RoboTag: Using Autonomous Mobile Robots to Simulate a Childhood Game

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Abstract

This project explores the use of artificial intelligence in the area of robotics. The goal is to illustrate how two autonomous mobile robots interact with the use of light and touch sensors in a game of tag. Observations are implemented using two robots constructed from the LEGO Mindstorm set. One robot is designated as the prey, and the other as the hunter. Each robot has the ability to seek out light, avoid obstacles, and respond accordingly. Areas of artificial intelligence playing an integral role in the simulation are reflex agents and subsumption architecture.

Introduction

Childhood memories are abundant in the minds of college students as they try to remember a time of little stress. Pastimes include running around the playground during recess, playing hopscotch, jumping rope, or throwing a ball around. Almost every student remembers a time when the opposite sex had cooties, but somehow had no problem chasing them around the playground. No winners were declared in this game, as it lasted until both parties were exhausted, or the whistle blew to signal the end of recess.

This game, usually called “boys chase girls or girls chase boys,” later developed into the simple game of tag. This game became a little more complex as the boys and girls would actually have to touch each other for the game to continue. As one would tag another, the person who was “it” would then have to find someone else to tag, and so on. Variations on the game included freeze tag and a much later more technological based game called laser tag.

Another childhood pastime was more of a rainy day, home activity. When no one of the opposite sex was around to annoy, children would drag around their box of LEGOs. As they opened the box, eyes widened as their minds started to develop intricate architectural plans for buildings, cars, and creatures. The possibilities were endless.

LEGOs, developed in Denmark in the early 1930’s, have spanned generations as a one of the most popular toys of the Twentieth century. The name LEGO came from combining the Danish words "Leg” and “Godt," which translate to “play well”. Appropriately, it was later realized that LEGO in Latin means, “I study” or “I put together” [1].

As the toy developed, more pieces were added as the brainstorming team at LEGO continued to create new models and projects. In the 1970’s, the TECHNIC set was introduced. The kit included motors with which to control LEGO vehicles. This started a whole new era for LEGO Company.

It was soon realized that people could program the LEGOs and build more intricate models. Concurrently, in the mid-1980’s, a research group at the Massachusetts Institute of Technology (MIT), inspired by the advancement of LEGOs, started developing a programmable brick [2]. Additionally, they developed multiple sensors for use with the brick. Their research led to the eventual production and release of the LEGO RCX in 1998. The model was adapted from the original work at MIT and became part of the LEGO Mindstorm System.

The World of Robotics

This branch of LEGOs led the product into the exciting realm of robotics. Previously, only scientists in large research labs experimented in this extensive area of artificial intelligence and engineering. It was now apparent that people of all ages would be able to program autonomous agents to complete a multitude of tasks.

Early work in the area of autonomous mobile robots included endeavors into using machines with simple reflex actions. Often the machines were constructed of vacuum tubes, motors, and an uncomplicated light or touch sensor. Walter, in a 1951 Scientific American article writes about his attempt to develop a simple robot [3]. Named, *Machina speculatrix*, it was able to move about an area and find a favorable atmosphere. In other words, it moved towards areas with a moderate concentration of light and was deterred by high levels of light. His results are representative of what is now called behavior-based robotics [4].

Behavior-based systems consist of numerous behaviors, represented by sensors that act accordingly to a certain set of conditions. For example, an avoid-obstacle behavior is activated if an obstacle is encountered, as signified by the depression of a touch sensor. The same theory applies to light sensors, temperature sensors, and other means of retrieving data from the outside world. An article in *Trends in Cognitive Science* outlines a behavior-based robot as being "controlled by a structured network of interacting behaviors" [5].

Further research led to the discovery of another division in the methods used to control robots. Robots could either be reactive, as previously noted, or functional. As can be inferred from the name given to this new subset, these systems generally were created to reach a specific goal. Their primary function remained the same in any situation. Using great amounts of knowledge, they planned a route before proceeding to carry out its assigned task [6].

Advantages and disadvantages exist in both approaches. Functional mechanisms are slow in responding to variations in the environment. Much of its time is spent analyzing the new atmosphere and planning a new course of action. To make changes is a tedious process because of its top-down design. A behavior-based system can often be confused if more than one behavior is stimulated at the same instance. As it reacts to one behavior it may ignore another, thus causing the robot to fail. Even so, a behavioral architecture can respond quickly to changes in its surroundings [6].

One such system employing the bottom-up technology of behavior-based robotics is the Koala robot [7]. This machine, developed at the Laboratory of Microcomputing at the Swiss Federal Institute of Technology, is an autonomous vacuum cleaner. Sensors are utilized to allow Koala to follow along a wall, avoid obstacles, and change cleaning speeds to accommodate for dust. While the system is operating, these tasks run in tandem.

Rodney Brooks, a professor at MIT, further explored these parallel operations [8]. He referred to these multiple behaviors as subsumption architecture. Appearing in an extremely organized manner, his research outlines the works of previous scientists. Systems are divided into several tasks with a sensor assigned to each. Sensors perceive changes in the environment. As a change is noticed, the appropriate behavior is executed by use of actuators.

