CEng 491 -- Project KickOff Document

“RoboDetection” KickOff Document

Project acronym: RoboDetection

Description

Unfortunately, there are lots of natural disasters happening in Turkey. To rescue our people, we cannot risk even a second. Therefore, technology used in search and rescue operations matters a lot.

The project aims to develop a system that can be used in search and rescue operations. Under challenging scenarios such as earthquake debris, the system will detect the humans in the environment and inform the rescue operator accordingly. The system will be used in search and rescue operations in areas that are difficult to reach by humans. By using our robot dog with its ability to detect and track humans, more people can be saved.

The project consists of three main parts: A control system, a web server, and a simulation environment. The robot dog has an onboard camera that will be live-streamed to a control system. The user can see the robot dog's camera footage and control it using the control system. Moreover, the camera footage will be processed by a web server to detect humans and report detected objects to the control system. The user can select an object to be tracked from the detected objects, and the robot dog will track the selected object. In addition to autonomous human tracking, users will be able to generate a 2-D occupancy grid map from the laser and pose data collected by the robot.

The web interface will contain four parts: Web Control Interface, Web Camera Interface, Web Map Interface, and Web Human Tracking Interface. Web Control Interface will allow the user to control the robot dog's movements manually. Web Camera Interface will show the detected humans taken from the camera footage. Web Map Interface will display the live map updates during the map generation process. Web Human Tracking Interface will enable the user to select and autonomously track a human in the camera footage.

We will develop and test these features of the robot dog in a simulation environment. We are also planning to try out these features on a physical robot dog; however, it all depends on the project's progress and the availability of the robot dog provided by Aselsan.

Master feature list

1. It will provide a 3D robot dog model in a simulation environment to test and simulate several features of the robot dog provided by Aselsan.
2. It will provide a web interface for the remote control of the robot dog.
3. The simulation environment will be connected to the web interface.
4. The web interface will control the movements of the 3D robot dog model in the simulation environment.
5. The robot dog will use a detection algorithm running on the server to detect humans.
6. The robot dog will use a tracking algorithm embedded in the detection algorithm to track the detected objects in the camera footage taken from the simulation.
7. The 3D robot dog model in the simulation will have a camera model to take images in the simulation environment.
8. The simulation will send the camera footage from the camera model to the web interface.
9. The web interface will receive the camera footage taken from the camera model in the simulation.
10. The web interface will process the camera footage and show the detected humans in the simulation environment.
11. The 3D robot dog model in the simulation will create a 2-D occupancy grid map from the laser and pose data collected by the robot.
12. The simulation will send the created 2-D map to the web interface.
13. The web interface will allow the user to generate a 2-D occupancy grid map from the simulation environment.
14. The 3D robot dog model in the simulation will track the selected object while avoiding obstacles in the simulation environment (Enhanced Object Tracking).
15. The web interface will allow the user to select an object to track in the camera footage taken from the simulation.

Here is the list of bonus MFs planned to be completed depending on the project progress and the availability of the physical robot dog provided by Aselsan:

16. The robot dog in the physical environment will be connected to the web interface.
17. The web interface will send commands to the robot dog in the physical environment to control the dog's movements.
18. The physical robot dog will send the camera footage captured by the onboard Intel RealSense D435 depth camera to the web interface.
19. The physical robot dog will follow the selected object autonomously while avoiding obstacles in the environment.
20. The physical robot dog will create a 2-D occupancy grid map from the laser and pose data collected by the robot.

Workpackages

WP #	Term	WP title	Estimated number of person-months
1	491	Project planning and architecture design	1
2	491	Simulation Setup	3
3	491	Web Control Interface	3
4	491	Human Detection Algorithm	2
5	491	Adding Tracking Algorithm	2
6	491	Camera Integration	3
7	491	Web Camera Interface	3
8	492	2D Map Generation	6
9	492	Web Map Interface	3
10	492	Autonomous Human Tracking Algorithm	6
11	492	Web Human Tracking Interface	3
		Total:	35

Detailed Descriptions of High-Level Workpackages

WP-1 - Project planning and architecture design (09.10.2023 - 31.10.2023)

In this workpackage, the following functionalities/features/work items will be implemented:

1. Develop the list of master features of the project. (All MFs)
2. Produce project development plan in accordance with Master Feature List. (All MFs)
3. Design the overall architecture of the project. (All MFs)
4. Analyze risks and make a management plan. (All MFs)

