Salisbury University

Weed Removal through Laser Technology and Robotic Automation Report

Daniel Bradley

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1. Project Goals

The primary goal of this research project is to explore an alternative method of weed control via a laser mounted robot which can target and destroy weeds through automation. During the semester I investigated how robotics, automation, and laser technology can be used as a possible method of weed control. While this is not an original idea, the use of robotics in combination with lasers as weed control is very recent. With currenting testing and studies, I believe that the combination of the three fields can be a potent form of disposing weeds, compared to herbicides.

2. Introduction

To control the growth and spread of weeds, accurate targeting of weeds is required. Primary methods of weed control are with herbicides and manual labor. Herbicides being the most convenient option comes at the price of having a negative impact on the surrounding environment. A study by Karl V. Miller shows that the adaptivity of weeds proves to be detrimental to the effectiveness of herbicides when it comes to repeated treatment (Miller 2004). Manual labor requires a heavy investment of time compared to herbicide yet does not harm the environment.

While less common methods are being researched, such as uprooting, an alternative to these methods is laser technology in combination with automation (Kurstjens 2001). The laser will be able precisely target weeds and disrupt their growth. A robot can transport a laser while being piloted through artificial intelligence. According to a study by C.Wöltjen, damage to the meristem of a weed via diode laser (Figure 1) has shown to inhibit growth.(Wöltjen 2008). If a laser can be efficiently transported and navigated to a weed and fired at the meristem, then it would prove to be an effective way to counter weed growth.

3. Design

To achieve automation, the robot had to be able distribute its power supply to an Arduino and control multiple different components to assist in movement and guidance. To be able to move from point a to point b, four TT motors with wheels were required for movement. Two motor controllers were used (one for two motors each) so the Arduino could control the direction in which the motors would spin. The last step of automation was the ability to control the power of the laser independently. This was done by connecting a relay in between the 18650-battery pack and the AC adapter for the laser pointer. With this installed, the Arduino will have control on whether the laser will be on or not.

