Course Project - AM5011 Virtual Reality

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Title - Digital Twin of an Autonomous Mobile Robot

Objective - The aim of this project is to create a digital twin of an autonomous mobile robot.

Introduction -

Autonomous robots travel around unmanned regions, they come with different sensors and it is usually of interest to map the regions traversed by them, eg: The mapping can be a form of mapping obstacles on their path, mapping tactile information encountered.The purpose of this work as follow

- Path mapping of the autonomous robot's movement in the real world.
- Tactile sensing of the surface traversed by the robot and mapping it onto the virtual world

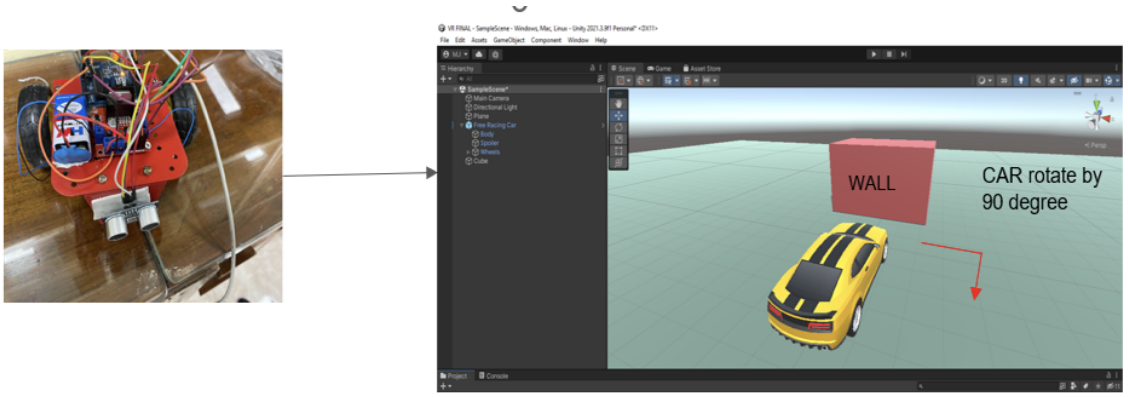
Literature Survey-

A digital twin is a nonphysical model that has been designed in order to accurately reflect an artificial or physical system, where sensors are placed to acquire a variety of data regarding different aspects concerning the performance of the system. These data are then transmitted to a data-acquisition system and applied to the digital copy. When the digital copy is updated with the relevant data, the virtual model may be used for the implementation of various simulations, which can lead to potential improvements, by creating valuable information that can then be applied back to the original system existing in the physical world. In this way, physical processes and products together with their accompanying elements can be digitally transferred and described in a cyber-world context [