WP-2 - Simulation Setup (18.10.2023 - 30.11.2023)

1. Research on the simulation environment and the 3D robot dog model. (MF-1)
2. Set up the simulation environment. (MF-1)
3. Add the 3D robot dog model to the simulation. (MF-1)
4. Perform basic movements on the 3D robot dog model. (MF-1)

WP-3 - Web Control Interface (18.10.2023 - 17.12.2023)

1. Develop the web interface for controlling the 3D robot dog model. (MF-2)
2. Set up the communication protocol between the web interface and the simulation environment. (MF-2)
3. Establish a connection between the simulation environment and the web interface. (MF-3)
4. Send movement commands from the web interface to the 3-D robot dog model in the simulation. (MF-4)

WP-4 - Human Detection Algorithm (01.11.2023 - 17.12.2023)

1. Select and use an object detection algorithm to detect humans. (MF-5)
2. Prepare a dataset to train the human detection model. (MF-5)
3. Train and fine-tune the algorithm to detect humans. (MF-5)

WP-5 - Adding Tracking Algorithm (18.12.2023 - 17.01.2024)

1. Use a tracking algorithm that works in conjunction with the detection algorithm to track humans. (MF-6)
2. Ensure the tracking algorithm can follow and maintain the trajectory of detected objects in the camera footage. (MF-6)

WP-6 - Camera Integration (01.12.2023 - 17.01.2024)

1. Research and add a 3D camera model to the 3D robot dog model in the simulation. (MF-7)
2. Implement a data transmission mechanism to send the camera footage to the web interface. (MF-8)

WP-7 - Web Camera Interface (18.12.2023 - 18.02.2024)

1. Get the camera footage stream sent from the simulation in the web interface. (MF-9)
2. Process the camera footage on the web server using the detection and tracking algorithms. (MF-10)
3. Enhance the web interface to display the detected objects in the camera footage. (MF-10)

WP-8 - 2D Map Generation (18.01.2024 - 17.03.2024)

1. The 3D robot dog model in the simulation will create a 2-D occupancy grid map. (MF-11)
2. The simulation will transfer the saved map to the web interface. (MF-12)

WP-9 - Web Map Interface (19.02.2024 - 31.03.2024)

1. The web interface will let the user generate a 2-D occupancy grid map from the simulation environment. (MF-13)
2. The web interface will display the map updates to the user during the map generation process. (MF-13)

WP-10 - Autonomous Human Tracking Algorithm (18.03.2024 - 18.05.2024)

1. Use autonomous navigation algorithms with obstacle avoidance in the simulation. (MF-14)
2. Implement control logic using autonomous navigation to track the selected object autonomously in the simulation environment. (MF-14)

WP-11 - Web Human Tracking Interface (01.04.2024 - 18.05.2024)

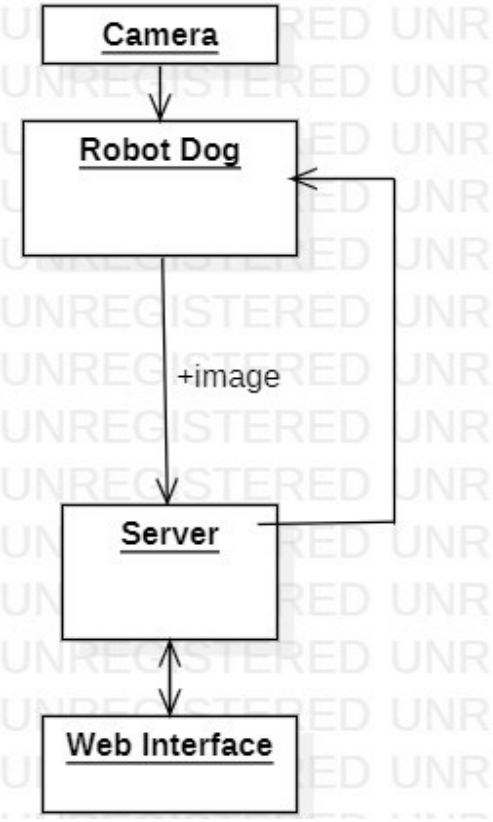
1. Update the web interface to allow users to select an object to track within the camera footage. (MF-15)
2. Enable the user to select a new target to track in the web interface. (MF-15)

Here is the bonus work package defined for MF 15-19. This work package is planned to be completed depending on the project progress and the availability of the physical robot dog provided by Aselsan.

