PatrolBot

Revised Concept & Project Management

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Team 08
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Abstract

The PatrolBot project is about creating a semi-autonomous patrol robot. The PatrolBot project is intended to be an essential tool for campus police forces and other small security operations in properly monitoring their grounds. The project will utilize a robot connected to the internet, a web server, a website, and machine learning models. Our team must implement a web server, control a robot through the internet, build the front-end website, and train the machine learning models. The purpose of this document is to describe our project's main goals, significance, roadmap, legal and ethical challenges, risks, and team member responsibilities.

Project Description

The Patrol Bot is a robot which utilizes machine learning to help detect bike theft. The robot is meant to autonomously patrol UNR's campus and provide real time alerts to campus police regarding potential threats. Additionally, the robot has the ability to accept manual controls from users if needed. Information such as camera feed from the robot, current position, and log data, are readily available on the system's user interface, so officers can quickly understand all of the data processed. All of the data from the logs can be saved into text files with the press of a button. Upon the video feed, users can enable the display of bounding boxes for key items. This is done with the use of an object detection model which classifies people, bicycles, bolt cutters, and angle grinders. With the use of the object detection model, the system is able to make predictions regarding the threat of a given scenario, and these alerts are presented on the system's user interface. The interface itself is customizable through the use of an options menu. This menu allows users to select which objects they would like to display onto the camera feed if at all and which objects they would like to be logged.

Due to the robot's planned ability of mobility, the intended users for this project would be organizations that need to increase their ability to secure and monitor a large area that has a lack of cameras. Specifically, our system could help lower the strain on campus police by helping detect and stop the most prevalent crime on campus: bike theft. Less officers would need to be around campus bike racks throughout the day, and more students would be able to fully immerse themselves in their studies without having to worry about their ride home.

The project is going to incorporate many different libraries within Python such as OpenCV and PyTorch. The model running within the main video processing application will be using YoloV5 for its object detection. The web application will be based on Django which works in tandem with Python. System hardware components include a camera, GPS sensor, robot with the ability to traverse terrain using ROS, and a backend web server to host the website and application data.

The robot itself should be able to reliably connect to any intended user with an internet connection and provide a steady video stream back to the user. The website should be able to handle this traffic without showing signs of lag. This could be done with a strong back end and sufficient wireless transmitters. The robot needs to be visible, large enough, and programmed to avoid collision, to prevent harm to any people nearby. This is a physical requirement that can be solved with reflective tape, and the programming will need to be set within ROS. Security for the web application and video stream will need to be configured with secure protocols in addition to hashing and digital signatures.

Significance

This project is worthwhile and interesting to pursue for Team 08 since it incorporates multiple aspects of computer science: machine learning, robotics, and data science, that team members are most interested in pursuing careers in. This topic is also something that is important to UNR specifically since bike theft is a significant problem the police department has with their limited resources.

This project could help team member's professional growth by progressing skills needed to work in industry later on. By having five team members, Team 08 is developing team communication skills since members must consistently communicate effectively to ensure work is progressing toward a final product. Since there are so many moving parts accompanying this project, team members are also learning version control skills as well as learning how to merge work between teams that is needed in an actual job. Members of Team 08 are also learning new skills related to machine learning and robotics that were previously weak or nonexistent.

Threat assessment using posture detecting machine learning models is a newer topic in deep learning. These algorithms attempt to assess the level of threat of a person based on what they have in their hands as well as the positioning of their body. Adding this feature to an autonomous security robot is the most innovative part of Team 08's project. Similar products and projects to our project include superdroid's autonomous patrol robots, [Security Robots], a 2020 deep learning model that took human poses and gave them an assessment of high threat, medium threat, or low threat, [Comparison of Skeleton Models and Classification Accuracy], and Knightscope's security robot, [Knightscope]

Team 08 has not come across an autonomous patrol robot that utilizes object detection and threat detection based on body posture. Having a patrol bot that can determine threat detection using posture and not just associated threatening items could be a successful product since potentially threatening items do not always mean immediate threat. For example, if a robot was patrolling in a place where people are legally allowed to openly carry guns, guns wouldn't be a very good identifier for threat. Past CS 426, next steps would be creating an optimal robot for the task it is given. This includes off road capabilities, optimal camera positioning, and other robotic needs. Combining features that have not previously been combined does lead to future product potential.

