2019

Real Robots

AIAB REPORT

168908

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Abstract

In the natural world, the behaviours shown by animals toward light sources can be simple and from the implementation of simulated robots in the previous report, it is vital to attempt to build such robot in the real world an see the behaviours in the realistic environments. In this study, I will be using the LEGO Mindstorms EV3 robots to implement those phototaxis behaviours by having two wheels and sensors of different kind. And explore the different ways to have different layers of behaviours built into the robot.

Hypothesis: The behaviours explored in the previous study (simulated robots) can be implemented in the real world only if both the role of the body in the computation and the role of the action is equally designed. And the difference between the actual implementation in the real world will be drastically different to that of the simulated robots due to noise and other real world factors.

1 Introduction

In the real world, there are many differences to the simulated robots in the previous study. The physical robots will experience realistic environments and be validated to be practical in the real world whereas, simulations lack the necessary evidence to be conclusive in the study on acquired intelligence and adaptive behaviours. In the real word, the physical robot will be subject to some complex agent-environment interactions such as reflections of lights and various other unpredictable factors such as the effect of the surface materials (i.e. friction). Furthermore, it is much more expensive to conduct such real-world experiments because the robot takes many hours to construct and perfect that may lead to more expense to the research, also the obvious price tag of buying the parts for the robot is considerably more costly than simulated robots. However, it is very important to test such robot in real life because often the result will lead to some surprising finds that cannot be discovered by simulations.

In the previous study, I have done simulated robots for understanding simple behaviours in terms of the structural design of a robot. It helped me learn the concepts of how robots could be automated to be phototaxis without a complex system and in this study, a real robot will be tested for similar behaviours. And currently, battery technology has improved significantly and will continue such trend in the foreseeable future so robotics have or will have one of the biggest obstacles removed. As mentioned in the paper (Grand challenges for evolutionary robotics), the problem of interest is compositionality, scaling and autonomy according to Eiben (2014).

Compositionality is the problem where a robot could be designed for a task but how it could have multiple behaviours stacked up together and executed. Dealing with many functionalities in the real world. To scale the ability of a simple robot to have compositionality into that of a bigger and more complicated robot is of interest. And an independent robot that will be adaptive and function for an extended amount of time known as autonomy. These challenges will be discussed and explored in this study.

Phototaxis: the locomotory movement, that occurs when an organism reacts to a light source either moving closer or further away. This behaviour could be observed in many organisms in the natural world, most notably the moths and zooplankton mentioned by Jekely (2008). They are the biological basis for the robots in this study because the moth features a two-eyed positive phototactic behaviour and the zooplankton features a single-eyed positive phototactic behaviour which is like the robots experimented in this study.

In the previous study on simulated robots, the emergent phenomena displayed shows how low-level components can use simple rules to create high-level or even complex behaviours. In this report, we will implement the simulations into reality and try to discover what are the differences between simulation and reality. After conducting all the test with the three various types of robots, I have discovered a great difference in how robots' function in real life and how the body and software are both important in achieving good results.

2 Method

In this study, I will be building the robot with the LEGO Mindstorms EV3 and using Robot C to code the necessary behaviours for this system to function. The LEGO Mindstorms EV3 provides sophisticated hardware which includes wheels, motors, CPU, sensors and many other components that will provide the platform for our robot to be built from.

Two-eyed phototaxis

Firstly, we created a robot with a pair of wheels on the front end of the robot using LEGO Mindstorms EV3, it featured a single pivot wheel on the back which prevents the vehicle from constantly touching the ground. The pivoting wheel has no power to it, so it acts only as support for the practical implementations of the two-motor system. As shown in figure 1, the front of the robot has two sets of wheels powered by their respective motors. Also, the robot has light sensors