Bonus WP - Physical Robot Dog Integration

1. Establish a connection between the physical robot dog and the web interface. (MF-16)
2. Send movement commands from the web interface to the physical robot dog. (MF-17)
3. Show the camera footage stream taken from the physical robot dog in the web interface. (MF-18)
4. The physical robot dog will track the selected object while avoiding obstacles. (MF-19)
5. The physical robot dog will provide a 2-D occupancy grid map from the laser and pose data collected by the robot. (MF-20)

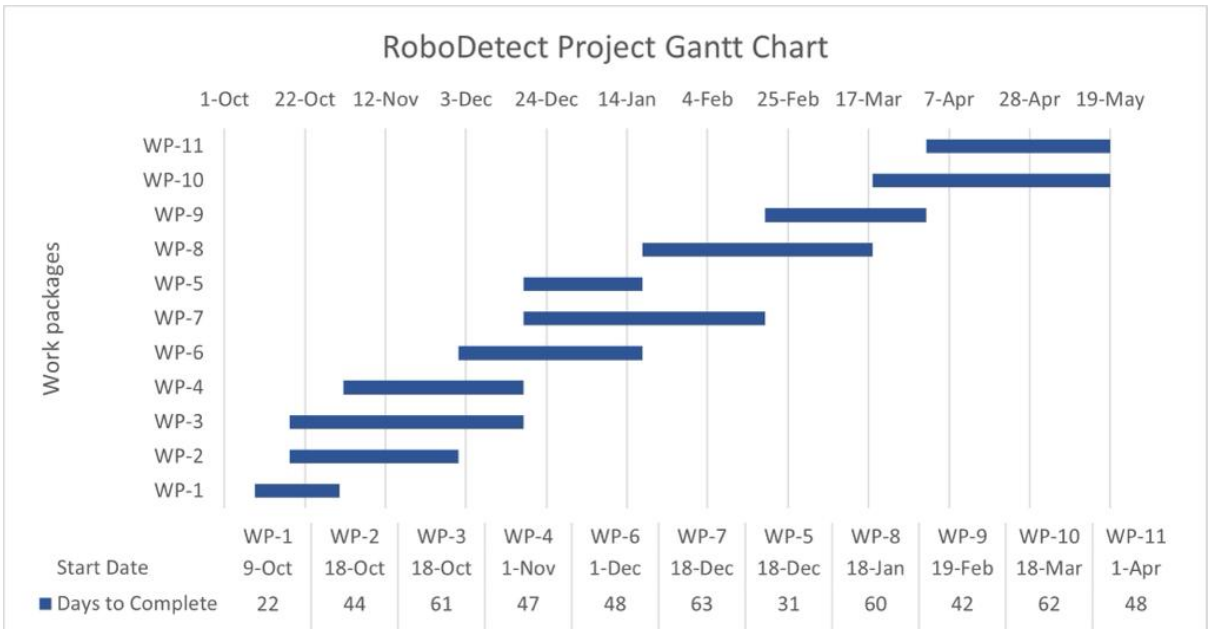
Overall System Architecture



The robot dog will have an onboard camera. The camera footage of the robot dog will be sent to a server for processing the image for object detection and tracking tasks. The server will process the image and report the detected objects to the web interface. Also, it will give movement commands to navigate the robot.

If the user manually controls the robot, the manual movement commands will be directly sent to the robot. When the human tracking mode is used, the server will use the autonomous navigation algorithm to track the selected human while avoiding obstacles in the environment. The movement commands will be sent to the robot according to the output of the autonomous navigation algorithm.

Timeline



Risk Assessment

Risk #	Description	Possible Solution(s)
1	The 3D robot dog model may not meet the expectations of the project.	A similar model can be found and used.
2	Establishing a connection between the physical robot dog and the web interface may not be possible.	Other protocols can be tried to establish the connection.
3	The camera model may not reflect the behaviors of the actual camera onboard, e.g., the integration of the depth camera.	Additional camera models can be added to the 3D robot dog model.
4	The physical robot dog may not behave as expected.	Additional tests may be required.
5	The enhanced tracking algorithm may not work in the physical environment as in the simulation environment.	Incremental tests can be planned and executed.