robots to adapt quickly to changing conditions.

University of Sheffield

Researchers in the Sheffield Centre for Robotics, jointly established by the University of Sheffield and Sheffield Hallam University, have been working to program a group of 40 robots, and say the ability to control robot swarms could prove hugely beneficial in a range of contexts, from military to medical.The researchers have demonstrated that the swarm can carry out simple fetching and carrying tasks, by grouping around an object and working together to push it across a surface.The robots can also group themselves together into a single cluster after being scattered across a room, and organize themselves by order of priority.Dr Roderich Gross, head of the Natural Robotics Lab, in the Department of Automatic Control and Systems Engineering at the University of Sheffield, says swarming robots could have important roles to play in the future of micromedicine, as 'nanobots' are developed for non-invasive treatment of humans. On a larger scale, they could play a part in military, or search and rescue operations, acting together in areas where it would be too dangerous or impractical for humans to go. In industry too, robot swarms could be put to use, improving manufacturing processes and workplace safety.The programming that the University of Sheffield team has developed to control the robots is deceptively simple. For example, if the robots are being asked to group together, each robot only needs to be able to work out if there is another robot in front of it. If there is, it turns on the spot; if there isn't, it moves in a wider circle until it finds one.Dr Gross said: "We are developing Artificial Intelligence to control robots in a variety of ways. The key is to work out what is the minimum amount of information needed by the robot to accomplish its task. That's important because it means the robot may not need any memory, and possibly not even a processing unit, so this technology could work for nanoscale robots, for example in medical applications."This research is funded by a Marie Curie European Reintegration Grant within the 7th European Community Framework Programme. Additional support has been provided by the Engineering and Physical Sciences Research Council.The robots were showcased on Channel 5's The Gadget Show this week and will be demonstrated at this year's Gadget Show Live, to be held at the NEC in Birmingham from 3-7 April 2013.

