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Intelligent Tactical Robotics

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Abstract—In order to carry out tasks which are mundane or are repeated and mechanized in some manner, we can make use of robots to help us achieve the desired objective. Robotics is a field of science and technology which is very popular because of its immense potential in getting the job done efficiently and precisely. Researchers and engineers are continuously working hard to explore this field and make use of its immense potential to the fullest. It has long been recognized that there are several tasks that can be performed efficiently in coordination with multiple robots and that is why collaborative robotics is where many innovations are taking place. In this work it is proposed that a concept to initiate communication between two robots which can be done with the help of the master-slave concept, thus implementing collaborative robotics. The concept is collaboration of various algorithms and technologies which will execute different tasks in coordination and also the existing standard algorithm has been modified in a specified way to carry out the desired task.

Index Terms— Robot prototype, Master-Slave, Arduino, Object recognition, X-Bee, Robotic Arm.

I. INTRODUCTION

A. Robotics

Robotics is branch which was developed to ease the life of humans by effectively performing the task at a faster rate which human fail to do so. Collaborative Robots are those robots that are designed to work in collaboration with a human or a robot. It is an extension to the primary field of robotics which makes use of coordination between machines and humans to get the specified task done successfully.

Robotic teams/Collaborative robotics has several advantages over single-robot operations. There are some problems that require multiple robots to participate and thus require cooperation of several working agents. There are various tasks that require completion within a specified time frame and here a cooperative approach would result in the completion of task in a more efficient manner. Having said that, collaborative robots are also more efficient and resistant to failure compared to mainstream robotics[1]. There has been extensive study and literature on control and coordination for multiple mobile robots, its application in tasks such as exploration, surveillance, rescue, mapping of environments and transportation of objects. To design and implement autonomous robots which are programmed to perform various tasks in a collaborative manner and design would surely be a task worth completing. In our system, the idea or the concept of Master-Slave system is used in which the slave would receive the commands or orders from the master and thus would complete the assigned task.

B. Object recognition

Object recognition is the feature that the Master robot uses to distinguish between an obstacle and a target. The target object is marked with distinct pattern, or can have a distinct shape and colour, and the Master robot uses the object/pattern recognition technique to distinguish whether the object is an obstacle or target. This decision which will be taken by the master will determine whether to clear the object in case of an obstacle or grab the object in case the object is a target. There are many techniques used to recognize patterns which include edge detection, corner detection, angle detection etc. Out of these above mentioned techniques, the system uses edge detection technique. An edge is the boundary between an object and the background, and indicates the boundary between overlapping objects. This means that if the edges in an image can be identified accurately, all of the objects can be located and basic properties such as area, perimeter, and shape can be measured. Since a computer vision involves the detection, identification and classification of objects in a captured image, edge detection is an essential tool [2]. There are multiple edge detection techniques available out of which canny edge detection is best suited for our system and thus tis technique has been used. A typical example of the edge detected image is shown in Fig.1.

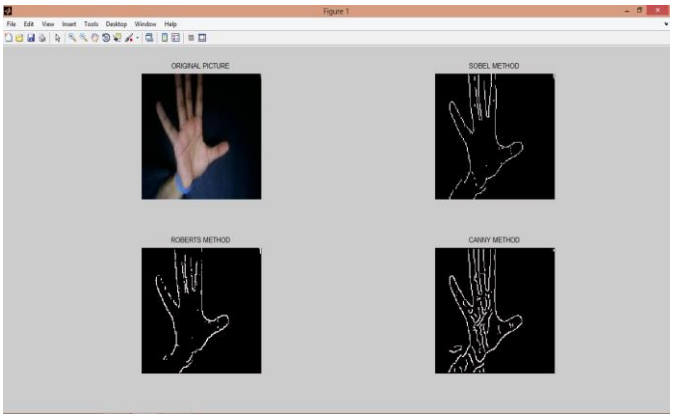

Fig. 1 Example of edge based object

C. Wireless Communication

The communication between the master and computer and the master and slave and vice-versa has been done using a wireless RF 2.4GHz module. One of the modules which satisfy our requirements is Digi's International's X-BEE module. Xbee's are a family of low power, low cost and low bandwidth wireless communication modules. They work on Zigbee communication protocol. Xbee's have been used instead of Bluetooth communication system and Infra-red communication systems because the later are less reliable and have a small range when compared to Xbee's. Our System requires a highly reliable and efficient wireless communication system and that need is satisfied by Xbee's. Fig.2 shows an actual image of Xbee modules.

Fig. 2 Xbee

D. Programming using Arduino:

To interface all the hardware with software signals, wireless modules and feedback networks, Atmega microcontrollers, programmed using Arduino environment are used. We use Arduino boards as they are very functional and are open source. This has an added advantage of allowing standalone circuits to be made. Arduino boards come with 6 analog input and 6 output ports. It has 6 digital I/O ports, one transmitter and one receiver port. The integration of Xbee's, communication between them, is made possible using Ardunio boards.