It should be noted that the word "autonomous" has been mentioned frequently within this paper. A definition is needed to broaden understanding of this term. Maintaining autonomy is important in the development of a robot. It should be able to move independently and reactively. This movement is often compared with insects [4].

Illustrating a Childhood Game with Robots

At this point we have described autonomous systems implemented using various artificial intelligence techniques. We have also explained previous attempts at building autonomous robots. Using the concepts of subsumption architecture in behavior-based systems we have successfully been able to illustrate a simple game of tag.

Our implementation utilizes the LEGO Mindstorm kit. Each kit includes a variety of LEGO pieces, 2 motors, 2 touch sensors, a light sensor, and connecting wires. The backbone of the kit is the RCX programmable brick. This rectangular-shaped LEGO has six inputs and a LED window for viewing the readings of each sensor. It could be programmed using a variety of languages developed specifically for the RCX. We chose Not Quite C because of our familiarity with the C language. However, before programming the RCX, a mobile vehicle, to be used as a tag agent, had to be constructed.

In advance, we composed a list of the characteristics of the game and deducted that the following properties had to be applied to any model we created:

- The robot must be able to avoid obstacles.
- A device with which to tag must be developed.
- The robot should be capable of maneuvering in any direction.

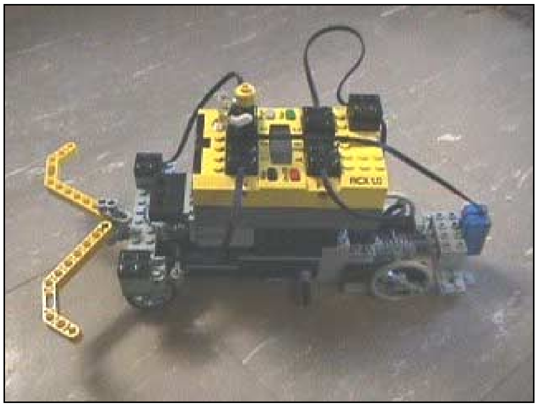

Figure 1 – Prototype #1

Figure 2 – Prototype #2

Initial attempts at assembling the robot were unsuccessful. Pieces would either not stay together or the alignment of certain bricks would not allow for expansion. It seemed that all hope was lost without gluing or duct-taping everything together.

After further investigation online [9] and in bookstores [10] we were able to arrive at our first prototype (Figure 1). This vehicle used a combination of back-wheel drive, rack and pinion steering, and a left and right bumper. A subsequent newspaper article followed the development of this model [11].

The weaknesses of this model were quickly apparent in the steering mechanism. We realized that in order for the robot turn around completely, a large area would be required. This would work to the disadvantage of the robot in a game of tag. Additionally, the steering had to be constantly adjusted because the wheels would not remain in perfect alignment. Moreover, pieces from other LEGO kits were utilized and duplicates were not available.

Advantages were observed in the configuration of the bumpers. The autonomous agent could easily avoid obstacles. If the left bumper became depressed, it would back up, turn to the left, and then continue forward. The same actions would occur for the right bumper. Ultimately, after much hard work is was concluded that this approach did not meet all of our criteria. Mainly, it was not an efficient vehicle for moving about an area.

Accordingly, many changes were made until we arrived our next prototype (Figure 2). Restrictions on this model allowed it to stay within a course outlined on the floor by black marker. The light sensor pointed downwards in an attempt to recognize the boundaries of the environment. Moreover, the light sensor was attached to a front bumper, used as the tag agent. This design benefited from the tank-like treads, which allowed it to turn in a minimal amount of space. After experimenting with his model we discovered that it still did not fully meet our criteria.

We could now observe some features that would work the best in our final design. Treads, allowing the robot to move freely, and a bumper system were seen as necessities. However, a method by which to find the other robot had still not been discovered. With this in mind, we began constructing our autonomous mobile robots.

In contrast to previous designs, we placed the light sensor on top of the RCX brick, facing forward. This would allow the robot to locate levels of light, represented by the values 0 (dark) to 155 (light). A battery pack, containing four double A batteries, was placed on top of the robot. Attached to the positive and negative outputs was a small white light. This would become the key to searching for another robot.

The Hunter and the Prey

A simple game of tag requires two objects, the hunter (Figure 3) and the prey (Figure 4). The hunter's task is to find the prey and tag it, while the prey tries to avoid the hunter. With a final design chosen, we proceeded to develop an algorithm for both robots.