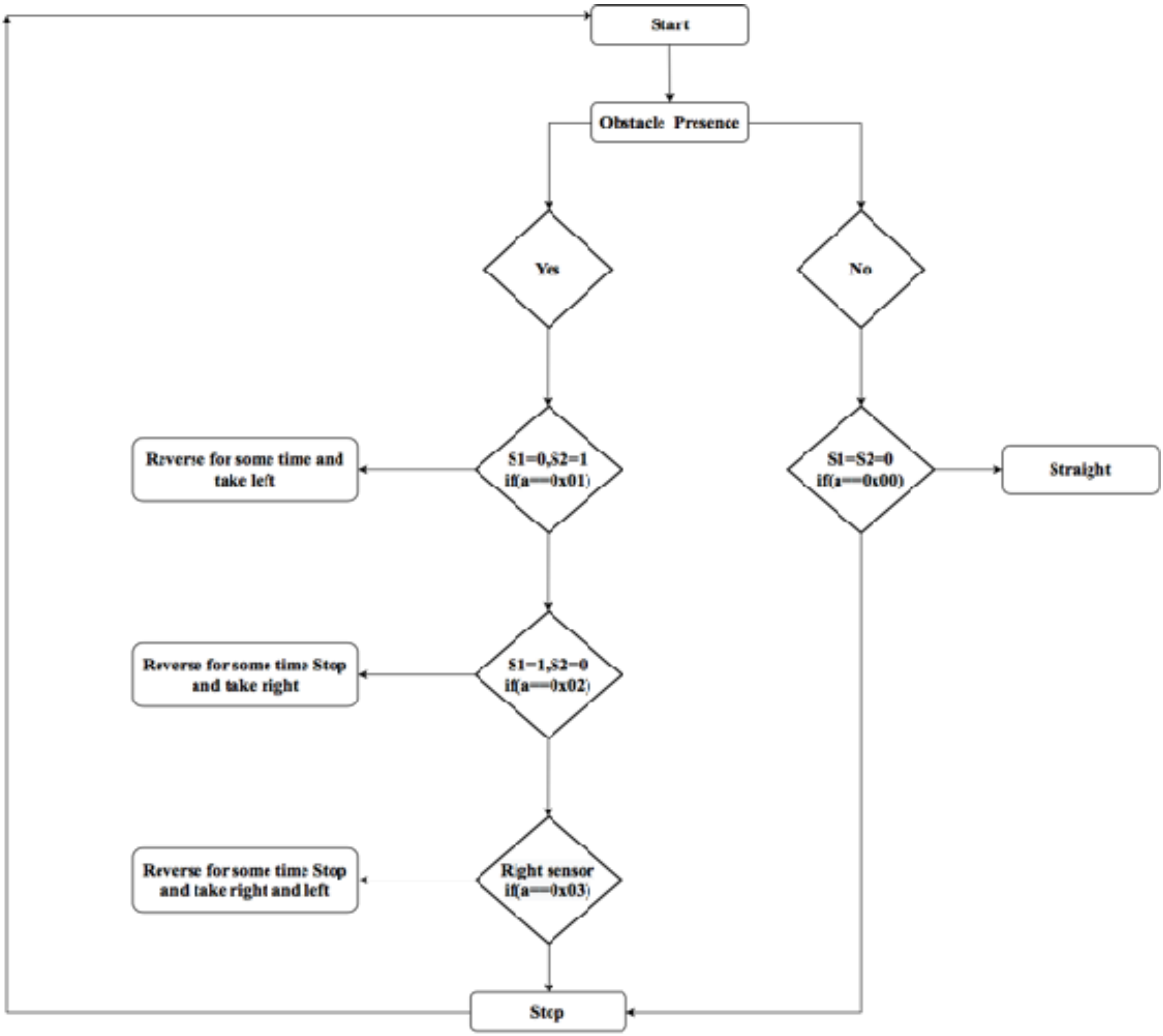
4. Plan of Work

Task	Completion Date
Formation of group	**1st July, 2020**
Domain Selection	**8th July, 2020**
Allocation of Guide	**12th July, 2020**
Submission of topic (min 3)	**22nd July, 2020**
Presentation of Project topics to FYPQ Committee	**8th to 17th August, 2020**
Finalization of Project topic & submission of topic with abstract	**21st August, 2020**
Topic Presentation to guide (Block Diagram, Component List)	**19th October, 2020**
First Project Preview with 30% implementation and Synopsis Submission	**25th January to 30th January, 2020**
70% Project Implementation	**22nd July, 2020**
Final Project Preview with Black Book Submission	**11th February, 2021**

