ScouterBot: Design of a Low Cost Autonomous Ball-boy Robot

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Abstract

In 2011, 25 million amateur and professional people played tennis in the U.S alone[9]. People enjoy the game so much that they are willing to pay an instructor approximately $20 - $80 per hour[1][7][14] just to learn the tricks of the game. But as they don't want to pick up tennis balls after their training, so some of them end up paying an extra fee for the service or hire a personal ball-boy to do the work for them.

However, many tennis players don't want to spend the money for hiring a ball-boy to pick up all the tennis balls they used even though they don't like to do this tiresome task because they feel the job is trivial but the cost is expensive. So the solution proposed is the creation of a fully autonomous ball-boy robot that would automatically pick up tennis balls while the user is playing a tennis game or during training hours.

This solution was reached by building a robot called ScouterBot, which as its name implies, performs the task of "scouting" by using a robot sensing strategy based on ultrasonic sensors, being its principal objective to pick up tennis balls in an open environment without depending on human control. Prototyping and issues of implementation of the ScouterBot are discussed and explored on the paper.

Keywords: Autonomous, sensing strategy, robot, tennis balls.

1. Introduction

Nowadays we find different kinds of machines that make human lives easier. New inventions and technology keep being developed, allowing society to step each day closer to an era where machines are going to form a more important part of human lives as well as economy impact on society. However, it is people's desire on having more advanced machines to work with, what makes actual inventors explore further and deeper, always looking for a way to create a robot that works at human service.

Service Robot

Since the year of 1836 [8] we have had complex machines working with us. The industrial revolution [8] brought us the definition of "machine", starting the era in which humans and machines work together. But, what about service robots: robots that work for humans instead of working along humans. That was the next step:"*The first electronic autonomous robots were created by William Grey Walter in Bristol, England, in 1948. The first digital and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate. Devol sold the first Unimate to General Motors in 1961 where it was used to lift pieces of hot metal from die casting machines at the Inland Fisher Guide Plant in the West Trenton section of Ewing Township, New Jersey. Since then we have seen robots finally reach a more true assimilation of all technologies to produce robots such as ASIMO, which can walk, and move like a human. Robots have replaced humans in the assistance of performing those repetitive and dangerous tasks which humans prefer not to do, or are unable to do due to size limitations, or even those such as in outer space or at the bottom of the sea where humans could not survive the extreme environments*."[16]But in the field of sports, people still has machines not robots working for them.

Tennis Field Robot

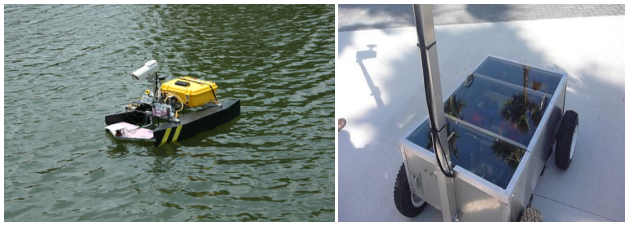
In tennis courts we find ball-throwing machines, as well as in baseball fields. People own them because they make possible to train individually, and also because the features of a ball-throwing machine allow the player to change how often the machine throws balls so the player can practice at his own pace and it has a random oscillator that automatically throws balls in a sweeping pattern from side to side so the player gets a complete workout while hitting balls on the run [19]. Hence, it is easier and more comfortable for the player or amateur to play his favorite sport. But, what about when the training time ends, there is no robot to help the tennis player to collect the balls. Of course, there are robots such as: the playmate and gamma ball mower [25][26] that have retractable arms and a spring loaded arms mechanism that allows the machine to collect tennis balls while the user is pushing it around the field, but

those are controlled by humans, it is not the same as having a fully autonomous robot that picks up balls by its own. Having one of those robots on a tennis court would be the best complement for a tennis player or amateur's equipment. Thinking of this, ScouterBot project was started, so people would have a ball-boy robot working for them.

