ACCOMPANYING HUMANS AND ACHIEVING DESIGNATED TASKS WITH AUTONOMOUS MOBILE ROBOTS USING SWARM INTELLIGENCE (TAG-A-LONG-BOT)
ROKETSAN A.Ş.

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Abstract. This project aims to to implement mobile robots that can participate in swarm behaviour based activities. These autonomous mobile land robots are designed to track a designated human, avoid nearby obstacles by detecting and dodging them, smoothly move on the terrain, via odometry information provided by beacons placed around the implementation zone.

PROJECT DESCRIPTION

This project aims to implement mobile robots that can participate in swarm behaviour based activities, in collaboration with ROKETSAN. These autonomous mobile land robots are intended to track a moving human and adjust their motion parameters such as speed and direction, with respect to the motion of the tracked object. Additional robots are able to avoid nearby obstacles by detecting and dodging them, and move smoothly on the terrain.

These autonomous mobile land robots are intended to be used for various military services of Türk Silahlı Kuvvetleri (TSK), or Turkish Armed Forces, in English. ROKETSAN is trying to create and implement autonomous systems that can be used for several tasks such as accompanying soldiers in the field such as but not limited to tracking and scouting, transporting equipment and gathering military intelligence. There are several projects which intend to develop similar technologies to our, such as human identifying drones [1] and drone swarms moving in pre-determined trajectory to accomplish various tasks [2].

Our robots are required to follow walking or running soldier at 5 km/h, with the maximum speed of 7 km/h. Our model is required to detect the target (marked soldier) from no further than 15 meters with a minimum confidence of 45 percent. Under full operation the algorithm is expected to run at 12 frames per second. Software related functional requirements, as for the simulation part, we require a LIDAR scan rate of 7-9 Hz. Leg Tracker module requires maximum of 5m range in simulations. Robots are to be designed to help armed forces by following them on terrain operations. Modem of the HW v4.9 Starter hardware set has 100 m range for radio signal coverage HW v4.9 Beacons need to be places at least 2 m apart from each other. HW v4.9 Beacons should be facing each other in order to receive and transmit ultrasonic wave for localization.

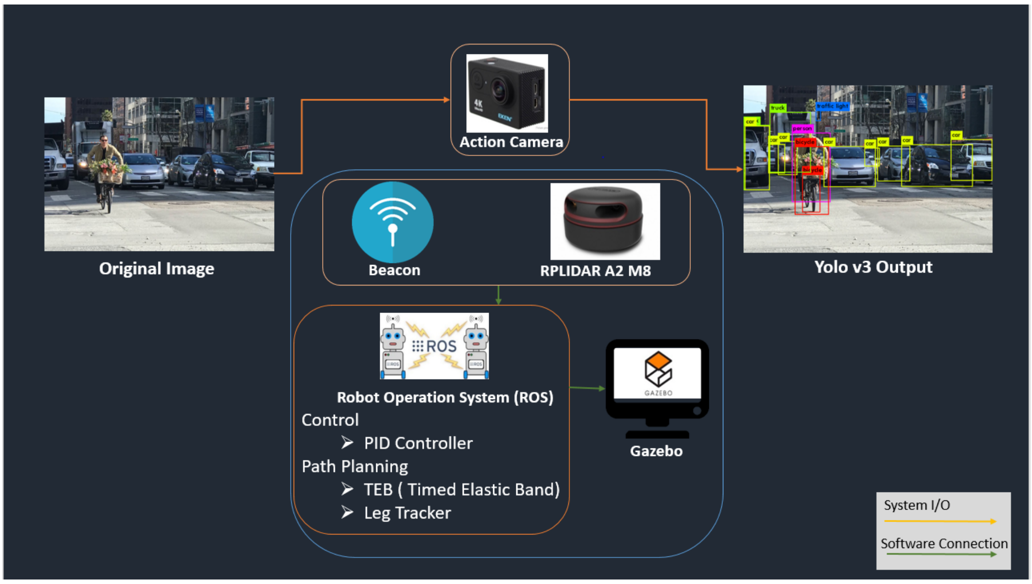

FIGURE 1. Big Picture

Big Picture contains computer vision software components such as object classification with YoLo and obstacle sensing with LIDAR. Using LIDAR data, human target is identified via Leg Tracker. Its output is passed on to TEB algorithm and path planning is commenced. The simulations are generated in ROS's Gazebo environment. In addition, Beacon data is used for odometry input of the robot's controller. Controller and path planning parts are done on ROS with simulations on Gazebo.

MILESTONES

The project has 3 major milestones which are **Mechanical Setup of the Robot, Object Tracking and Avoidance, and Simulations and Real Life Testing**. The Mechanical Setup of the Robot is the milestone related to acquiring the components of the robot and its assembly. In the Object Tracking and Avoidance, the aim is to use LIDAR and Action Camera sensors to obtain dynamic path from robot to the designated target. Simulations and Real Life Testing possesses the sub-tasks that are associated with the generation of the real world inspired simulation demo and application of the algorithms developed in other sections.