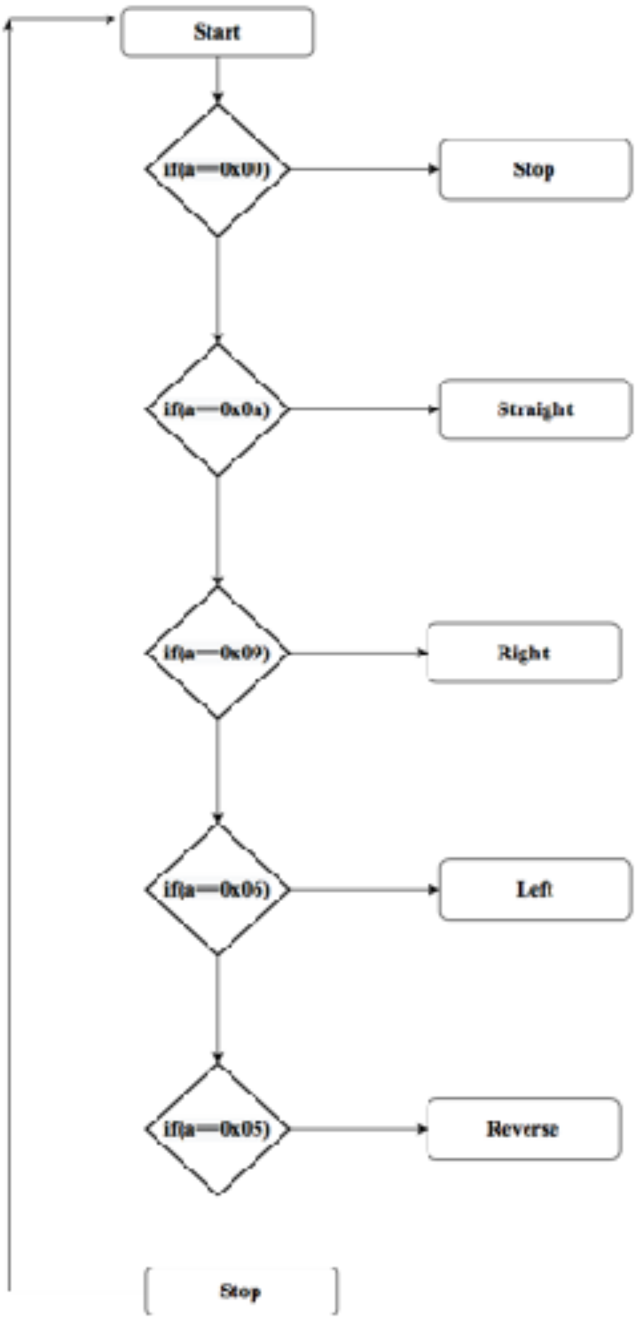
5. Flowchart and Algorithm

Figure of flowcharts

Master



Slave


Start
if(a==0x00)
Stop
if(a==0x0a)
Straight
if(a==0x09)
Right
if(a==0x06)
Left
if(a==0x05)
Reverse
Stop

Algorithm

Master

- Start
- If a==0x03meaning when obstacle is present at the front of both sensors(S1=1,S2=1), the robot should reverse for a while, stop then turn either left or right.The master vehicle will continue to follow the command and direction unless another input is detected by the sensors.
- If a==0x01meaning when obstacle is present in the front of the right sensor(S1=0,S2=1), the robot should reverse for a while, stop and then turn left.The master will continue to follow the command and direction unless another input is detected by the sensors.
- If a==0x02meaning when obstacle is present in the front of the left sensor(S1=1,S2=0), the robot should reverse for a while, stop and then turn right.The master will continue to follow the command and direction unless another input is detected by the sensors.
- If a==0x00meaning when no obstacle is present in the front of both the sensors(S1=0,S2=0), the robot should continue moving straight.The master will continue to follow the command and direction unless another input is detected by the sensors.