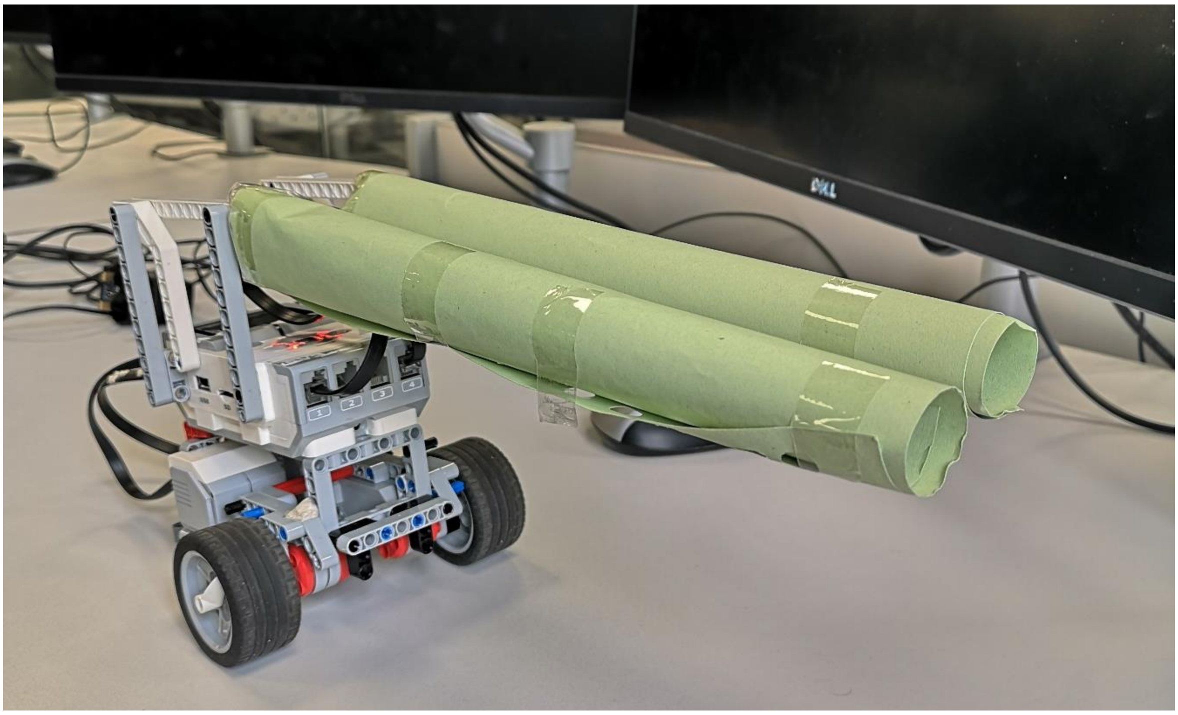

Figure 1 two-eyed phototaxis robot, we have the two motors at the front with a third pivot ball at the rear and it is very evident that we have very long cones covering the sensors facing directly forward.

attached high up. The design is unique in that we decided to place the sensors parallel next to each other and have a very long tube so that the long tube will try to reduce the amount of noise from the environment. So, the light that comes to the sensor is only from the direction straight ahead. Without the long tube, we might that there was too much light reflected from different objects and sunlight from the window which made it perform particularly bad so the implementation of the long due helped us have a better sensor.

Pseudo Code:

1. *set default speed of left sensor*
2. *set default speed of right sensor*
3. *if leftSensor greater than rightSensor OR both sensor below threshold*
4. *right Motor increases speed*
5. *left Motor reduces speed*
6. *else*
7. *left Motor increases speed*
8. *right Motor reduces speed*

Motor D is the left wheel and the motor A is the right wheel. This is to make it contra-lateral so that it will display the aggressive behaviour going towards the light.

As the pseudo-code shows, the amount of light received from the sensor is multiplied by 30 so that there would be a significant value to act upon. We chose to code the robot so that when left sensor is having lower values than the right sensor or when both sensors have a reading value less than 2 then the robot will turn to the left side. Else, the robot will turn to the right. This would allow the robot to find the direction of the light and travel towards it. The values we chose where through experimentation and reading the displayed values, we've deduced the values for which the robot will have the maximum speed whilst performing the task of reaching the light.

Video for the two-eyed robot is attached to this report.

Note: Our group Terminator X came first in the competition

One-eyed phototaxis

After experimentations with two sensors, we decided to remove one sensor and place a single sensor in the middle of the robot. According to the simulated robots, in order to implement a one-eyed approach then the robot must be able to use a single sensor to locate and head towards the direction of strong light intensity. To achieve this, we have written the following code.

Pseudocode:

1. *multiply sensor value by a constant value*
2. *RightMotor set to max speed*
3. *LeftMotor speed increases as more light are detected*

Although a very simple bit of coding, it surprisingly works perfectly as our robot managed to reach the light every time. To understand how it works, firstly, there is a maximum limit to how fast each motor can go, so the Motor A set as 10000 is just to make sure it is going as fast as possible. And the other Motor D will have a default value of 5 and it will speed up when more light is detected and when light is strong enough, both wheels will spin at maximum speed hence allowing the robot to reach the light at a fast speed.

