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Lighting the Way

Abstract

In the new field of robotics, human-robot interaction is crucial to the integration of robots into the office, school, and, in general, society. Currently, the BWI Robots at the University of Texas at Austin have no mediums to directly communicate their status with the humans that surround them, especially when it comes to movement status. In response to this void in the BWI Robots, our team used the existing lighting structure on the robots to implement algorithms that would communicate the current movement or cognitive status of the robot with humans around it. Before identifying how to send messages through the lights of the robot, we needed to identify the messages we wanted to send through trigger of what status indications on the BWI Robots. We found that the most important actions were displaying the direction and speed of these BWI robots. In addition, we included animations to communicate when the robot needed specific assistance or was under distress. After experimenting and testing, our results returned positive feedback for most actions, but we found that some animations were not as perceptive. With our contributions to the project, we hope to extend the narrow boundaries we attacked to encompass other important actions and display them effectively. Moving forward with this project, we believe the integration of other dimensions of the BWI Robots can lead to potential publications for the BWI Intelligence Project at the University of Texas at Austin.

Introduction

This research project centralized on the current-status communication pathways of the Building Wide Intelligence (BWI) project at the University of Texas at Austin. Currently, no sufficient, convenient communication medium exists between the the BWI Robots and humans besides cumbersome terminal, raw-data access. In addition, access to certain basic elements through the terminal requires extensive pre-processing. The main goal of the research project is to create an efficient, quick method access to the current status of the robot. In specific, the movement motion of the robot is critical to display as it is crucial to the information processing behind the robot's back-end structure. Currently, the robot has a long array of light-emitting diodes, which does not currently run with the robot during normal operation. With these light-emitting diodes, this research project wants to provide a communication channel the details and displays the current movement-status of the robot. Certain actions were predetermined to implement as they were natural to human characteristics. For example, forward-intensity, reverse, turn, and assist movements are a sample of the predetermined movements implemented within the robot. The premise of this project is further than simply implementing functionality to create a distinct communication medium between the robots and humans, the group aimed to integrate human-friendly communication samples that intuitively deliver a message through color and its movement.

With this further sample, intuitive colors and movements were to be implemented to fabricate an efficient communication medium. Ultimately, the goal of the project is to create a HRI pathway for the BWI Intelligence Project. To test the success and validity of the color mapping scheme, samples of the movements would be surveyed to humans for natural detection of the action.

Background/Related Work

Related to this research project, multiple other projects share some elements that helped us further our own development and results.

First and foremost, a critical research project, titled "Mobile Robot with Preliminary-announcement and Indication Function of Forthcoming Operation using Flat-panel Display," inspired many underlying functionalities behind the high-level operation of our project. Presented at the IEEE International Conference on Robotics and Automation, this research group wanted to determine the most functional method to display future movement information on the exterior of their robot. The group attempted various methodologies; however, the two most successful measures were the flat-display on the top of the robot and the array of bulbs. In the case of the array of bulbs, the research group implemented an algorithm that turns on a certain half of the array depending on the direction of the turn. In addition, the magnitude of the turn factored into the process: the intensity correlated to how much of the half that the array would be powered. For example, if the robot was making an extremely sharp right turn, all of the right half of the light array would turn on. The same would map to left turns and so forth.

In the other approach to the same research project, a flat-display was integrated onto the top face of the robot. On this face, the display would indicate the future movement status of the robot. If the robot were to turn right, a right turn arrow would appear on the screen. Additionally, the intensity of the turn was correlated with the opacity of the image on the screen. For instance, a light turn to the right would display a faint right turn arrow. For the opposite, a fast right turn movement, a completely opaque arrow would appear on the display.

This project was theoretically parallel to our project in determining the most efficient method to display movement information to other humans. However, the data collection method of the group led to a bias in results. The group utilized a visual scale to collect data, which led to a sway in results that led to some future biases in the project. To correct this visual scale bias in data collection, we implemented a binary data collection system that understood if the human could interpret the animation color scheme or not. This led to a more appropriate data representation as no small human biases were introduced.