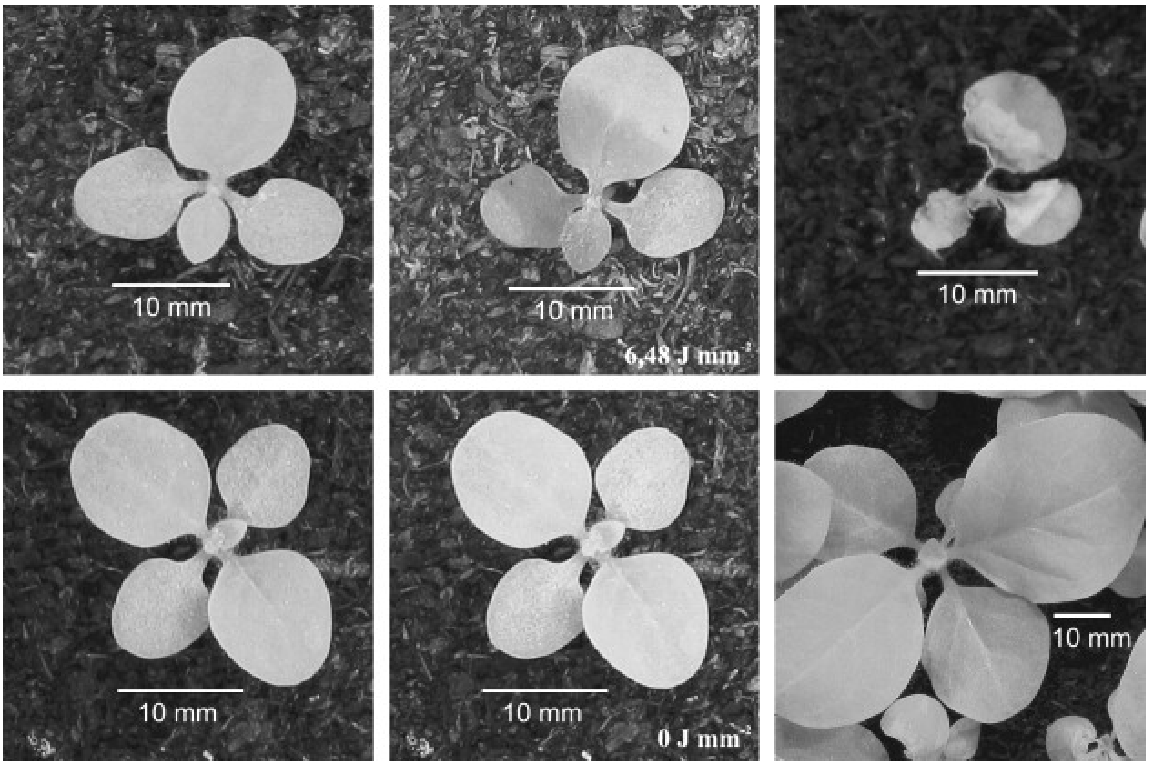

Figure 1. Top 3 pictures from left to right (untreated, immediately after laser treatment, week after laser treatment). Bottom 3 pictures from left to right(untreated,untreated, a week after).(Mathiassen et al., 2006)

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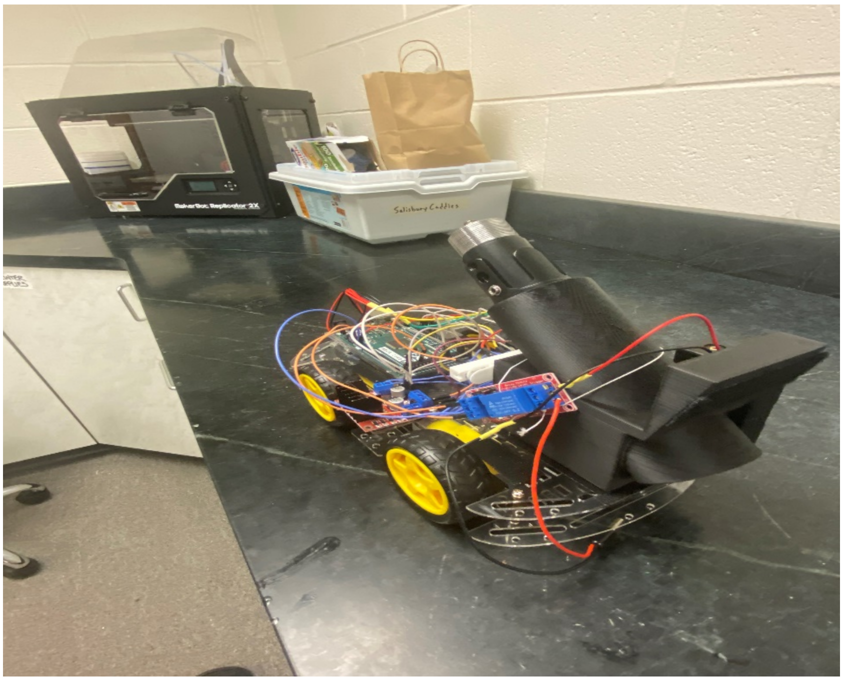


Figure 2:Laser – Mounted Robot

However, none of this would work without sufficient power supply. Powering the Arduino, two motor controllers, four TT motors, and the relay is done by four 9v batteries taped together in a harness. To power everything together, a breadboard was placed in the center of the robot. Here, all the positive and ground wires of the components and batteries would come together.