Picture 1. The Ball Picker [24]

Previous projects such as "The Ball picker" and "Mobile Robot Navigation and target tracking System" have shown that ScouterBot idea is not recent but comes in different packages that need to be put together.

Both projects present deficiencies. "The Ball picker" project picks up tennis balls successfully but its design is rudimentary and very unreliable, it lacks kinetics, and speed in its motion. On the other hand, the "Mobile Robot Navigation and target tracking System" is more than successful avoiding obstacles by using sensors from Xbox's [28] and Kinect's [10] devices, which not only increases costs but also requires a more powerful system than a microcontroller to support the data collection.



Picture 2. Mobile Robot Navigation and target tracking System [13,17,18]

2. State of the Art

A ball-boy robot should have a mixture of features that will allow the robot to be fully autonomous and that would make the robot efficient when collecting balls. In order to make this possible, three important aspects need to be considered:

- The type of tennis courts surfaces on which the robot will move,
- The robot's hardware
- The robot's programming code.

A ball-boy robot should be able to move on the three different types of tennis courts surfaces [22], which are: grass courts, clay courts, hard courts and carpet courts.

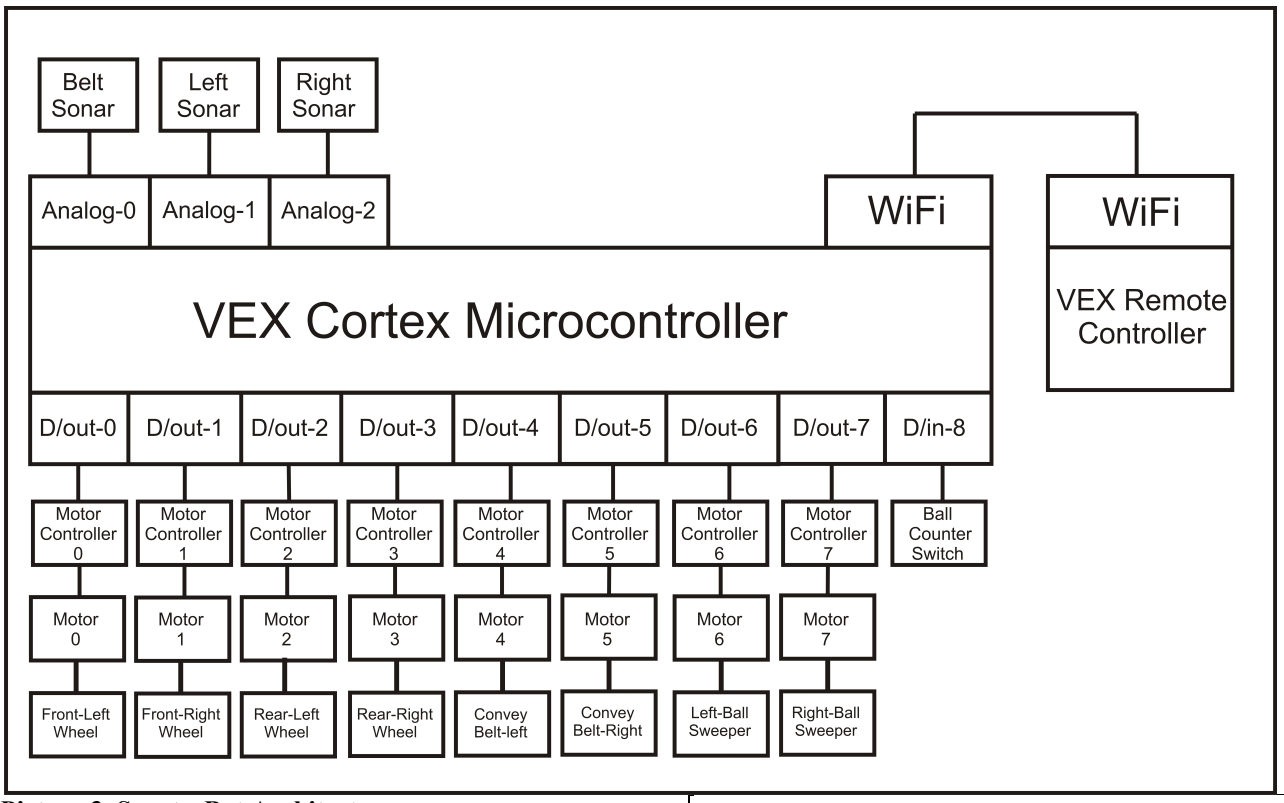
A ball-boy robot's design should not be easily breakable since it is going to be wandering around the tennis court for long intervals of time, depending on the amount of balls that it has to collect. Also, it has to resist erosion and changes in humidity and temperature. Its design has to show a solid structure but it should be simple for a faster and easier maintenance and it should allow the robot to have smoothness during its motion.