The social impact of an autonomous robot varies among different perspectives. Stories about living in a dystopian world of robots patrolling and taking over human jobs may make people hesitant about this concept. However, improved surveillance to ensure safety in society can be a great benefit, but it also comes with a lot of social responsibility from the developers. We must

ensure there is no bias in our models, as this can worsen social issues. The environmental impact of our PatrolBot can only be negative. The cost of processing the materials needed to make our robot platforms will not help the environment directly or indirectly, although it is not directly harmful.

Legal and Ethical Aspects

Patrol Bot's target deployment areas are university campuses. This requires the permission of any university interested in utilizing the robot's capabilities to allow their presence on campus as well as allow potential filming of any staff and students that cross paths with the robot. It would also require the university to allow access to their network to maintain a reliable connection between the user and the robot. An agreement must also be made to delegate the responsibility of replacement or repairs if the product is stolen or damaged while deployed by a client.

With regards to the ethical considerations of the project, Patrol Bot must be developed to the best of our current technical capabilities to ensure a reliable product for any future client. Specifically, the threat assessment algorithm must ensure that no bias exists based on race or gender when surveying a university campus or any other area of deployment. As a group, we plan to train and test our machine learning models on a variety of robust data sets, both existing and self-created, to ensure our product meets the ACM ethical standards.

Changes and Progress since Initial Project Concept

During the fall semester we developed a machine learning model utilizing YOLOv3 to detect the presence of people, bicycles, bolt cutters, and angle grinders. A prototype robot was built utilizing a Raspberry Pi 4 as a microcontroller. The user could control the robot's movements using a keyboard while connected to the Raspberry Pi remotely using VNC. A local application was developed as a prototype UI that allowed a user to create an account, login and logout of their account, view a live feed of the model running on an attached camera, control the robot using keyboard input, and customize the objects detected by the model.

Our initial project concept involved building a robot to detect violent behavior and aggression on a university campus. After consulting with our advisor, Officer Matthew Stewart of the UNR police department, our focus shifted to detecting bike theft on campus as it is the most frequent crime that occurs at UNR and a common problem among universities around the country. Another major change is our choice to scrap our initial idea of running the models on the Raspberry Pi as it does not allow for the processing power required to view the models effectively in real time. We instead intend to stream the camera feed from the robot's camera to a host machine that is running the models. We are also transitioning our UI from a local application to a web application to allow for the camera stream mentioned above as well as other improvements.

Major accomplishments include developing the machine learning model to accurately detect the objects necessary for our product, building a robot prototype that a user can control remotely, streaming a camera feed from the robot to a user's machine, and running the machine learning models on the camera feed of the robot.

Project Responsibilities

Robot Software - Michael Stepzinski

The robot we use needs some software modification to run properly. It must stream its camera feed to a server and be controlled through Robot Operating System (ROS). The responsibilities of this team member would be to learn how to properly use ROS, collaborate to create the server connection to the robot for commands, and stream a camera feed to a server over WiFi.

Robot Hardware Communication - Connor Callister

The robot used will utilize several hardware components including sensors, cameras, motors, and a microcontroller. Ensuring all of these parts function properly is paramount to the goals of the product. To achieve these goals, this team member will focus on the communication of these components to ensure the robot functions as intended.

Web Server & UI/UX - Jesus Aguliera

The robots backend will be powered through a web server. The camera feed captured by the robotics camera system will be fed to the web server for the machine learning models to perform on. The web server will also provide the interactive online dashboard for the robot and contain a text log of all its actions, a threat computation security log, the GPS location of the robot, and various other functionalities. This team member will focus on user interface and user experience to accommodate a fully interactive and functioning dashboard.

Detection model - Max Orloff

The camera monitoring software will need to detect humans, bikes, angle grinders, bolt cutters, and potentially other weapons in the future to assist the threat detection model. The responsibilities of this team member are to create the object detection model and incorporate the model into the user interface with extra features for ease of use.

Threat Prediction - Brandon Banuelos

The camera monitoring software will need to make threat assessments based on a number of items detected by the camera on the robot. These items may include objects detected by the detection model such as bolt cutters and angle grinders and their proximity to bikes.

Project Monitoring and Risks

This project comes with many subdivisions of work that will need to be completed to have a successful final product. To ensure that all of this work is completed on time, Team 08 plans to meet weekly to discuss completed work, struggles, necessary changes, as well as future plans and meeting times. Meeting weekly ensures that all team members are constantly on the same page and work is consistently progressing. If team members are struggling with parts of the project work can also be divided amongst others to ensure everything is completed. Once items are completed and ready for demonstration, team members responsible for these items will demo for the rest of the team to ensure sufficient quality. Any other roadblocks along the way can be solved by contacting team advisors or Senior Projects professors and TAs. Table 1 outlines a summary of risks associated with each part of the project.