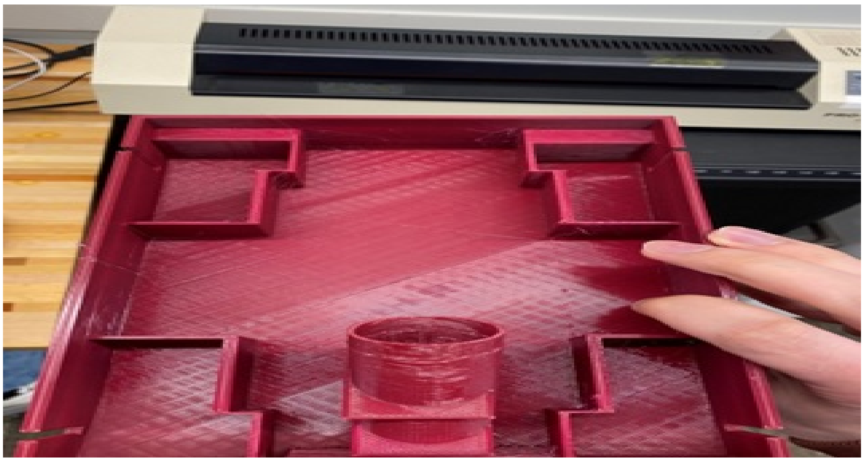


Figure 3:3D Printed Robot Frame

Initially the design of the robot was going to consist of a 3D printed frame designed in CAD to hold all the components of the robot. These components consist of an Arduino, 4 TT motors with wheels, 2 motor controllers, 4 9V batteries, a protoboard, and a holster to hold the laser. The prints however were not sufficient to hold the laser and other components. This was caused by either misprints by the 3D printer or inaccurate measurements in CAD. Instead, a robot frame was purchased, and a laser holster designed from CAD was 3D printed to be velcroed to the frame.

The plastic frame provided much more space than any of the previous CAD designs. The plastic frame was longer and wider than that the 3D printer workspace could provide, as well as the platform having two layers. The first layer of the plastic frame holds four 9v batteries and four TT motors. The second layer holds the laser holster, the laser, the Arduino, two motor controllers, the breadboard, and the relay. With this set up, I effectively had double the space since some components were in between to two plastic frames.

Starting from the front of the Robot, the laser holster in the centerpiece. The camera, battery pack, relay, breadboard, and laser are all in contact with the holster. While the holster is Velcroed on the frame of the robot, The camera, battery pack, and breadboard are velcroed to the holster itself. For the camera, thin strips of Velcro were attached to the frame of the camera to protect the screen and placed onto the laser holster. Since the wire connecting the battery pack and the relay is lengthy, the battery pack is velcroed to the left side of the holster while the relay is tied to the right side. The Arduino is in a plastic Arduino frame, which is velcroed to the robot frame.

A special note referring to the Velcro of the breadboard, in order to remove the Velcro the tabs on the right hand side of the white Velcro must be pulled to loosen it.

4. Components

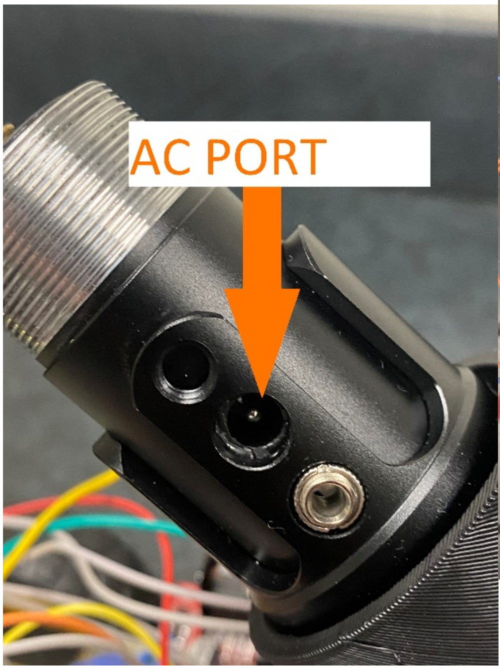
Laser: A 5W 445 nm diode laser (PL-E Pro series) will be used throughout the project. The idea was that a laser that was strong enough to burn materials such as plants was required. In addition, the laser must have the ability to be controlled through a relay by an Arduino. In my research I found the laser pointer was strong enough to burn basic and organic materials as well as become automated by the Arduino.

3D Printed Laser Holster: Since both the laser and the camera must be in front of the robot, I decided that a holster that could hold both would be beneficial. The holster has a diagonal tube where the laser is placed. The diagonal angle lets the laser shoot in front of the robot and can be aimed into corners where the robot could not physically go. Facing the front of the holster is a platform where the camera is placed. The platform is angled slightly down so that the camera can see the ground in front of the robot where weeds would appear.

Husky Lens Camera: The Husky Camera has two buttons on the top side of the camera, with the screen pointing towards the user. The left side is for selecting different algorithms such as face identification, object identification, object tracking, and color identification. The right button is used to make the camera “learn” whatever is in the highlighted square on the screen. Once is recognizes an object, it will highlight the object on the screen and output information of its position on the XY axis and its size on the screen.

Laser Wiring/Power Procedure: Proper power procedure starts with making sure the cap is not on the laser, this must be twisted off for the laser to work properly. There are two ways to power the laser pointer. The first way is to insert two 18650 batteries into the battery tube and then the tube is twisted onto the laser. Then press the button on the end to the battery tube to power the laser.