A ball-boy robot's programming code has to make the robot able to recognize the difference between the balls that it should pick up, the obstacles that it has to avoid, and other different objects. Including the features of speed and sensoring techniques, the first one would help the robot to control its speed depending on the surface on which it is working, and the second one would improve the robot's recognition and understanding of its surroundings as well as the robot's productivity and effectiveness.

Overview of ScouterBot

ScouterBot was built following these three aspects as mentioned; consisting of two pairs of Omni-wheels that allow ScouterBot to move on clay courts, hard courts and carpet courts. Its structure is not easily breakable and durable, and can be carried around without problems as well as it has no difficulties on maintenance. ScouterBot has three ultrasonic sensors, two at its sides for detecting obstacles, and one at the center for detecting the balls to be picked up making ScouterBot a fully autonomous robot whose programming code is programmable so it can be programmed to pick up balls of different sizes.

3. ScouterBot Architecture

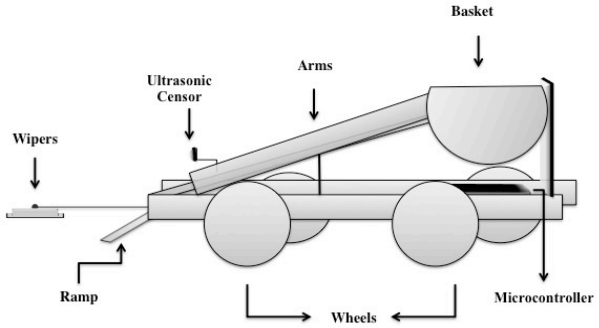


Picture 3. ScouterBot Architecture

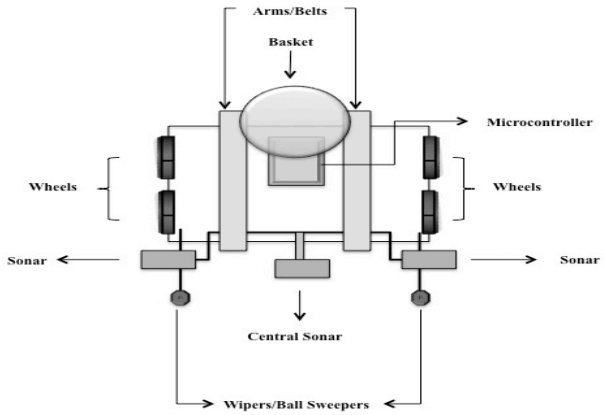
ScouterBot's system consists of two parts, one main system controller and a remote controller. The main system controller consists on the VEX Cortex microcontroller and uses eight digital outputs and one digital input. Eight motor controllers are connected to each digital output and to eight motors respectively. The first pair links the motors of the front wheels to the microcontroller as well as the second pair links the motors of the rear left and right wheels. The fourth and fifth motor controllers link the convey belt's motors to the VEX cortex and so do the sixth and seventh motor controllers by linking the ball sweeper's motors to the cortex. The only one digital input is linked to the ball counter switch and the belt sonar, left sonar and right sonar sensors are connected to the three analog ports respectively. Finally, the VEX remote controller is connected to the VEX cortex using Wi-Fi.

