Preliminary Report - Project - Planning and Decision Making

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I. INTRODUCTION

This project aims to provide students with a deeper understanding of planning and decision making by developing a motion planning algorithm based on robot kinematics [1]. The chosen morphology of the robot for this project is a non-holonomic wheeled service vehicle.

The environment is modelled after a hospital and will gradually be made more complex throughout the project. First a *Static Task* will be created, containing a simple environment with obstacles that stand still. This will consist of hospital beds in an ICU, where the vehicle should transport goods to a goal location. If this proves successful, a *Dynamic Task* will be performed, combining moving obstacles such as doctors with static obstacles. This application was chosen because it has a direct application in a real-world scenario, and such a solution could increase the quality of health services and well-being of hospital patients.

The selected motion planner is the optimal informed Rapidly-exploring Random Tree (informed RRT*). The workspace of the robot is $\mathbb{R}^2$ and the configuration space of the robot is $\mathbb{R}^2 \times \mathbb{S}^1$.

II. ROBOT MODEL

Regarding the robot model, the vehicle of this assignment will be described by means of the kinematic bicycle model illustrated in Figure 1. This provides a mathematical description of the motion without considering forces, as described by the equations of motion 1 - 4, which are based purely on geometric relationships governing the system.

Note that in spite of the simplicity of the kinematic bicycle model, it was regarded as appropriate for the assignment since the focus of the group will be the development of the RRT algorithm from scratch to get a better fundamental understanding of it.

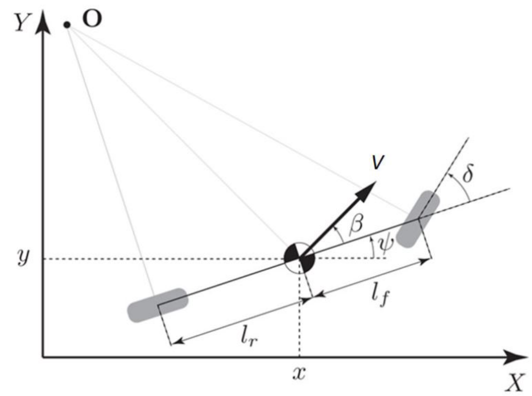

Fig. 1. Kinematic bicyle model [2]

$$\dot{X} = V\cos(\phi + \beta) \tag{1}$$

$$\dot{Y} = V\sin(\phi + \beta) \tag{2}$$

$$\dot{\phi} = \frac{V}{l_r}\sin\beta \tag{3}$$

$$\beta = \arctan\left(\frac{l_r}{L}\tan\delta\right) \tag{4}$$

III. MOTION PLANNING

Variants of RRT will be used for motion planning. Initially, plain RRT will be implemented in a simple obstacle avoidance scenario, such as the one described by the *Static Task*. Once this is achieved, the algorithm will be gradually improved to RRT* and further on to informed RRT*. This approach will allow for a gradual increase in code complexity, with performance improvements at each step.

RRT* was chosen due to its asymptotic optimality to encounter the best path and its relative simplicity (compared to MPC). Moreover, by employing informed RRT*, once the first feasible path is determined, an upper bound on the distance can be set. This leads to less unnecessary exploration and thus greatly improves performance.

It is worth noting that the RRT algorithm will only need to be run once for the *Static Task*, but will need to run continuously for the *Dynamic Task* to account for the changing environment. The latter is more realistic for real-world applications, but does require an efficient algorithm to work in real-time.

Finally, the RRT algorithm and variations require a steering function to guide the robot throughout the encountered path. Since the vehicle used in this assignment is non-holonomic, the steering function will be defined by Dubins car model, where the car can only move forward. At first, the set of steering actions the robot will be able to perform will be discretized to a small number such as 3 (forward, full turn right and full turn left). Having achieved this, the next step would be to do a finer discretization so that the range of motion is more flexible. As a final remark, the option of implementing the Reeds-Shepp car model so that the robot can also move backwards has also been considered, but will be left as a potential future improvement.

IV. EVALUATION AND SIMULATION ENVIRONMENTS

For the environment, first the plan is to visualise the algorithm in a plotting tool. In this way, it can be verified that the path generation is working.

To verify that the vehicle is working, the system can be tested with a simple kinematic model. In this case it can be verified that the vehicle with kinematic constraints works with the path generation.

As a last step, the vehicle is going to be simulated in a fully simulated environment, for example, PyBullet or MuJoCo, to verify that the whole system also works in a dynamic environment.

For the *Static Task*, a simple room can be modelled with a small amount of hospital beds that are modelled as rectangles. For the *Dynamic Task*, the same simple room can be used but then with moving humans in the room that are modelled as circles.

V. CONCLUSION

In conclusion, an RRT planning algorithm will be used on a non-holonomic wheeled service vehicle, which will be modeled using the Dubins kinematic bicycle model. Environments with both static and dynamic obstacles will be investigated.

REFERENCES

[1] Javier Alonso-Mora. Planning & decision making project, Nov 2022.

[2] Bary Shyrokau. Kinematics & dynamics of mobile robot automated vehicle, Nov 2022.