In terms of fabricating our specific animations, we had to create truly intuitive animations and color schemes that would correlate to their desired meaning. A study on the interactions between a vehicle and pedestrians put it best when they mentioned that “people associate certain colors to certain feelings” (Matthews 2). In this sense, we can conclude that it is inherent nature to map the actions to animations that are universally understood. Related to this idea was a particular study on the mapping of color to certain meanings, emotions, and actions. In this study, the group outlined a detailed history of color and its specific mapping in ancient civilizations. In fact, Shirley Williams had a detailed “Color Codification of Emotions” (Nijdam 4) color wheel that related many different colors to certain meanings. In specific, Williams related fear and panic with the color yellow, which inspired us to implement the color to our animation with removing an impediment in the way of the robot’s movement plan. Through this specific example and others, the paper “Mapping emotion to color” influenced our project immensely.

Another project that contributed to our understanding of the extent of human robot interaction was titled "Enabling Robots to Communicate their Objectives." This project dealt with a self-driving car communicating how it will be switching lanes in different situations. However, more importantly for us, we adapted and modified the method by which the study tested how successful the communication was between the human and the robot. To test how humans respond to the actions of the robot, new people were put into the car and were asked to correctly infer how the car was going to switch lanes. Then, they recorded the results and used probabilistic models to improve their approach and continue from there (Huang). Similarly, we hoped to survey people on what actions they believe our segbots were undertaking and mapped them to a binary intuitive and unintuitive scale.

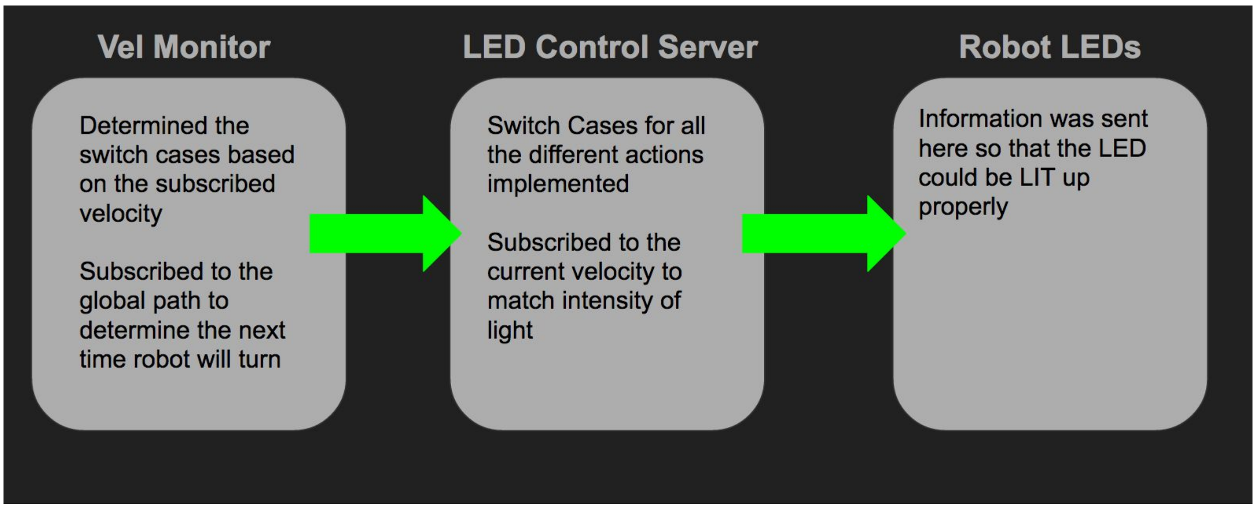
Technical Approach

Initially, the technical process started with the high level understanding of the existing LED system. The current Arduino system allowed for an interface to select which specific LED light to turn on and how to send messages to trigger certain actions on the lights. After understanding the existing structure, we cloned “bwi_common” and “segbot” repositories to modify their elements. The bwi_common repository was cloned to modify the specific LED Light messages that were being relayed in the internal ROS System of the BWI Robot. The segbot repository was cloned to modify the light structure and access modifiers.