Developing the robot to function autonomously in the amount of time the team has presents a significant risk. This requires localization of the robot, a method of mapping its patrolable areas, and communication of its location to the web application on the user end. A possible solution if time does run out before this can be achieved is to ensure the user can remotely control the robot at the very least. This will allow the robot to serve its primary purpose of bike theft detection with the help of a user for movement.

Table 1: Risk register for all five sections of Patrol Bot

Risk Register											
		Current risk							Residual Risk		
Risk ID	Risks	Likelihood	Impact	Severity	Status	Owner	Raised	Mitigation Strategies	Likelihood	Impact	Severity
Category 1: Robotic Software											
R	Software dependency updates cause main software to stop working	3	8	8	Open	Michael	Feb-01	- Use only open-source software - Ensure all steps taken to get project working are well documented and replicable	5	4	3
R	Software in development gets deleted	2	10	10	Open	Michael	Feb-01	- Frequently upload software to source control	4	3	2

								(Github) - Ensure that all team members have access to Github			
Category 2: Robotic Hardware											
R	Robot hardware gets physically damaged during testing	4	10	9	Open	Connor	Feb-01	- Have team member with robot at all times to physically prevent dangerous maneuvers - Keep robot on sidewalks and away from busy roads - Have high-visibility markings on robot	3	2	5
Category 3: Web Server & UI/UX											
R-0	Developing a fluent front end user dashboard	6	2	1	Open	Jesus	Jan-31	- Learn html/css/js from all possible resource - Use free online templates as a starting resource to develop good looking frameworks	1	1	1
R-0	Providing a secure connection between the web server and robot	10	10	10	Open	Jesus	Jan-31	- Use cloud based data pipelines that are ROS friendly to securely transmit data - Allow connectivity to the web server to be possible through the campus wifi that the robot will be connected to	3	2	6

R-0	Developing a cloud-based web server	10	8	6	Open	Jesus	Jan-31	- Choose a cloud server provider (CSP) and follow the CSP's documentation for setup - Publish the web application using the CSP	3	2	3
R-0	The camera feed from the robot should securely be fed to the web server	8	7	9	Open	Jesus	Jan-31	- Select the correct camera type to properly feed the video stream - An API gateway from the CSP's should allow for this to be possible - Connect camera to a remote device adapter	5	5	7
R-0	Various robot data sources should be transmitted to the web server	6	5	2	Open	Jesus	Jan-31	- Transmit GPS location, image, 3-dimensional data, and streaming video data using cloud data pipeline tools - Use existing backend integrations that will allow specific data sources to be transmitted to the web server.	5	4	2
Category 4: Detection Model											
R	Inaccurately detecting angle grinders and bolt cutters	2	10	9	Open	Max	Jan-31	-Create better dataset to train model by acquiring objects being detected	1	1	1

								-Test model on robot camera stream with real life situations			
Category 5: Threat Prediction											
R	Poor threat estimation	4	6	7	Open	Brand on	Jan-31	-Threat prediction can be based on many categories -Implementation will first focus on the most simple categories while still adding more features during development	2	2	3
R	Biased threat estimation	3	8	7	Open	Brand on	Feb-1	-Threat prediction models can have inherent biases -Testing will be done to ensure that threat can be assessed objectively	1	4	3

Contributions of Team Members

Connor

Tasks: Legal and Ethical Aspects, Changes and Progress since Initial Project Concept, Robot Autonomy Risk
Time: 2 hours

Brandon

Tasks: Significance, Threat Detection Model Risks, Threat Detection Model Responsibilities
Time: 1.5 hours

Max

Tasks: Significance, Object Detection Responsibilities, Object Detection Risks, Project Monitoring, Editing
Time: 3 hours

Jesus

Tasks: Web Server & UI/UX Description, Risk Register Table, 5 Related Risks
Time: 1.5 Hours

Michael

Tasks: Cover page, abstract, robot software responsibilities, robot software risk
Time: 3 Hours

References

Comparison of Skeleton Models and Classification Accuracy ... https://www.researchgate.net/publication/340820820_Comparison_of_skeleton_models_and_classification_accuracy_for_posture-based_threat_assessment_using_deep-learning.

“Knightscope Security Robots - First Look” , YouTube, https://www.youtube.com/?gl=NL.

“Security Robots.” *SuperDroid Robots*, https://www.superdroidrobots.com/SPAR-Security-Robots.