Note: Our group also won the competition with the one-eyed competition (Terminator X)

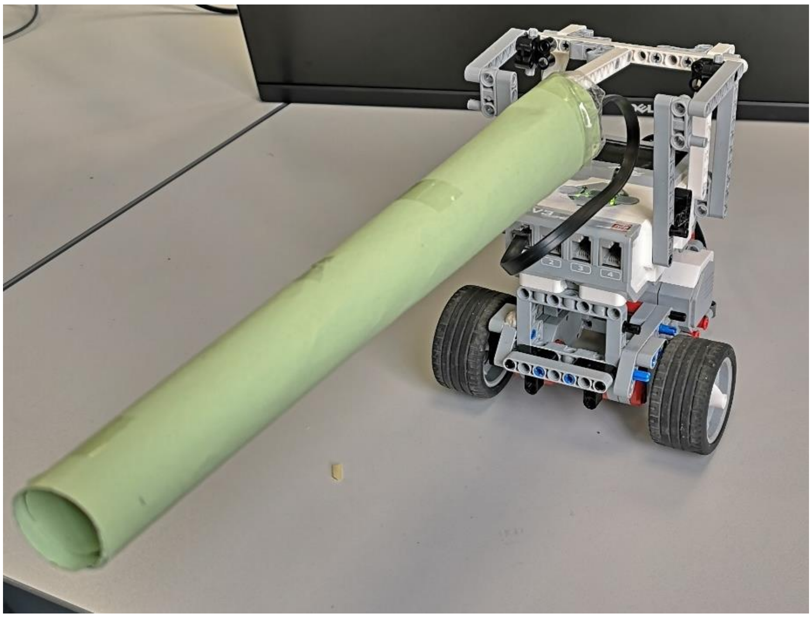

Figure 2 The one-eyed robot, we've removed the other sensor and restructured the frame to allow the installation of a single sensor in the middle of the robot, all other features of this robot is identical to the two-eyed robot.

Phototaxis + collision avoidance

The collision avoidance behaviour is a very important skill in the natural world and often it is a matter of life or death, so nature has developed very ways organisms are performing collision avoidance. In this study, I will attempt to append this sophisticated avoidance behaviour to the existing phototaxis vehicle with two sensors. Based on the original two-eyed robot, we've managed to add two sonar sensors in front of the two wheels and initial testing revealed that the sonar sensors must not be both pointing directed head on because it is impossible for the robot to go around objects if the sonar

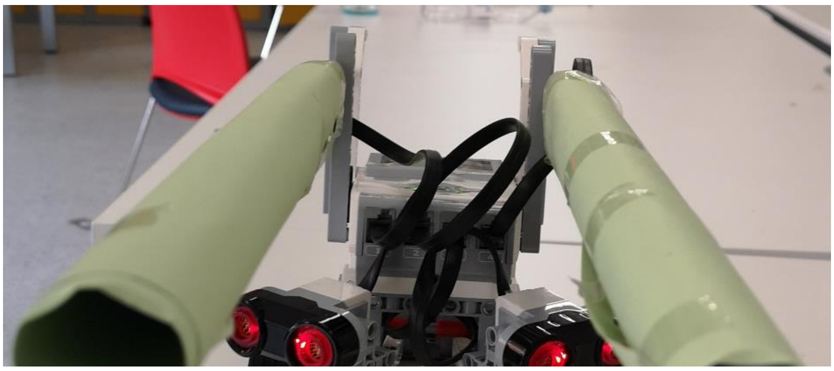

Figure 3 Obstacle avoiding robot with two sonar sensors, the sonar sensors are pointing outwards at an angle. The spacing of the light sensors have been increased to help improve the performance with detecting light.

sensor readings are identical so we decided to change the angles of the sensors so that they are both pointing around 30 degrees outwards. It was particularly time-consuming to obtain the correct numbers for the sonar sensors and the value for the light value for this obstacle avoiding robot because when it gets closer to the light, the robot would detect the light as obstacles, so the code included if statements to force the robot to continue to go towards the light even if the sonar readings are high.

Video of the obstacle avoiding robot is in the attachment.

Pseudo-code:

1. *Multiply rightAmbient by a constant and make it photoLeft*
2. *Multiply leftAmbient by a constant and make it photoRight*
3. *if photoLeft greater than 100, cap to 100*
4. *if photoRight greater than 100, cap to 100*
5. *if leftSonar AND leftSensor AND rightSensor below threshold do*

   reduce photoLeft value

   increase photoRight value;

6. *else if rightSonar AND leftSensor AND rightSensor smaller than threshold do*
   reduce photoRight
   increase photoLeft
7. *if leftSensor greater than right Sensor OR all sensors are below threshold*
   increase rightMotor speed
   reduce leftMotor speed
   else
   increase leftMotor speed
   reduce rightMotor speed

The values in the code were done in trial and error method, because very often with this robot if the values in the code are not perfect then the robot will behave wrongly. As seen in the pseudo code, the robot attempts to rotate to the side with more light intensities and will turn away from obstacles before hitting it and only if the robot detects strong light intensity, the motor will not stop or change speed so that once the light value is great enough, it will stop the robot from doing obstacle avoidance.