After attaining the existing code base for our project, we identified the specific files to create and the existing files to modify for an accurate approach to our project. With this in mind, the group created a ROS Node to send messages to the Node that modifies the lights through the

ROS/Arduino System. The node we created was called “vel_monitor” because it specifically monitored the velocity of the robot by subscribing to the “/cmd_vel” ROS topic. In turn, the “vel_monitor” node sent a LEDAction message to the node associated with the executable “led_control_server”. From here, the “led_control_server” sends signals to each individual LED light depending on the current situation.

In a high level diagrammatic solution, the image below represents the process of our final project.



Moving to lower levels of understanding, the sample code below represents how our team was able to identify certain actions the robot was currently taking.

```
if(vel_msg.linear.x > 0)
{
    ROS_INFO("POSITIVE SPEED");
    goal.type.led_animations = bwi_msgs::LEDAnimations::FORWARD;

    //CODE FOR TURN FUNCTIONALITY FROM PREVIOUS FRI PROJECT
    // We only traverse the first quarter of the Global Plan Array
    for(int i = 0; i < current_path.poses.size() / 4; i++) {
      double yaw = tf::getYaw(current_path.poses[i].pose.orientation);
      if(abs(current_yaw - yaw) > 0.2) {
          // Right turn
          if(current_yaw - yaw < 0) {
            ROS_INFO("RIGHT TURN");
            goal.type.led_animations = bwi_msgs::LEDAnimations::LEFT_TURN;
          }
          // Left turn
          else {
            ROS_INFO("LEFT TURN");
            goal.type.led_animations = bwi_msgs::LEDAnimations::RIGHT_TURN;
          }
      }
    }
}
else if(vel_msg.linear.x < 0)
{
  ROS_INFO("NEGATIVE SPEED");
  goal.type.led_animations = bwi_msgs::LEDAnimations::BACKWARD;
  }
```

vel_monitor Snapshot

The code to the left determines the proper bwi_msg to send, based on the cmd_vel rostopic and the global path.

The code belongs to the “vel_monitor” node written in the project. With this code, the velocity of the robot is detected through the instance variable updated through the “/cmd_vel” rostopic. Then, depending on certain aspects of the velocity, i.e. whether the linear velocity is positive or negative or when the angular velocity is at a certain point, we send the appropriate LED animation message as a goal. In addition to subscribing to the velocity of the robot, we also take a look into the future global path that is formulated. Looking forward into the next quarter of the path, if the robot plans on rotating past a certain threshold value, then we can sent the proper turn signal message.

Related to the “vel_monitor” node, a specific research project that advocated situational awareness for robots helped us recognize how to approach the task. In the paper “Design and Evaluation for Situational Awareness Enhancement,” the group gained knowledge of how to track the relative situation of the robot. In our case, the monitoring of the ROS topic “/cmd_vel” allowed us to evaluate our own situational awareness. In addition, the paper dived deeper into the mechanics of keeping situational awareness in more complex situations. Looking forward, the group is keen on adding the functionality of instilling “holistic processing strategies” to accommodate further components that can strengthen the ability of our project to communicate with humans.