E. Distance Measurement and sensing:

To maintain constant distance between the master the slave and to detect the target or the obstacle, Ultrasonic sensors are used. Ultrasonic sensors use sound waves rather than light, making them ideal for stable detection of uneven surfaces, liquids, clear objects, and objects in dirty environments. These sensors work well for applications that require precise measurements between stationary and moving objects. Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function. The modules includes ultrasonic transmitters, receiver and control circuit. Ultrasonic sensors are attached on the front end of both the Master and the Slave. The Master uses the sensors to sense the environment around it and halt before an object, the Slave uses ultrasonic sensors to maintain a constant distance between itself and the Master.

F. Live image feed:

To continuously monitor the environment and send a live feed to the Base station, FPV is used. First Person View (FPV) is a method used for viewing the live video. FPV used in our system works on 1.2GHz frequency, with CMOS camera attached as a transmitter to master and receiver to ground station as shown in fig. 5. The FPV will be attached on the Master and it continuously transmits data to the base station for it to compare the image sent with the existing database stored in the base station. The FPV is attached at the front end of the Master and is connected to Xbee via Arduino to continuously send information.

Fig. 3 First person view

G. Robotic Arm:

To grab the target object or to clear/sweep an obstacle in the path of the Master, the Slave is equipped with a robotic arm. The robotic arm uses servo motors at the shoulder end as well as at the grabber end also. The master uses its FPV to scan the environment around it and compare the objects scanned with the existing database. When the object encountered is an obstacle, the master orders the slave to clear the path using the robotic arm and when the object encountered is the target, the Master orders the Slave to grab the object and place it on its chassis. The robotic arm has a 360 degree base movement which enables it to access greater area to grab or clear the object. Fig. 4 shows the robotic arm. The base motor has a torque of 5Kgs, thus the arm can also have multiple axis.

Fig. 4 Robotic arm

H. Robot Chassis Design:

The design of the chassis of both the Master and the Slave are of prime importance. The Robots should have agility to take quick turns and at the same time should be strong enough to carry weight of the target. The material, shape, size, weight measurements are to be taken into serious consideration. The Master and Slave used in the system have circular design which allows the robots to maneuver freely in any direction. The material used is acrylic which is light in weight and has considerable strength to carry

the target load. The acrylic thickness is 5mm which makes it light and thick enough to carry the load. The heavier the robot chassis, the more the chances of their arising problems with the motor driver, thus proper weight considerations were made. To reduce weight and size and yet have enough space to have all components on the chassis, layered approach was used in the Master design. Fig. 6(a), 6(b) show the images of the Master and the Slave.

Fig. 6(a) Chassis design of Master using layered approach

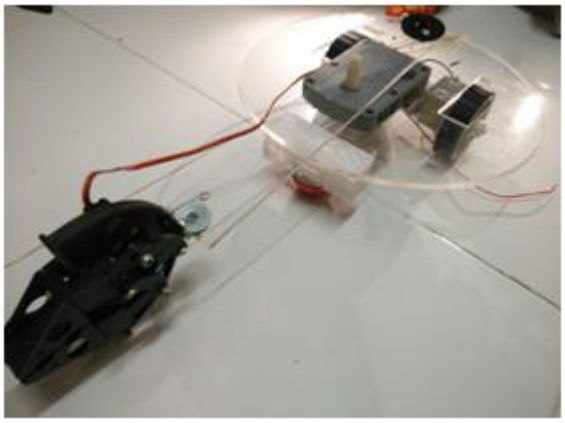

Fig. 6(b) Slave Chassis with arm attached

II. OBJECTIVES FORMULATED

The following were the objectives or the system development steps:

1. Studying of Xbee modules and various image processing techniques.
2. Establishing a connection between the wireless modules (Xbee's).
3. Writing the MATLAB code for object detection with multiple parameters.
4. Programming the controllers, Arduino, to establish communication between the Master and the Slave.
5. Designing of Robot chassis with proper size, weight and shape considerations.
6. Designing of Robotic arm taking into account the weight and material to be used.
7. Writing the MATLAB code for robotic arm movement and integration.
8. Integration of all the hardware components.
9. Initial testing of the system.

10. Rectification of errors encountered and removal of software bugs.
11. Final implementation of the desired collaborative robotic system.

III. METHODOLOGY

To carry out the above mentioned steps, the following methodology was used:

1. The proposed system comprises of one master robot that will guide a slave robot to the target and in turn would lead to completion of a task.
2. The task which is to be performed by the master is to identify the target and command the slave to either to clear the obstacle or pick the target using the robotic arm.
3. The master has a FPV camera attached to it and it continuously monitors the environment and scans for potential targets.
4. Once an object is scanned, the image of the scanned object is sent to the base station for comparison between the target image stored in the database and the image captured.
5. The way this is done is that the image acquired by the video transceiver is sent to the base station where via MATLAB, image is processed.
6. Based on the results of the image processing, MATLAB generates a value that is sent to the Master via Xbee.
7. MATLAB is interfaced with Xbee and the Xbee sends command to the Master, which has another Xbee interfaced with it.
8. Based on the command, if the object is the target, the master commands the slave to pick up the target using its robotic arm, else if the object is an obstacle, it commands the slave robot to clear the obstacle by moving it aside using its robotic arm. A flowchart showing the above mentioned process is shown in Fig. 7 below.