The second way to power the laser pointer is through the relay. The AC adapter connected between the relay and the battery pack is inserted into the AC adapter. Insert the two 18650 batteries into the battery pack, then place the AC adapter that connects to the battery back and the laser into the AC port of the laser pointer.



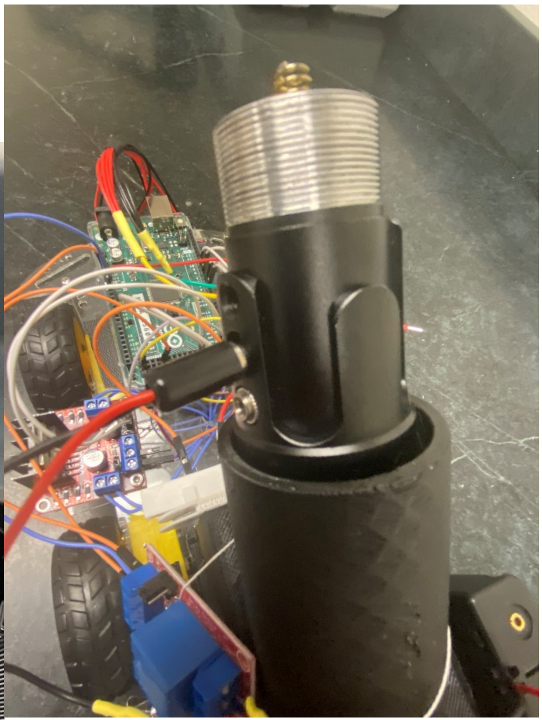


Figure 5. AC port Figure 6. AC adapter

Now the laser is able to be powered once the Arduino is on. Once the lights appear on the opposite side, it is ready to fire. To fire the laser, press on the center silver button (mechanical button) to click on the laser. To turn it off, press the button(mechanical button) again. The mechanical button is flatter and stubbier than the other silver button on the laser, which fires the laser when pressed and turns off when you stop pressing

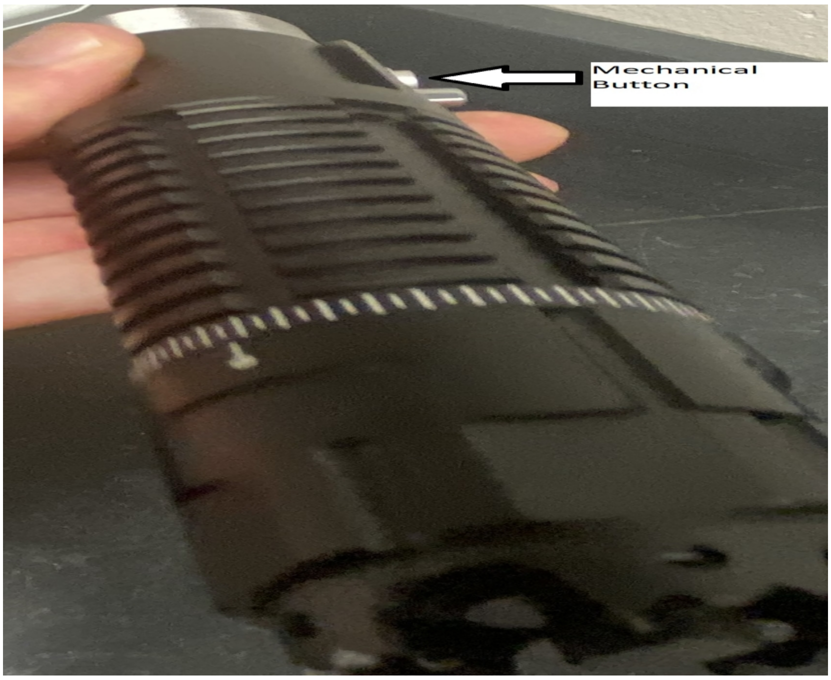


Figure 6. Mechanical Button

Wiring the Components

The breadboard is the primary source of power, it powers the Arduino Mega, two motor controllers, and four motors. All the positive and ground ports of these components will likely be connected to the breadboard. As of now there is only the ground wire from the 9v batteries in the breadboard, <u>once the positive wire from the 9v batteries is inserted into the breadboard the robot will be powered.</u> Which is why the best practice is to have either the robot propped off the ground where the wheels hang freely, or make sure the code will not have the robot perform any unexpected actions.