4. Mechanical Design

In the paper, we propose efficient ball picking mechanism which consists of the belt system and two sweepers for conveying balls to the basket as well as guiding balls to the gate of the belt.



Picture 4. Side View of ScouterBot Design



Picture 5. Front View of ScouterBot Design

As shown in Figure 4, ScouterBot's body structure consists of two pairs of wheels and the Vex cortex microcontroller attached to its base fame. The basket is supported by a thin piece of metal and also attached to the arms.

The ramp and wipers are hold by the base frame and the ultrasonic sensor is located on one of the arms.

Figure 2 shows a better diagram of where the ultrasonic sensors or sonars are located.

5. Implementation

Since we are aiming for a low–cost autonomous picking up balls robot it was decided to use the VEX kit for robotics classroom [5]. The metal pieces that come with this kit allowed us to make a solid hardware structure for ScouterBot, easy to maintain and easy to carry.

Structure Subsystem

* Basket: At the superior extreme of both arms is attached the basket, which is the one that retains a certain number of tennis balls (between 8 and 9). It was carefully designed so the balls would stay inside without rolling down or obstructing other balls' path.

* Body Frame Dimensions :

- Height: 28cm
- Base's lengh:37cm
- Base's width:33cm

Motion Subsystem

* Wheels: Considering the clay courts, hard courts and carpet courts it was decided to use the Omni wheels [30], since they reduce the friction during its motion and make the turning much faster and smoother.

* Motors [31]: In total ScouterBot uses 8 motors with one microcontroller each one.VEX website link)

* Arms or conveyers: The arms or conveyers are on the base, attached by one pair of thin cylindrical columns located at their sides and two metal plates. Both have a length of 31.5cm and the motors installed on their superior extremes when activated make the conveyers rotate so the ball is pushed up towards the basket.

* Wipers: A pair of wipers is also located at the lateral sides of ScouterBot. They are almost horizontally parallel with the front wheels, and have the task of pushing any ball outside the central sonar range into its range. So the cycle of collecting the ball and guiding it inside the basket is repeated.

Sensoring Subsystem

* Ultrasonic Sensors [29] : One central sensor is attached half way of the arms, almost at the end of the bottom extreme. This ultrasonic sensor has a range of 8 inches within which it detects the ball to be collected. To then, immediately activate the motors installed on the arms, so the conveyers will take the ball inside the basket. Two sensors are at each side of the arms. They have the function of detecting the obstacles allocated within their respective ranges so then the robot proceeds to avoid crashing with the obstacle.

Power Subsystem [4]

* Battery: 7.2V Rechargeable Battery(NiMH)
* Capacity : 2000 mAh

Manual Control Subsystem [2]

* Joystick for manual control: ScouterBot can change from an autonomous mode to a manual control device like a joystick.

Programming Language

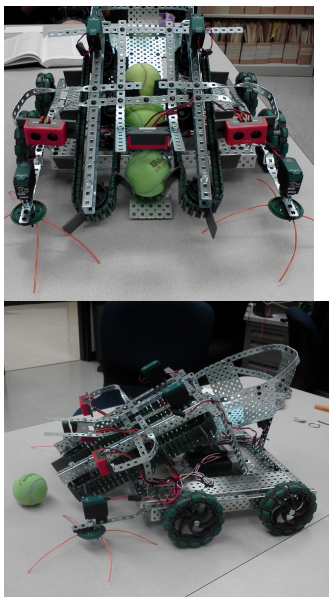
* Software: to make the sensors work along with the motors requires a programming language. The VEX cortex microcontroller [3] was used and the language to write the programming code is ROBOTC [15].

ScouterBot has been going through many improvements to reach is actual condition. A limit switch (Sensoring Subsystem) was added and the programming code was modified so ScouterBot will know how many balls it was collecting.