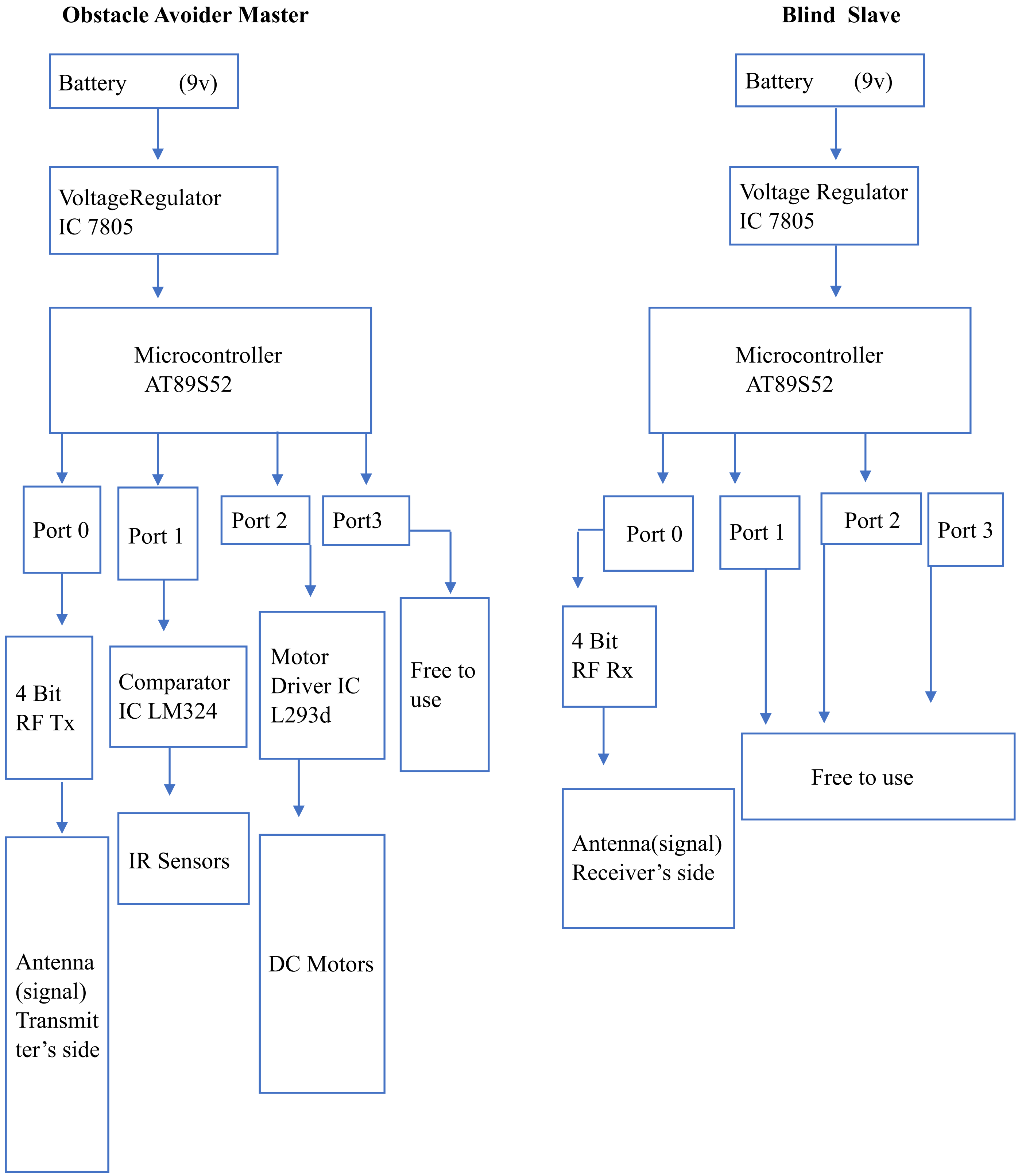
Slave

- Start
- If a==0x0a meaning this motor input causes straight movement of the bot.The slave vehicle will continue to follow the command and direction unless another input is changed by the motor rotation.
- If a==0x06 meaning this motor input causes left movement of the bot.The slave vehicle will continue to follow the command and direction unless another input is changed by the motor rotation.

- If a==0x00 meaning this motor input causes stop the bot to stop.The slave vehicle will continue to follow the command and direction unless another input is changed by the motor rotation.
- If a==0x09 meaning this motor input causes right movement of the bot.The slave vehicle will continue to follow the command and direction unless another input is changed by the motor rotation.
- If a==0x05 meaning this motor input causes reverse movement of the bot.The slave vehicle will continue to follow the command and direction unless another input is changed by the motor rotation.

6. Block Diagram and Explanation

Swarm robots



1) Battery- 9 volts batteries are used in this project.There are two motors, each requiring 9 volts supply.To power up the development board, another battery of 9 volts is used.The voltage provided by batteries are typically 1.2V, 3.7V, 9V and 12V. This is good for circuits whose voltage requirements are in that range. But, most of the TTL IC's work on 5V logic and hence we need a mechanism to provide a consistent 5V Supply.