3 Results

The result for the two-eyed robot shows our robot managed to turn right and when the sensors detected the light, both motors speed up to maximum speed toward the light without having to re-adjust its direction. The performance shows that it will find the light source without being distracted by the noise in the room because the tubes have managed to only gain light from the same height as the robot itself so that the light from the windows cannot shine towards the sensors and the only light source that could increase our sensor readings is that of the light. When the robot over turns, the sensors will detect a difference in the light intensity value and thus will turn back towards the light, this behaviour can be seen in the video attached.

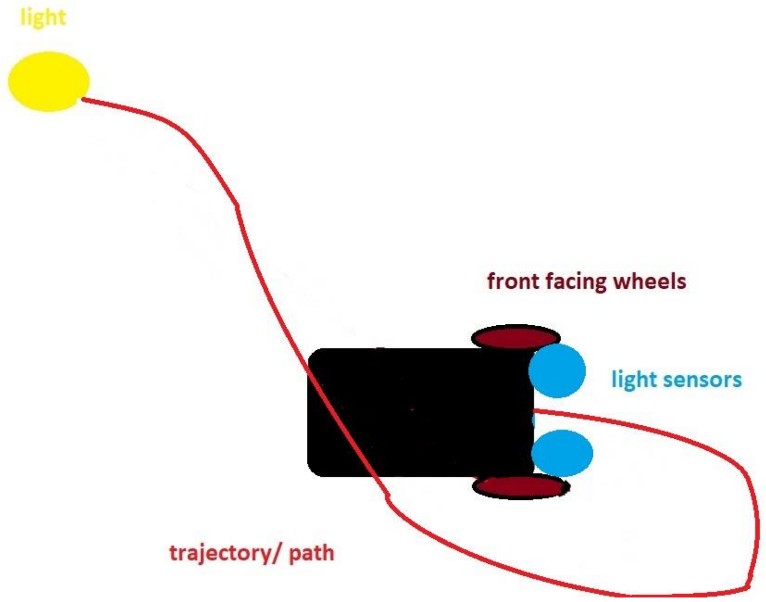

Figure 4 this shows how the robot facing the other direction away from the light managed to turn around and go to the light, also can be seen in the video attached

The success of the one-eyed robot is due to the implementation of the long tube that covers the single sensor because the robot will continue to turn until it is directly facing the light source and then the robot will go towards the light. This is far superior to other designs because if the tube wasn't as long then it will be impossible for the sensor to know exactly where the light is, and our approach would've not been possible. It highlights the importance of having both a suitable hardware implementation and a good design in the coding. Without the two sides of designs complimenting each other, it would be impossible to achieve such a great result. Throughout the competition against other robots, we came first with our design, so it proves that it is repeatable when having different starting positions, showing the robustness of our robot.

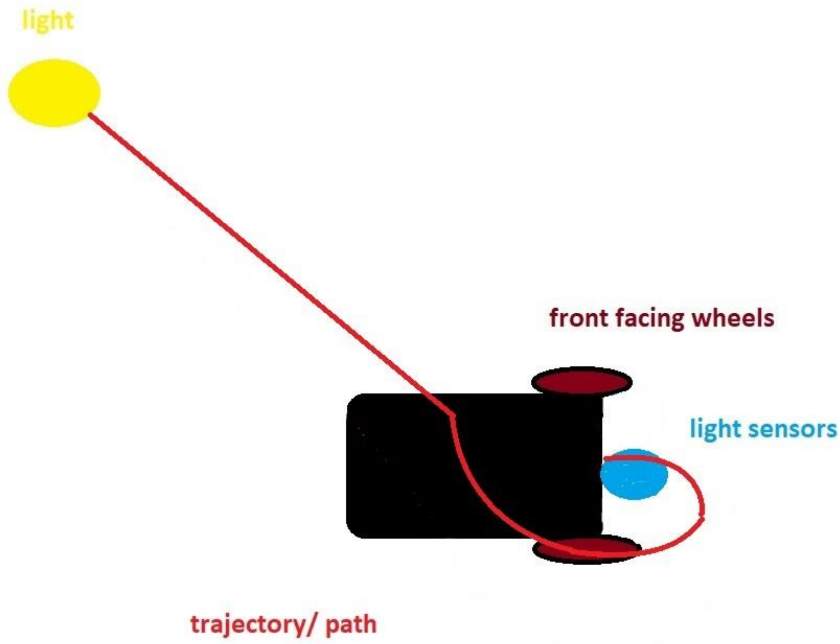

Figure 5 The robot with one light sensor rotates on the spot and when the sensor detects a light intensity above a certain threshold, the motor both move at the same speed towards the light. So the resulting trajectory is very efficient and went straight towards the light hence winning the competition against other robots.