Another attempt to make of ScouterBot a suitable autonomous ball-boy robot was also made by changing the programming code in order to make ScouterBot stop completely once it collected a fixed amount of tennis balls.

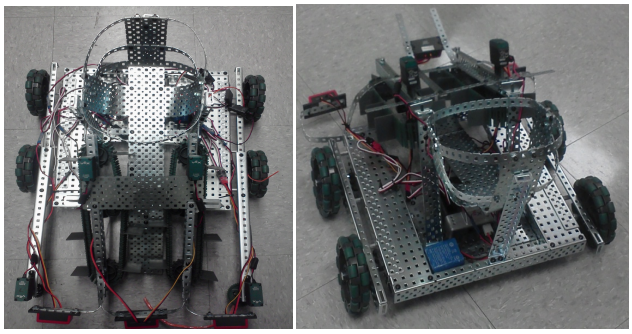
6. Prototyping

For the prototyping of ScouterBot, we used VEX robotics classroom Kit which allows us to build this design quickly and efficiently.

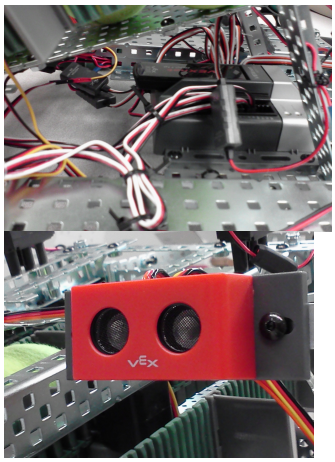


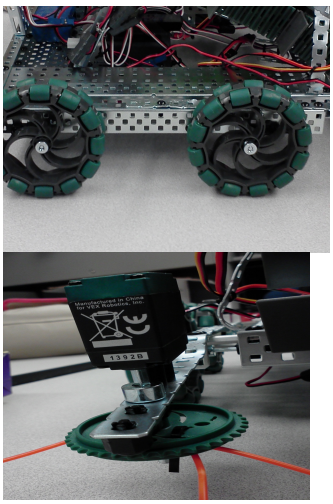
Picture 6. Front and Side View of Prototype ScouterBot

In picture 6, the prototype of ScouterBot shows how to pick and convey tennis balls to its basket using a pair of belt system. Two sweepers guide the balls to the gate of the belt system so that ScouterBot can collect balls efficiently.



Picture 7. Top and Back View of Prototype ScouterBot





Picture 8. VEX Cortex Microcontroller, Sonar, Omni-wheel, and Sweeper.

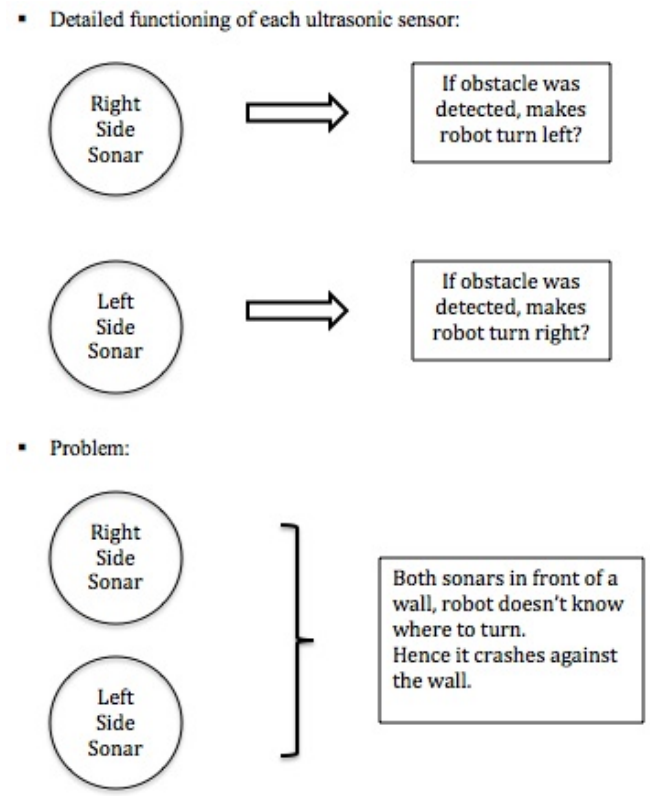
In Picture 8, the VEX Cortex Microcontroller is attached at the base frame for an easy wiring. An image of the sonar is depicted to show its ultera sonic emmiter and receiver. The Omni-wheels' structure help ScouterBot to have a smooth motion when going forward,backwards and turning to the sides. The ball weeper is attached on the motor as shown in the picture.