2) Voltage Regulator IC 7805- It is an IC in the 78XX family of linear voltage regulators that produce a regulated 5V as output.The best alternative to using Batteries is to provide an unregulated but rectified DC Voltage from an AC Source. Since AC Source is easily available as mains supply, we can design a circuit to convert AC Mains to DC and provide it as input to the 7805 Voltage regulator IC. The AC power supply from mains first gets converted into and unregulated DC and then into a constant regulated DC with the help of this circuit. The circuit is made up of transformer, bridge rectifier made up from diodes, linear voltage regulator 7805 and capacitors.

3) Microcontroller- The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard 80C51 instruction set and pinout.

4) Port 0- Port 0 is an 8-bit open drain bidirectional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high-impedance inputs.Port 0 can also be configured to be the multiplexed low-order address/data bus during accesses to external program and data memory. In this mode, P0 has internal pull-ups.Port 0 also receives the code bytes during Flash programming and outputs the code bytes during program verification. External pull-ups are required during program verification.In the master and slave,AD0 to AD3 are the address and data busses connected to 4 bit RF Tx and 4 bit RF Rx module respectively from B0 to B3.

5) Port 1- An 8-bit bidirectional I/O port with internal pull-ups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins, they are pulled high by the inter- nal pull-ups and can be used as inputs. In master, it is connected to the LM324 comparator.It is kept as free to use in the slave.

6) Port 2 - An 8-bit bidirectional I/O port with internal pull-ups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins, they are pulled high by the internal pull-ups and can be used as inputs. In the master, it is connected to motor driver.It is kept as free to use in the slave.

7) Port 3- An 8-bit bidirectional I/O port with internal pull-ups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins, they are pulled high by the internal pull-ups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pull-ups.Port 3 receives some control signals for Flash programming and verification.It is kept as free to use in the master and slave.

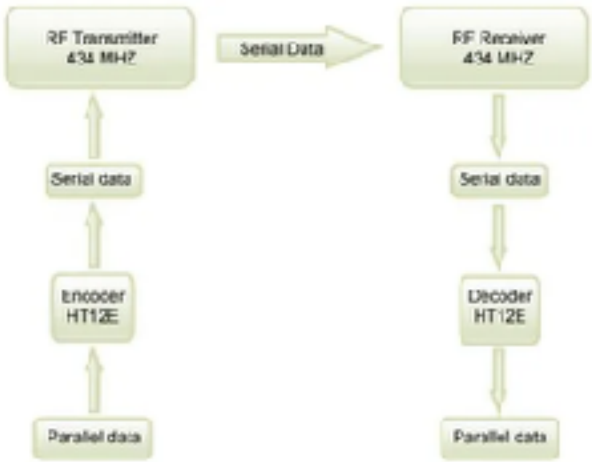


Fig.2

8) 4 Bit RF Tx and 4 Bit RF Rx - This includes RF transmitter module,HT12E Encoder and Antenna.This radio frequency (RF) transmission system employs Amplitude Shift Keying (ASK) with transmitter/receiver (Tx/Rx) pair operating at 434 MHz. The transmitter module takes serial input and transmits these signals through RF. The transmitted signals are received by the receiver module placed away from the source of transmission.The system allows one way communication between two nodes, namely, transmission and reception. The RF module has been used in conjunction with a set of four channel encoder/decoder ICs. Here HT12E & HT12D have been used as encoder and decoder respectively. The encoder converts the parallel inputs (from the remote switches) into serial set of signals. These signals are serially transferred through RF to the reception point. The decoder is used after the RF receiver to decode the serial format and retrieve the original signals as outputs. These outputs can be observed on corresponding LEDs.Encoder IC (HT12E) receives parallel data in the form of address bits and control bits. The control signals from remote switches along with 8 address bits constitute a set of 12 parallel signals.