To wire the motors to the motor controllers, OUT1(output 1) and OUT2(output2) must be wired to the inputs of the same motor. In the current state of the robot, the outputs are wired to the proper motor inputs to avoid confusion in the code. Once two motors are wired to the motor controllers, the ground and the 12v port will be connected to the breadboard. To have the Arduino control the movements of the motors, connect IN1,IN2,IN3,IN4 (the inputs) into four separate digital ports on the Arduino Mega.(Tip: set the digital number port as a value for the define variable in code).

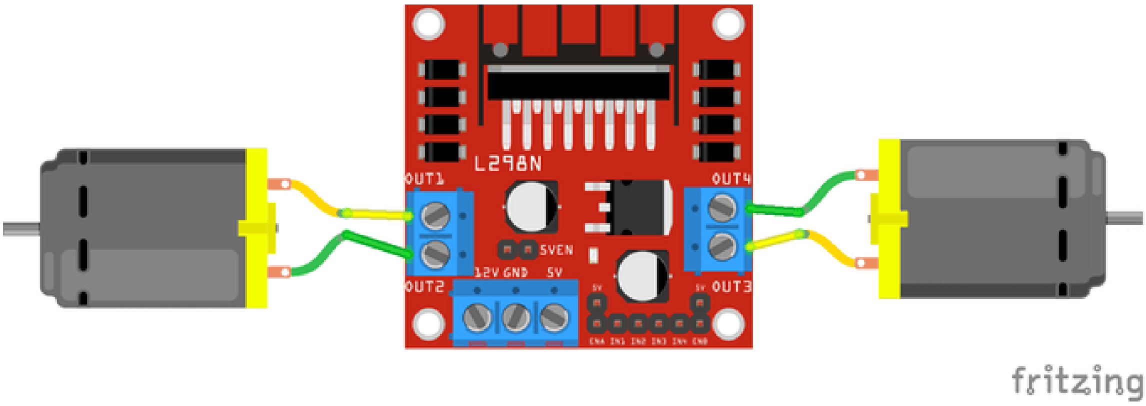


Figure 7. Wiring from motor controller to motors

4. Testing

The first test was the movement of the robot with the laser in the holster. There was initial concern that the laser would be too heavy to transport. However, testing the robot's movement showed that there was no such issue. At times the wheels would rub against the plastic frame causing stuttering. This was fixed by adjusting the wheel in the motor axis as well as filing down the point of contact between the wheel and the platform.

Once movement was squared away, I connected the Husky Lens camera and had it identify any object that was light green. With the code I used, the robot would rotate left and right if the object was pulled to either side of the screen. Testing on making the robot go forward and backwards based on the distance of the object did not work. More testing is required to see why the robot did not act accordingly.

As mentioned before, the motors require a HIGH,LOW output to go forward. Here in the forward function I set each motors 1,2,3,and 4 to forward. To go backwards I call the Backward function, which sets all to LOW,HIGH. This results in the robot moving backwards.

```
void Forward(){
  digitalWrite(LMOTOR_IN1,HIGH); // HIGH,LOW sets the motor fowards
  digitalWrite(LMOTOR_IN2,LOW); //LIN1 and LIN2 is motor 1(Left side)
  digitalWrite(LMOTOR_IN3,HIGH);//LIN3 and LIN4 is motor 2(Left Side)
  digitalWrite(LMOTOR_IN4,LOW);

  digitalWrite(RMOTOR_IN1,HIGH); // Both left and right side go foward
  digitalWrite(RMOTOR_IN2,LOW);
  digitalWrite(RMOTOR_IN3,HIGH);//RIN1 and RIN2 is motor 3(Right side)
  digitalWrite(RMOTOR_IN4,LOW); //RIN3 and RIN4 is motor 4(Right side)

}

void Backward(){
  digitalWrite(LMOTOR_IN1,LOW); //LOW,HIGH sets the motor backwards
  digitalWrite(LMOTOR_IN2,HIGH);
  digitalWrite(LMOTOR_IN3,LOW);
  digitalWrite(LMOTOR_IN4,HIGH);

  digitalWrite(RMOTOR_IN1,LOW); // Both left and right side go backwards
  digitalWrite(RMOTOR_IN2,HIGH);
  digitalWrite(RMOTOR_IN3,LOW);
  digitalWrite(RMOTOR_IN4,HIGH);

}
```