Mechanical Setup of the Robot consists of the Land Robot Chassis, Batteries and Chargers and Motor Drives. These names are derived from the necessary hardware components. They are completed after the obtaining these products. Object Tracking and Avoidance includes YOLO, LIDAR and Path Planning. YOLO is a Computer Vision tool which allows the identification of humans. LIDAR is the another peripheral required for object tracking. Path Planning is to create paths for the robot in an unknown environment in which a human is present to follow.

Simulations and Real Life Testing is the most comprehensive milestone. Gazebo is the simulation tool for the project. Modelling LIDAR is to obtain LIDAR output both in real world and simulation. Control with ROS aims to acquire stable movement with control algorithms. Beacon is the device to identify the robots location and its integration in real world is desired. Leg Tracker is the sub-task which obtains target position using LIDAR data.

DESIGN DESCRIPTION

Mechanical Setup of the Robot. The chassis is firstly identified as Dagu Wild Thumper 6WD model after a through research in the field. By acquiring the chassis, suitable components such as Batteries and Motor Drivers are identified. All the components are gathered and tested individually.

Object Tracking and Avoidance. Target Detection part of the project concerns with identifying a target human to follow among potentially a group of people. In order to identify humans YOLO Network was employed. This architecture yields a bounding box around the human to help the system navigate towards the designated target. In order to meet the performance requirements of this project with a relatively low performance hardware, target detection stack was optimized to run in specified intervals. These intervals were chosen to account for the maximum distance a person can move between two frames.

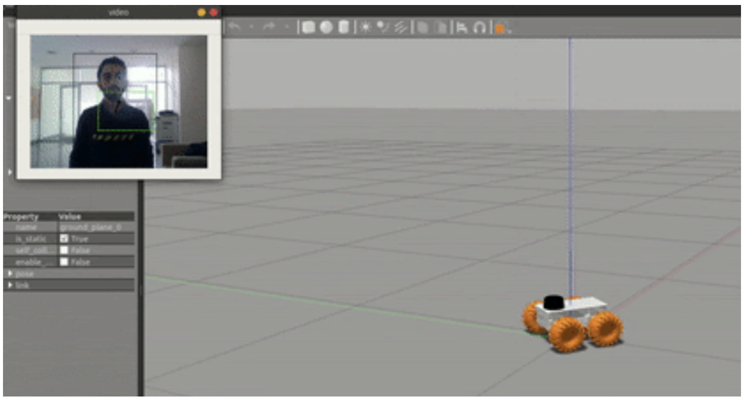

FIGURE 2. YOLO Network Example

Path Planning stage of the project refers to the design and implementation of a module that takes the information about the surrounding obstacles, and the target to be followed as input, then provides the necessary movement commands as output. For this purpose, Timed-Elastic

Band method [3] is used, based upon its robust performance and availability of its ROS node [4]. The information about surroundings is gathered and converted to cost-maps, where obstacles have negative values and target has positive. Utilizing this costmap, TEB can calculate an optimal global path, and adjust it by planning local paths that constitute the segments of initial global path in case the information obtained from sensors changes.

Simulations and Real Life Testing. Robot Operating System(ROS) possesses tools like Gazebo, which allows simulating the environment. With Gazebo, a simulation world based on EB building of Bilkent is implemented and Dagu Wild Thumper Robot is placed in simulation with its peripherals. An instance of the simulation can be seen in Figure 3

LIDAR outputs of RPLIDAR A2-M8 are demonstrated with RVIZ tool and used in other parts of the simulation such as Leg Tracker and Path Planning. Beacons indicate the relative position of the robot and its results are demonstrated both in Marvelmind Dashboard and RVIZ tools in real world. The demo done on both softwares can be seen in Figure 4. Based on its noise specification, Noised Odometry is generated in simulations. Through control with ROS tools, PID system is integrated into robot demo and the values are configured in order to stabilize the simulation. Considering the issues related to pandemic, a realistic implementation is attained in virtual world.

