Free Navigation and Calibration with Virtual Barriers and Forbidden Regions

I. Introduction

This study has been done as part of the **Natural Emotions as Evidence of Continuous Assessment of Values, Threats and Opportunities in Humans, and Implementation of These Processes in Robots and Other Machines**[1] project carried out by Prof. Jean-Daniel Dessimoz at the Lab for Robotics and Automation (LaRA), HEIG-VD.

Autonomous navigation is an important aspect in the development of mobile robots. While there has been tremendous improvement in navigation of robotic agents in scenarios like autonomous driving and aerial vehicles, there still lies several challenges in optimal navigation of cooperating robots. These machines operate along with other similar or varying agents to accomplish a standard job. One of the major challenges for these kind of bots is to ensure the safety of the robot system. Humans tend to safely navigate in complex situation and manage to protect themselves by making use of certain threat values and natural emotions.

The general navigation pipeline for a pipeline involves the acquisition of sensor and perceptual information, which is feeded to the decision making module. One of the earliest methods for the navigation of mobile robots involves the use of artificial potential fields around obstacles for safe trajectory generation. This is similar to how humans assign subtle threat values to surrounding entities while navigating. This works well for obstacles identified through laser sensors. But this with human constraints

To tackle this particular challenge in case of machines, we take inspiration from the human rule based navigation and make use of virtual barriers and forbidden regions. Cooperating robot agents are widely being used in warehouse management, as delivery agents in offices and amusement parks. All of these cases have a common characteristic that the robot operates in a fixed perimeter and a part of the environment always remains constant. emotion-related processes, when actually implemented in robots, can effectively replicate human behaviours.

In this report, we demonstrate the use of virtual barriers and forbidden regions with 2D LiDAR for navigation of mobile robots to address the method of human-like rule based navigation in known environments. We perform our experiments on the RH-Y robot [1] and Piaget development and control environment.

[1]IJCAI'17 paper: http://ceur-ws.org/Vol-2099/paper8.pdf

II. Methodology

The methods showed in the report can be divided into initialization of priori defined areas where the locomotion of the agent is not feasible, calibration of the agent for localizing in the synthetic map and free navigation avoiding the forbidden region and obstacles recognized via 2D-LiDAR.

A. *Virtual Barriers and Forbidden Regions*

Humans overtime develop a notion of safe and feasible terrain for navigation. For instance, a person walking around a pool would be carefully able to navigate their way such that they doesn't fall down into the pool. This could be attributed to the fact that the person from all his experiences has learned that it isn't possible to perform the walking behavior over the pool. The person, thus automatically assigns a high threat value to this particular region and safely navigates around it. We use this concept of threat values and define forbidden regions and virtual barriers as part of the virtual map of the environment. These regions that have a high threat value, which means that it is impossible for the robot to traverse through this part of the environment.

B. *Calibration of Location in Synthetic Map*

Placing small square tiles of reflecting glasses at defined intervals along the corridors, results in discontinuities in the LiDAR data. We use these discontinuities to our advantage to identify calibration spots. The robot then navigates to the position where this discontinuity occurs and performs the calibration maneuver of aligning itself perpendicular to the wall and placing itself at a given distance. Once the calibration is done, we reset the position of the robot in the synthetic map. Thus we are able to correct the error in localization that may occur overtime, and make it easier to move around for longer hours.

C. *Free Navigation*

To demonstrate the effectiveness of having forbidden regions, we perform free navigation i.e. a robot moving around randomly by simply adding gaussian noise to the translational and rotational motion. The collision avoidance subsystem uses a potential field based obstacle-map that takes into account the input from LiDAR and the virtual forbidden region to navigate autonomously.