Moving back to the robots, on the other side of the process, we have the “led_control_server” node, which takes the message passed through by the previous file as a parameter into a large switch case, controlling the actual animations on the LED strips. For the forward and reverse animations, we altered the brightness of the animation based on the magnitude of the velocity in that direction. For example, if the velocity was at its maximum of 1, then the LEDs would shine the brightest, as opposed to a dull color when the velocity was not as fast. Using this case switch was the most efficient way to go, as we would only need one animation to display at a time so that we do not confuse others interacting with the robot.

```cpp
        }
  // Forward
  case bwi_msgs::LEDAnimations::FORWARD:
    {
      // Executes as long as timeout has not been reached, Goal is not Preempted, and ROS is OK
      while(!as_.isPreemptRequested() && !timeout && ros::ok())
      {
        //creates an animation based on the velocity of the robot
        ros::Duration time_running = ros::Time::now() - start;
        feedback_.time_running = time_running;
        as_.publishFeedback(feedback_);

        //get the current velocity of the robot
        float current_vel = vel_msg.linear.x;
        //perform the calculation to get the intensity
        float briRatio = 0.57;
        float brightness = (current_vel - 0.3) * briRatio;
        //set the LEDs to that intensity
        for (int i = led_count; i >= 0; i--)
        {
             leds.setHSV(i, 118, 1, brightness);
        }
        leds.flush();
        // Microseconds
        usleep(75000);
      }
      break;
    }
```

led_conrol_server Snapshot

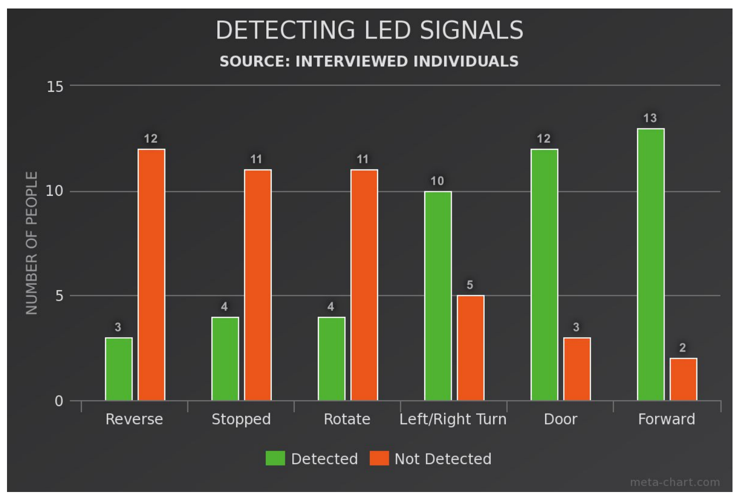
The code to the left is a particular case switch which takes the FORWARD bwi_msg and lights up the whole strip green with the intensity based on the speed of the robot.

Experiments/Evaluation

After mapping the specific actions that the robot could take to intuitive LED animations, we continuously ran performance evaluations by providing the robot with a navigational goal while running our nodes. We carefully observed the animations that resulted and altered them so that they would be easily and instinctively recognizable by our human testing volunteers.

With the mapping and technical functionality in place, the group displayed an array of video clips to the volunteers to identify the functionalities meaning in the LED lights. Then, volunteers were asked if they believed that the given animation intuitively correlates to the intended meaning. We implemented a binary data collection system that would avoid the biases that a group in our related works faced. They implemented a visual scale which led to human error; to correct this, a binary system was implemented to avoid simple human biases. The data was then transformed into a visual representation:

Right:
This bar graph depicts the results of our survey, where we recorded simple, binary responses to decide if the animations were appropriate.



With this representation, it is clearly evident which animations were natural intuitive to humans and which animations were not as helpful. In specific, the forward, door, and turn signals were the most naturally understood through the BWI robot. On the other hand, the reverse, stopped, and in-place rotation animations were not clearly understood to humans watching the BWI robots. In a study by Jamy Li and Mark Chignell, a robot with movable joints was tested to see how accurately it could display emotions to other humans. Realizing the limitations of the robot's movement, a few emotions. like fear and disgust could not be effectively modeled by the robot (Li). In a similar sense, we concluded that the animations for reverse, stopped, and stationary rotation were the least effective.