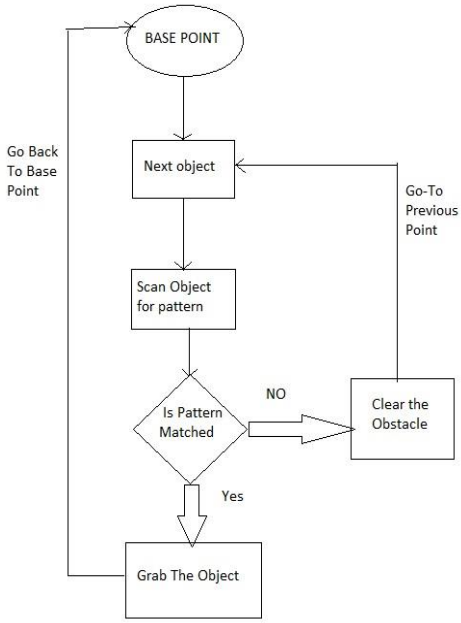

Fig. 7 Flowchart of Master-Slave task

9. All communication between Base station, Master and slave is done via Xbee's.

10. The slave is in direct contact with the master. The base station does not instruct the slave; only the master will be able to do that.
11. Once the task is completed, the master and the slave will return to the original starting points.
12. The individual working mechanisms of both the Master and the Slave are shown in Fig. 8 and Fig. 9 respectively.

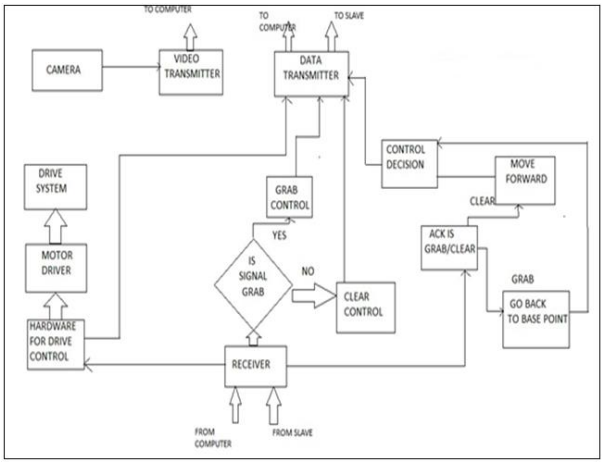

Fig. 8 Working diagram of Master

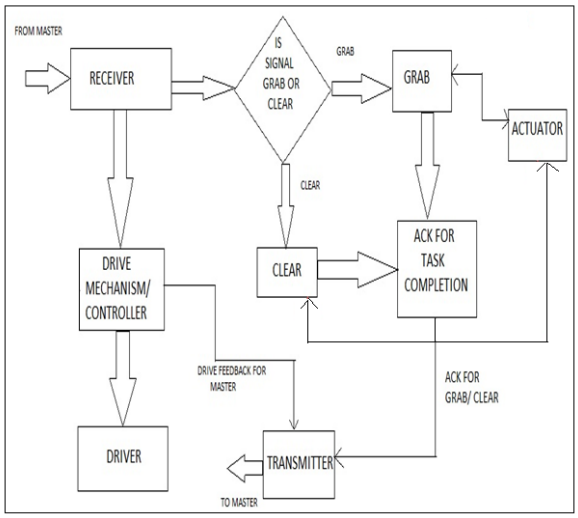

Fig. 9 Working mechanism of Slave

IV. RESULTS

The above explained system of collaborative robotics is an integration of various technologies including both hardware and software. Careful planning and execution was required to achieve the desired results. The Master and Slave work in synchronization using the ultrasonic sensors as the range and object detectors and communicate with each other and the base station with the help of Xbee's. The object is recognized as a target or as an obstacle with the help of image processing which compares the image using different parameters like shape and colour. The Slave carries out the task which is ordered by the Master and it uses its robotic arm to do the same. After the successful completion of the task, the Master and Slave return back to the base point and await further instructions from the base station. To assist the whole process, Arduino boards are used for

interfacing of the Xbee's and to run the motors. All the integration of software takes place using MATLAB.

V. CONCLUSION

In this work honest efforts have been made to develop a system of collaborative robots with varied functionalities to carry out tasks with high precision and efficiency. The ability of the Master to make the decision and command the Slave makes the system an intelligent one. Through this work an attempt has been made in the direction of achieving better results than the preexisting technologies and also making scope for useful future applications. The future applications could be in the field of defense and security, mapping of unexplored territory or rescue operations. This work, not to forget, is a prototype, thus is bound to have limitations and inaccurate results. Having said that, it is always open for improvement and can result in a much more advanced and enhanced version. The use of digital mapping, multiple axis arm structure, increase in the number of co-bots are just a few examples that show us in what ways the system can be improved or worked upon in the near future. Collaborative robotics is an interesting alternative to classical approaches to robotics because some properties of problem solving by social insects, which are flexible, robust, decentralized and self- organized can be made use by human beings.

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