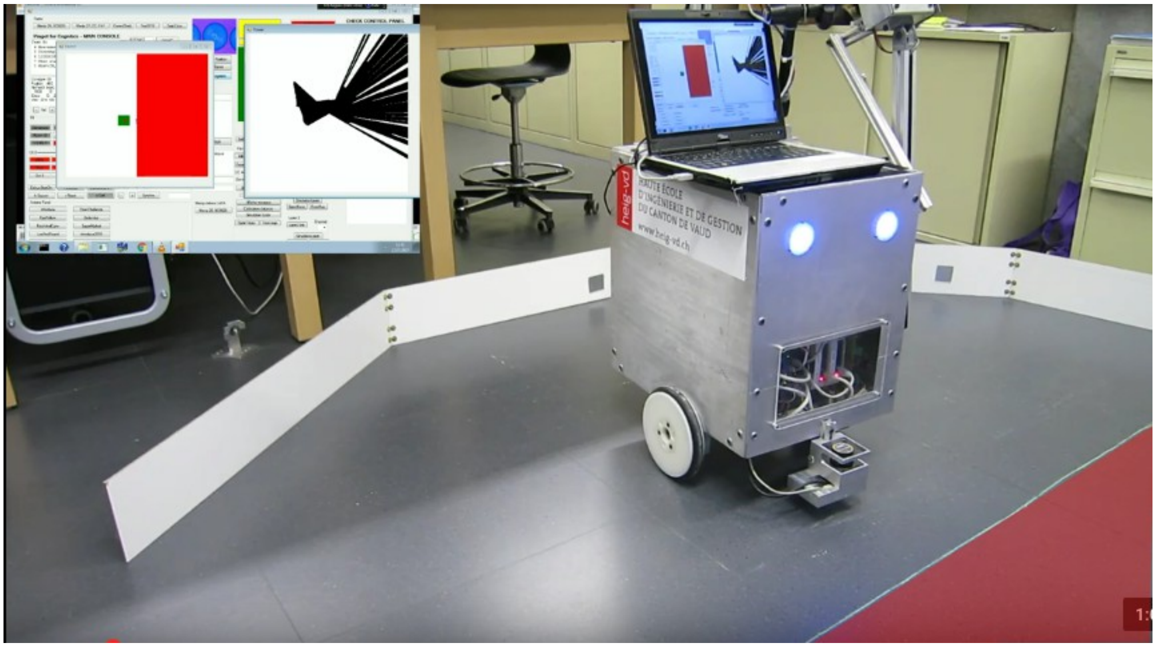

Fig. 1. RH-Y robot performing free navigation in a restrained environment. The translucent red section on the floor represents the forbidden region. The small grey tiles on the white wooden planes are the reflecting mirrors, used as calibration planes for robot localization.

III. Experiment

For the purpose of simplicity, we conduct all our experiment inside the lab workspace. The robot was placed in an empty space initially. A part of the environment is defined as forbidden region. In principle, this forbidden region could have been a pool, staircase or some region that the robot would not be able to traverse due to the structural and dynamics design of its body. The red region in the synthetic map represents the forbidden region. The red masked region on the real world image represents the position of the forbidden area in the real environment. We have also added the vertical flat slabs to showcase collision avoidance. Further, small mirrors have been setup on these slabs to create a ad hoc situation for calibration of the robot location in synthetic map.

We use the RH-Y robot for demonstrating our experiments. RH-Y robots are typically about 50x50x100 cm large, weight about 30 kg, consist in a mobile platform including 70W active wheels, arm, end-effector, power units and energy storage (batteries), many sensors (color camera, 3D ranger, 2D scanning ranger, wireless microphone, ultra-Sonic sensor, etc.) and control units interconnected with Ethernet, TCP-IP technology. For this experiment, we just utilize the 2D scanning ranger and control system.

Figure 1 shows our experimental setup. We simply use a map file that marks half of the region as forbidden (in red). The green box represents our differential drive robot RH-Y. Simultaneously, we also read the scan data from our 2D LiDAR and visualize it using our program. The robot navigates in the real environment, avoiding the from forbidden region it performs maneuver such that it does not enter it. At the same time it also uses the LiDAR data to avoid obstacles (if any) and continues to freely navigate in its environment. Overtime, it uses the reflecting mirrors to calibrate itself with respect to the map file.

IV. Conclusion

We present a system that navigates freely in an indoor environment, for example, office spaces and living room area. We use virtual forbidden regions to guide the robot about untraversable regions. Most of common architectural items (walls, doors, furniture) naturally provide potential calibration planes and thus we have a system that can function efficiently over a longer period of time.

References

[1] Jean-Daniel Dessimoz and Pierre-Franois Gauthey. Rh3-y - toward a cooperating robot for home applications. 11 2019.