9) Comparator IC LM324 - The LM324 operational amplifier IC can be worked as a comparator. This IC has 4 independent operational amplifiers on a single chip. This a Low Power Quad Operational Amplifier and it has high stability, bandwidth which was designed to operate from a single power supply over a wide range of voltages. The input comes from IR sensors to this comparator.

10) Motor driver L293d - Motor Driver circuits are current amplifiers. They act as a bridge between the controller and the motor in a motor drive. Motor drivers are made from discrete components which are integrated inside an IC. The input to the motor driver IC or motor driver circuit is a low current signal. The function of the circuit is to convert the low current signal to a high current signal. This high current signal is then given to the motor. The motor can be a brushless DC motor, brushed DC motor, stepper motor, other DC motors etc. The output of this is sent to Dc motors

11)Antenna(transmitter and receiver's end)- As Antenna resides between cable/waveguide and the medium air, the main function of antenna is to match impedance of the medium with the cable/waveguide impedance. Hence antenna is impedance transforming device. The second and most important function of antenna is to radiate the energy in the desired direction and suppress in the unwanted direction. This basically is the radiation pattern of the antenna. This radiation pattern is different for different types of antennas.

7. Component List with Cost

S.NO.	COMPONENTS	QUANTITY	COST
1	Battery (9v)	6	500
2	BOI Motors Straight Type	4	1200
3	Castor wheels	1	300
4	2 pin connectors	6	250
5	IR Sensors	2	300
6	USBASP Program Cable	1	250
7	4 Bit RFTx	1	75
8	4 Bit RFRx	1	150
9	Development Board	2	150
10	Microcontroll er AT89S52	2	1500
11	OP-Amp LM324	2	30
12	Motor Driver L293d	2	30
13	4 LEDS	4	50
14	4 Pots	4	50
16	Male pin connectors	12	50
17	Female pin connectors	12	50

S.NO.	COMPONENTS	QUANTITY	COST
18	Capacitors (100microfarad)	2	70
19	IC7805	2	80
20	Capacitors (10microfarad)	5	50

8. Pros & Cons

Pros

The whole task can be divided into subtasks, assigned to individual member of the swarm so that they can work in parallel to enhance the performance. Swarm robots work in a wider range area to accomplish a single goal task which is not possible in single robot system. If the single robot stops working in a group the task will not be halted, it will be done by the other members of the group. It means it is fault tolerant. It implements the distributed action, where a group of robots can actuate in different places at the same time. Parallelism means to accomplish a task concurrently. By using this technique task can be done more quickly than by a single robot. Robustness means no single point of failure for the system. If one system fails, the work doesn’t get stopped. Scalability means better performance as compared to centralized system, if it will have to cover wide area. Heterogeneousness means each members of the group is heterogeneous or different whose physical properties enable them to perform efficiently. Flexibility means easily reconfigured for the different applications. It has the ability to adopt different behavior as per the need. Complex problems can be solved easily using a swarm of robots which might be impossible for a single robot. Cheap Alternative means each group member of swarm is simple robot which is cheaper than single powerful robot for each separate task. Stable, if one member fails in a group, the work won’t get stopped but their performance may degrade. It is useful for the task where the environment is dangerous. Economical benefits, swarm robotics cost low in designing, manufacturing as compared to single robot. Energy efficient means that the life time of the swarm is large. In an environment which has no fueling facilities or where wired electricity is forbidden, the swarm robotics can be much useful than traditional single robot.