The obstacle avoiding robot managed to rotate until it was facing the direction of the light and then it will go towards the light. If there was an obstacle in the way, the robot will turn away to the side without the obstacle and will head back towards the light once it detects no obstacles. The implementation of the two sonar sensors on the sides of the vehicle was perfectly placed so that both sensors would not be detecting the same obstacle and rather they are looking at two sides slightly shown in figure 3. Our robot managed to navigate through obstacles without ever getting close to collision and found the light which demonstrates the robustness in both the software and hardware design.

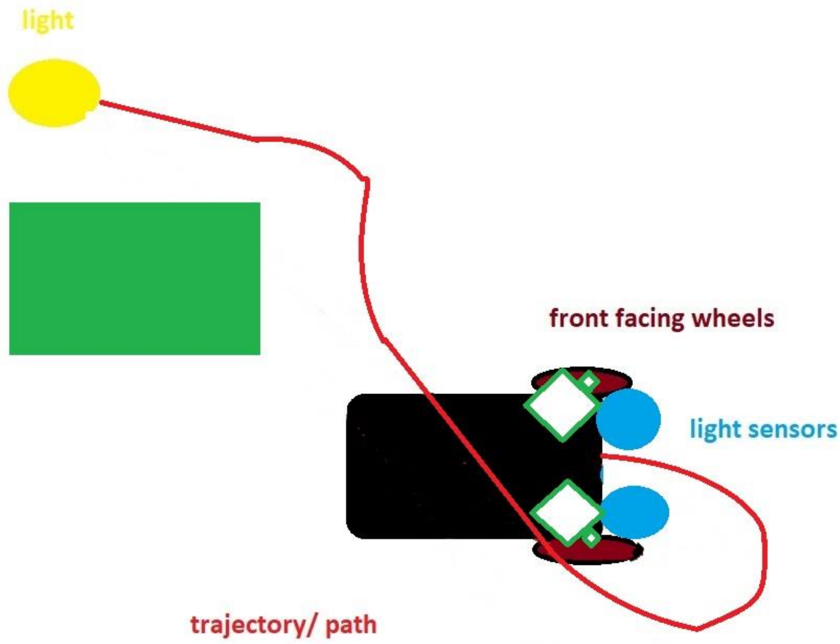

Figure 6 The two light sensors and two sonar sensors robot turns around searching for a side with more light and when going towards the direction of light, the robot had the obstacle on the left side of the robot and the sonar sensor on the left caused the robot to turn to the right until it no longer detected an obstacle and then the light sensors attempted to locate direction with more light and eventually reaching close enough to the light that the light sensors reached a threshold that prevented the sonar sensors from avoiding the light as an obstacle.

4 Discussion

During this study, we have discovered that real robots are far more complex than simulated robots because the engineering part of the physical parts plays a bigger role than that of the coding side. In the real world, there are far more interferences than in the simulated world and although software approach could solve some problems, the importance of the hardware implementations is far more important than originally thought from the simulated robot studies.

The real-life behaviours of the phototaxis are far harder to implement than the simulated robots. We experienced plenty of difficulties with interferences and noises in the real world, this was much simpler in the simulated world where all the parameters were predictable, and we realised that having a good physical design was as important if not more important than having a well-designed algorithm. Due to the noise in the room we've conducted this study, such as the reflections from the windows and such, it was rather hard to filter out the noises and allow the robot to neglect those factors. So, the correct use of the physical design in the way we implemented the cones that allowed the light sensors to only detect the lights in the front of the robot helped to eliminate the noise in the room, this is clear evidence that the physical design is a very important part to the performance.

Furthermore, we discovered that having simpler codes allowed the robot to be more robust and this proves that those simple organisms in nature must have very simple mechanisms to perform seemingly sophisticated behaviours.

As for the obstacle avoidance, we managed to implement subsumption in that, we managed to have the obstacle avoidance behaviour built on top of the phototaxis behaviour. It is very interesting to study to discover how complicated behaviours can be from very simple mechanisms and the finding that simpler mechanisms seem to behave better in the real world than that of complex nature.

5 References

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