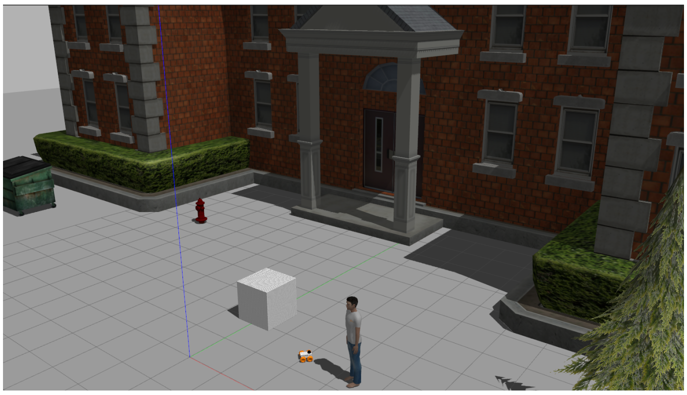

FIGURE 3. Sim Environment

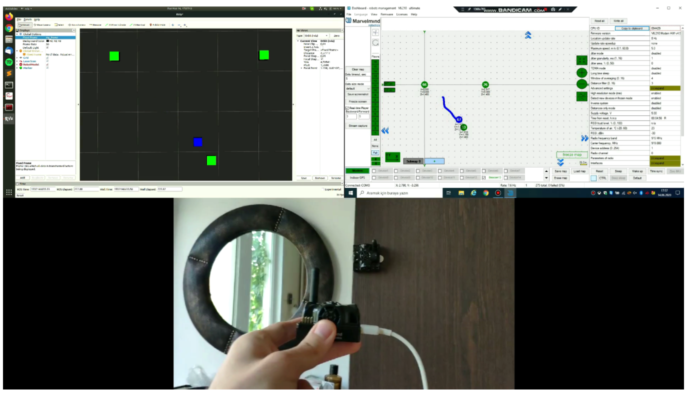

FIGURE 4. Beacon Demo

RESULTS and PERFORMANCE EVALUATION

Throughout the project several goals are attained in various milestones. Most notable ones can be listed as such:

- Mechanical Setup
- Human Detection System in Real Life
- RPLIDAR Real Time Processing
- Local Path Planning with Timed Elastic Band(TEB)
- Human Tracking with Leg Tracker
- Beacon Setup in RVIZ and Marvelmind
- Real Life inspired simulation Demo

The Mechanical setup is part of the first milestone. The required frequencies for the camera and LIDAR componets are identified and tested in real world. Local Path Planning is attained in an unknown environment dynamically in the simulations through TEB in Gazebo. In the last milestone, using the Leg Tracker with LIDAR data, human target is identified. Beacon tool worked successfully in the real world using ROS's RVIZ and Marvelmind tools. In order to generate a final demo of the product, due to Corona Pandemic, a real world inspired simulation

Demo is commenced. This demo integrated most of the milestones and imitated those which cannot be fully transferable to simulation environment.

Each work packet in the project was build around previously specified performance requirements. Therefore after achieving the given task each module was further optimized to meet these performance requirements. Aside from the modules that cannot be completed due to the pandemic, all work packets perform satisfactorily.

CONCLUSIONS and FUTURE DIRECTIONS

In a brief summary, most of the major milestones determined in the beginning of the project have been completed. The exceptions are the complete assembly of the peripherals and the swarm intelligence parts. Furthermore, "Target Module", as in Figure 5 should be implemented to process the outputs of Computer Vision and Leg Tracker modules to provide robust position data of the target to the TEB module. In theory, by utilizing methods such as Kalman Filter or Recurrent Neural Networks to predict the trajectory of the target in case it cannot be detected temporarily, Target Module will accomplish the tracking action, which we couldn't finalize due to Covid-19 breakdown.

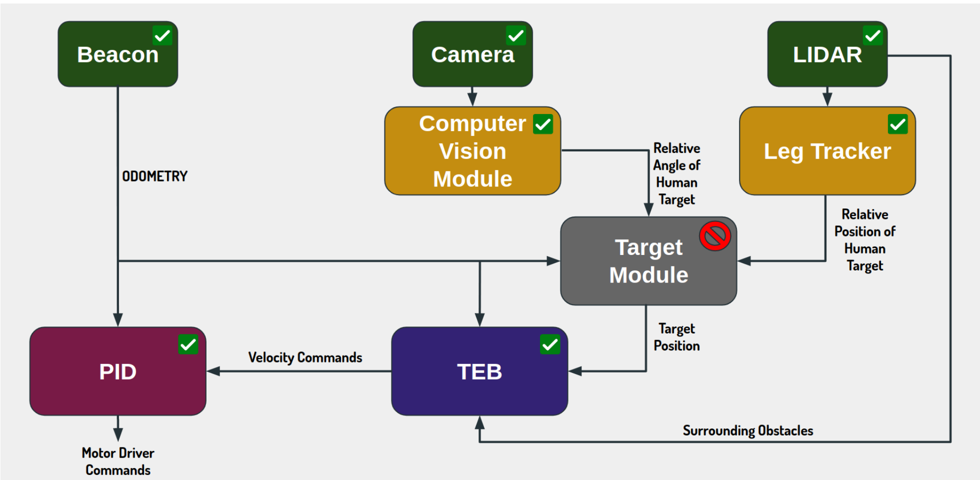

FIGURE 5. Possible Future General Structure

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[3] Christoph Rosmann, Frank Hoffmann, and Torsten Bertram. "Timed-Elastic-Bands for time-optimal point-to-point nonlinear model predictive control". In: *2015 European Control Conference (ECC)* (2015). DOI: `10.1109/ecc.2015.7331052`.

[4] *ROSWiki.* URL: `http://wiki.ros.org/teb_local_planner?distro=melodic`.

BEHIND THE SCENES