Figure 8. Forward() and Backward() function

```
void Left(){
  digitalWrite(LMOTOR_IN1,LOW); // Left side goes backwards,
  digitalWrite(LMOTOR_IN2,HIGH);// Right side goes forwards,
  digitalWrite(LMOTOR_IN3,LOW); // this results in the robot turning0 counter-clockwise
  digitalWrite(LMOTOR_IN4,HIGH);

  digitalWrite(RMOTOR_IN1,HIGH);
  digitalWrite(RMOTOR_IN2,LOW);
  digitalWrite(RMOTOR_IN3,HIGH);
  digitalWrite(RMOTOR_IN4,LOW);
}

void Right(){
  digitalWrite(RMOTOR_IN1,LOW); // Right side goes backwards,
  digitalWrite(RMOTOR_IN2,HIGH);// Left side goes forwards,
  digitalWrite(RMOTOR_IN3,LOW);// this results in the robot turning clock-wise,
  digitalWrite(RMOTOR_IN4,HIGH);

  digitalWrite(LMOTOR_IN1,HIGH);
  digitalWrite(LMOTOR_IN2,LOW);
  digitalWrite(LMOTOR_IN3,HIGH);
  digitalWrite(LMOTOR_IN4,LOW);
}
```

Figure 9. Left() and Right() Functions

To have the robot rotate, one side must spin in the opposite direction of the other side. To move left(counter -clockwise) the right motors are set to HIGH,LOW to move forward, while the left motors are set to LOW,HIGH to move backwards. The outcome is the robot will begin turning left when the Left() function is called. To have the robot rotate to the right, the motors will have the opposite directions compared to the left turn function. For turning right(clockwise), the right motors will be set to LOW,HIGH to move backwards, while the left motors will be set to HIGH,LOW to move forward. When the Right() function is called the robot will begin to spin right.

The other test had to do with the powering of the laser. Once the laser was connected to the relay. I programmed code to turn the laser on and off in 3 second intervals.

```
while(1){
  Brake();
  digitalWrite(relay_Pin,LOW);
  delay(3000);
  digitalWrite(relay_Pin,HIGH);
  delay(3000);


}
```

Figure 10. Relay Loop

In the code above, I have a while loop that last forever. In the while loop I have the Brake function called to cease movement from the robot. Afterwards, I set the relay pin to LOW with digital write then it sleeps for three seconds. The laser remains off for 3 seconds until the next digit write is called. Then the relay pin is set to HIGH and the laser is powered on for three seconds. This will repeat forever until the robot is unplugged. With the digital write function, I can set any conditional to set the relay pin to HIGH. If said condition is not meet, then the relay pin is set to LOW.

5. PROGRESS AND RESULTS

As of May 19th, the robot is able to move forwards, backwards ,turn right, turn left, and brake while carrying the laser. The robot is also capable of controlling the power to the laser. Also, components are attached to the robot to prevent any damage to the robot. Unfortunately, the Husky Lens camera module had a hardware failure during testing, so testing object tracking and laser activation through color recognition could not be done.

6. FUTURE WORKS

For the future, the hardware failure of the Husky Lens should be investigated. During testing of the Husky Camera module the metal components would become very hot, which I believe was the symptom of the problem. Once the camera is powered safely and efficiently, then testing of object tracking and color identification should be a priority.

When object tracking and color identification can be achieved consistently to target weeds, then testing the robot ability to follow along the sidewalk and target weeds should be done. Using the controls of the Husky Camera, the camera can learn the color of weeds using the color identification algorithm. The use of object identification on weeds can also be explored. The goal being able to accurately target weeds, minimize any misfires or overshooting, and minimize deviation from the sidewalk.

Once it can accurately target weeds, the next goal would be to explore a way to avoid obstacles. Since the Husky camera will be used to target weeds, an additional camera would have to be dedicated to obstacle avoidance. An ultrasonic senor would be able the measure the space between the robot and the ground. If an obstacle were in the way, the sensor would detect a difference distance from the distance to the ground. Then the robot could act according based on the distance measured by the sensor, like turn to the right or left and then adjust itself.

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