7. Discussion and Future Work

ScouterBot wasn't working well at the beginning of the project, there were some deficiencies on its design and on its programming code that wouldn't let ScouterBot have a good motion, nor detect obstacles. ScouterBot wasn't fully autonomous; we controlled it with a joystick and it did everything backwards. Although the wiring was correct we discovered that for some reason the motors were flipped, so we had to flip them again in order to make ScouterBot's motors go forward.

Understanding the RobotC programming language also took a while; we discovered that the perfect speed for the motors to either go forward or backwards was 50% of its maximum power due to stable mobility. The turning motion had the same speed, and the conveyer arms motors worked at a speed of 100 % of its maximum power.

However, once that we understood the programming language, coding the ultrasonic sensors didn't represent a challenge. The lateral sensors detected a wall or obstacle within a range of 15 inches. But when both sensors were in front of a wall, ScouterBot got confused and crashed into the wall. A brief explanation of the problem and the solution is shown below:



Picture9. The problem and solution for obstacle avoidance

* Solution applied

Inside the code we allowed ScouterBot to go back and forth four times and then turn right to then resume its task of collecting balls.

Problems noticed while testing

Ball wouldn't be picked up because the central sonar couldn't detect it. Because we had assigned a value of 10 inches to the central sonar's range. The appropriate value for it to detect the ball ended up being 8 inches, after recalculating the tennis ball diameter.

The limit witch or touch sensor turned off the whole robot when one ball was picked up. After further testing we discovered that the touch sensor is extremely sensible so that when the ball touched it, the value read by the sensor was of 3 units. Thus, ScouterBot understood that he had collected three balls, and stopped functioning. Solution: multiply the actual number of balls to be collected by 2 and input that as the limiting value.

*Remaining Problem: The robot picks up seven tennis balls and it turns off, except the motors at ports 8 and 9, which belong to the wipers. We are still testing and trying to find a solution.

Future Implementations

Within our ideas of giving ScouterBot a better understanding of its surroundings, we plan to install more ultrasonic sensors and a camera. These additional ultrasonic sensors will provide efficient obstacle avoidance while the camera would give ScouterBot the eyes that it needs to recognize the tennis-balls to be collected intelligently. Hence the programming code would be improved.

Because ScouterBot can move without any difficulties on tennis clay, hard and carpet courts, the idea of changing the model of the wheels is contemplated as well as changing the design of the wipers, in order to make ScouterBot work on tennis grass courts without presenting deficiencies in its motion.

Research on more efficient sensoring techniques would also make ScouterBot's awareness of its surroundings sharper and more accurate. Our goal is to have a similar sensoring strategy as the "Mobile Robot Navigation and target tracking System" project but it would take time since we have restrictions on our budget.

8. Conclusion

In this paper, we proposed a low-cost autonomous ball-boy robot called ScouterBot. ScouterBot is based on an ultrasonic sensor obstacle avoidance strategy combined with a conveyor belt mechanism being its main objective to pick up tennis balls autonomously. The prototype of this design demonstrates the feasibility of ScouterBot and its autonomous feature. More detailed examination on sensing techniques and improved programming algorithms remain as a future work.

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