In evaluating these results, we see that the project was approximately 50% accurate in integrating natural animations into the robot to create an efficient communication channel between two independent parties. Moving forward, the unsuccessful animations must be corrected through a feedback system to properly adhere to humanistic factors that naturally interpret the animations. In fact, using the related color mapping research project, we can implement further corrective actions using their color mapping graph-system. The group can go forward and implement a variation of the "Yan Xue color distribution" (Nijdam 5) to better adhere to emotional ties with colors.

Overall the process of implementing color systems with animations based on other research projects was reflected in the initial feedback from volunteers. Moving forward, correction of the inaccurate color animations will take place and further testing will be conducted to ensure the intuitiveness of the newly designed features.

Example Demonstration

After extensive testing and experimentation, we came to a consensus on the following animations for each action that would be demonstrated by the robots. These LED animations were articulated based on what would others a clear understanding of what state the robot was currently in.

Forward

While the robot is moving with a positive velocity, the LED strip on the robot will display a green color. To provide even more feedback to the environment, we chose to modify the intensity of the lights based on the magnitude of the speed of the robot. Faster speeds will induce brighter emissions while slower speeds will display dimmer lights.

Above:
Low light intensity levels indicate reduced speed of the BWI robot.

Above:
Higher light intensity levels Indicate higher speed levels of the BWI bots

Reverse

When the robot is moving with negative velocity, meaning the robot is moving backwards, the LED strip will light up with all white to represent the reverse action. Again, the intensities of the lights will vary depending on the speed with which the robot is moving at.

Left:
When the robot is moving backwards, the reverse lights display white, indicating that the robot is moving in reverse.

Turning Signals

Looking into a portion of the future global path, if we detect that the robot will need to make a significant turn, then we activate the left/right turn signals in order to indicate which way the robot will be turning. The animation is a segment of lights that move around the top circle of the robot. If these segments are moving to the right, then the robot will be turning right soon. If they move in the opposite direction, then the robot will be turning in the opposite direction.

Right:
Just before the robot needs to make a turn,the turning signals activate, motioning towards the direction of the turn.

Rotating

When the robot needs time to create its global path or when it is just simply lost as a result to poor localization or other factors, the robot rotates in place. While rotating, the LEDs will light up random colors throughout the strip, as to signal that the robot needs help localizing, cannot find a global path, etc.

Left:
When the robot resorts to its rotating mechanism, the lights flash with random colors.

Right:
The grabs the attention of people in its surrounding with the random lights while signaling that it needs the door to be opened with the light segment motioning towards the door.

Door Assist

As the robot is tasked with certain objectives, it may run into certain impediments that are out of its control, such as opening a shut door to an office. In order to efficiently get the attention of the people in its surroundings under these circumstances, the LEDs going down the robot will be lit with random colors. To show that the robot needs help opening a door, the LEDs on the side of the robot will light, with LED segments moving towards the door.

Conclusion/Future Work

With the introduction of so many different kinds of robots into mainstream society, human-robot interaction (HRI) is becoming increasingly important. Our project looked at the most effective ways to communicate the current state of the robot to its surrounding environment. This increases the safety of the robot and others in the surroundings, especially when people who have never seen these robots encounter them for the first time.

Evaluating our finished project, our team met and exceeded the goals that were initially set for our venture. In addition to implementing the forward and reverse animations along with improving the turn signal detections, we also managed to add animations that helped the robot communicate objectives not involving movement. We implemented the random animation for the robot’s rotating mechanism as well as prepared the animation for the door assist. This door assist animation ability is our start at furthering the BWI Robot's ability to extend HRI beyond simple movement communication.

This project stands as the framework for a larger project that can allow the BWI Robots to communicate with humans through multiple mediums and pathways. Potential extensions of our work include: multi-step commands, human path impediments, and voice feedback. All of the listed additions were also complimentary projects of this semester. Our group is confident that this project can serve as the catalyst towards a strong publication within the BWI Intelligence lab at the University of Texas at Austin that can help contribute to the greater robotics community.

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