- Robustness
- Flexibility
- Scalability
- Autonomous
- Few homogeneous groups
- Local sensing
- Decentralized

- Coordinating
- Parallelism

Cons

Despite its potential to promote robustness, scalability and flexibility, swarm robotics has yet to be adopted for solving real-world problems. Various limiting factors are preventing the real-world uptake of swarm robotics systems. It is non-optimal because they are redundant and have no central control, lack of central control sometimes swarms behave independently. So swarm systems are inefficient. Swarms communicate with each other through messages but sometimes indirect communications are required like communicating through gesture, posture but swarms cannot communicate indirectly. Social insects like ants are able to find the shortest path by sensing the global environment but swarm robotics cannot sense global knowledge from environment so they cannot behave dynamically and it leads to deadlock of the whole system, so recovery is required to move from the stagnation. Complex swarm systems with rich hierarchies take time to boot up. Greater the complexities, the longer it takes to warm up. So it is non-immediate to so many tasks where active attention is needed. The swarm robotics behave strangely in unpredictable environment so desired task cannot be performed. Swarm robotics is homogenous systems. All robots behave in a similar manner. If it is required to work in an environment where heterogeneity is needed then we cannot use swarm. Because of internet limitations sometimes swarms might not be able to communicate so creation of their own network required for uninterrupted work, and it might be costly affair. As compared to single robot, swarms are cheaper but maintenance is high. Weather affects swarm robots severely, as weather changes create communication problem among robots. So coordination between robots is affected. Human cannot take part in group of robots as sometimes natural intelligence is required to accomplish the task. For each and every behavioral change we need to reprogram and it may affect the previous coding of the robot .So whole swarm are required to be recoded again. But it cannot bring the natural intelligence inside the swarm. A systematic and general way to design robot swarms is still missing, even though a few preliminary proposals have been made. Securities issues are vital as Physical capturing of the robots are possible. There must be a provision to Identify and authenticate robot because a robot must know if it is interacting with a robot from its swarm or from an intruder robot. Communications can be intercepted or disturbed by an attacker.

- When it come down to central control, failure of the controller implies failure of the whole system.
- Robot to robot communication becomes very complex as number of robots increase
- Communication bottlenecks
- Adding new robots means changing the communication and the control systems.

9. Applications

- Military
- Submarine
- Radiation explosion plant the robot can send
- Graphical Creation,
- Wireless control in anywhere the robot is connected

10. Conclusion

As swarm robotics have lot of features but still it is not widely acceptable to solve the real life problems. Further research is needed on robotic hardware to overcome hardware shortcomings that limit the functionality of current robotic systems. Central control limits the functionality of swarm robotics but there can be a robot among swarm which has the capability of sensing and repairing hardware defect of other robots and also has leadership quality to control and guide distributed autonomous robots in desirable situation. Further research on behavioral control is needed to discover effective ways to let a human operator interact with a robot swarm. Indirect communication might get enhanced in future. In the remote location and for the outhouse applications, to charge battery solar energy might become feasible in near future.

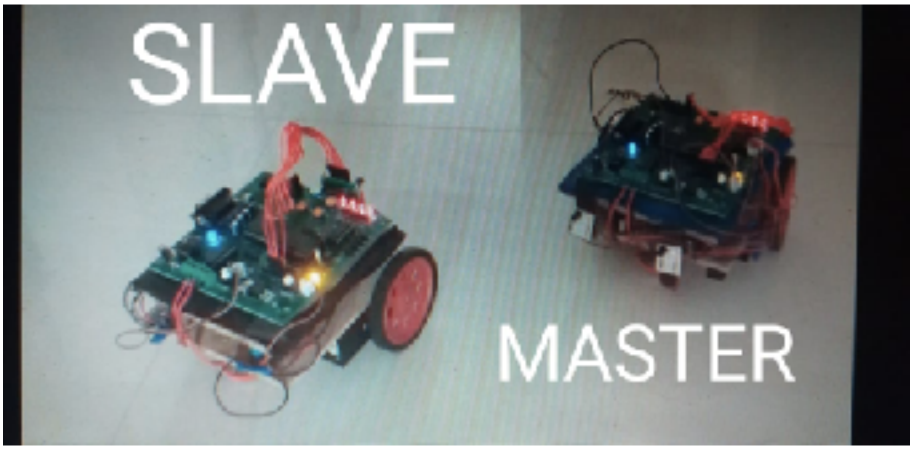


Figure of output of swarm robots

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