The prey is identified as the area from which the most light emerges. In order for the hunter to locate that area it must turn around in a circle and set the search value to the highest level of light. Then, the hunter will turn around again until the level of light is within a certain range of the search value. It will then make a slight advance towards the direction of the light. By

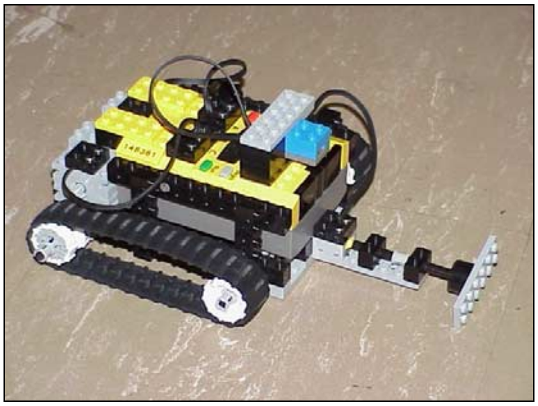

Figure 3 – The Hunter

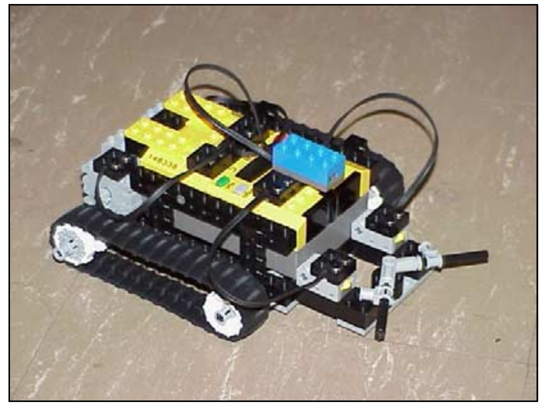

Figure 4 – "The Prey"

allowing the search to locate an area of similar light levels it allows for the movement of the prey.

With the search method in place, it was then important to construct a means for tagging another robot. Originally, it was thought that by making use of the infrared sensors on the front of the RCX brick a message could be relayed. This message, if received by the other RCX, would indicate that the prey had been discovered, and thus tagged. Problems were encountered with this implementation and as a result, a front bumper was added to the hunter. If the bumper became depressed, it was assumed that it had tagged the other robot. The algorithm used the subsumption architecture illustrated in Figure 5.

Next, using the same frame as the hunter, the prey was constructed. The only difference existed in the front bumper. Where the hunter only used one touch sensor, the prey employed a similar design to the first prototype. This allowed it to avoid obstacles and walls. The algorithm for this robot included one additional task. For a prey to avoid being tagged, it had to have the ability to run away from the hunter. This occurred when the light sensor identified a high level of light. The prey would then change directions in an attempt to move away from the hunter. The subsumption architecture for the prey can be seen in Figure 6.

Trial and Error

Before allowing the robots to compete with each other, we first tested them individually. Using a flashlight, we first tested the hunter to see if it could locate the light. After noticing that the light sensor had a low range for identifying light levels adjustments were made to the search. An extreme amount of difficulty was experienced when checking to see if prey ran away from light. It was discovered that the light had to be at a certain level for the sensor to recognize it.

After making numerous changes and adjustments to both the code and robot, we were ready to let them loose. It was quickly discovered that a dorm room floor was not the ideal surface for running these trials. The cramped floor space not covered by carpet allowed for very short test periods. Furthermore, the room light level interfered with the light sensor detection. To correct this problem we closed the blinds and turned off the lights. Satisfactory trial runs were finally made under these conditions.

Future Plans and Conclusion

While adequate results were found, future plans call for some simple changes. It has already been mentioned that the communication

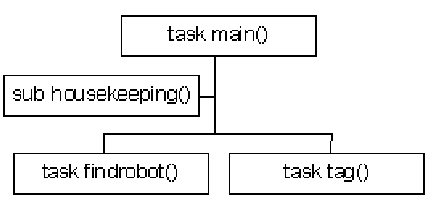

Figure 5 – Subsumption Architecture for The Hunter

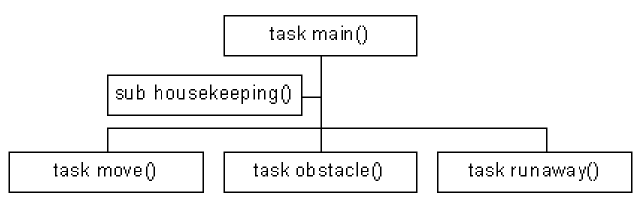

Figure 6 – Subsumption Architecture for The Prey

between the RCX bricks would be ideal for tagging. Additionally, with the infrared messages, the game could be continued. In a normal game of tag, when the prey is tagged it becomes the hunter and vice versa. With our current control system, once the hunter tags the prey, the hunter stops and the prey continues to move.

We would also like to experiment with other designs. Once such concept we have only imagined is making the light sensor turn in a circle. This implementation would be more life-like as it would simulate a person turning his or her head to see if someone is approaching.

In closing, we have described a simulation for the game of tag using autonomous mobile robots. The approach employs two main areas of artificial intelligence. Mainly, it deals with behavior-based control using reflective agents and subsumption architecture. Future exploration will assuredly discover new observations and designs.

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