Methodology-

Initial Prototype of Digital twin using Ultrasound sensor

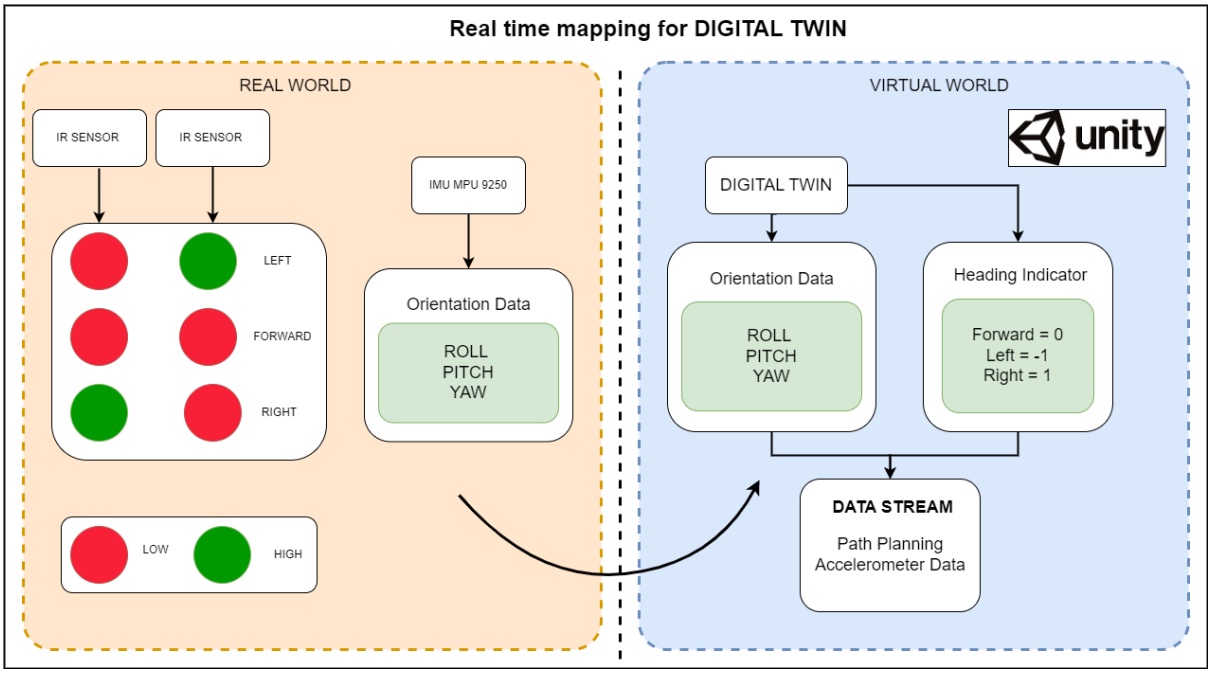
In my initial prototype of digital twin using the Ultrasound sensor to detect the obstacle in real environment, we faced a few challenges such as lack of speed control, high latency of the ultrasound sensor, lack of feedback on degree of turn taken by the robot, and lack of defined path traversed by the mobile robot. An interesting observation was that due to the high latency of the ultrasound sensor and high speed of the robot motors(lack of speed control) avoiding obstacles was a difficulty as by the time the sensor sensed an obstacle and issued a stop command the robot would have hit the obstacle.



Current Digital Twin Prototype

Following challenges were resolved in the final robot design bringing solutions to the issues discussed above.

- Lack of speed control was resolved by adding PWM.
- Line follower mechanism was adopted for traversing on a defined path, additionally the IR sensors used had a low latency.
- MPU9250 IMU for getting roll, pitch and yaw of the real-world robot.



For the real-world bot, an array of IR sensors were used (LEFT and RIGHT). The following controller commands were set up.

LEFT Sensor	**RIGHT Sensor**	**Bot Decision**
LOW	LOW	Forward
LOW	HIGH	Left
HIGH	LOW	Right
HIGH	HIGH	Undefined(Doesn't Occur)

In Virtual World, the orientation data roll pitch and yaw of the robot is used to map the path of the autonomous robot in Unity Software.
The Heading Vector Forward =0, Right =1 and Left =-1 help to decide the direction of the Robot in Unity.
If the Heading Vector is 0 the robot moves in forward direction.
(Clockwise direction) If Heading Vector is 1, the robot takes a right turn and moves in that direction.
(Anti-clockwise direction) If Heading Vector is -1, the robot takes a right turn and moves in that direction.

Note: The amount of rotation in clockwise/anti-clockwise direction is decided based on the readings of roll/pitch/yaw.

Mobile Robot Building Blocks

Hardware

- Arduino UNO
- IR sensor
- Battery 12V
- DC motor
- L298N motor driver
- IMU MPU9250

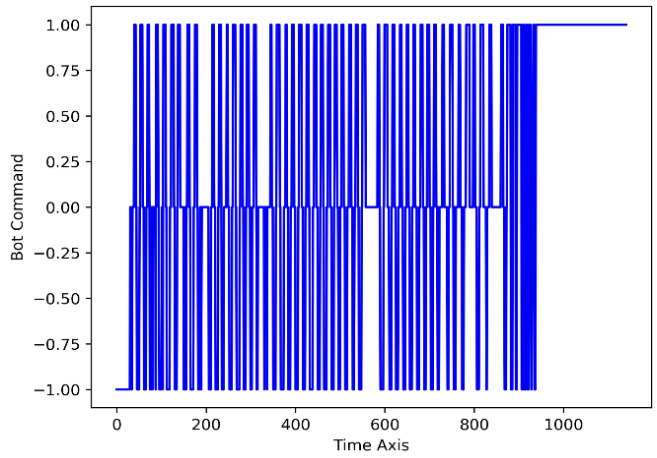
Software -

- Unity

Results and Discussion-

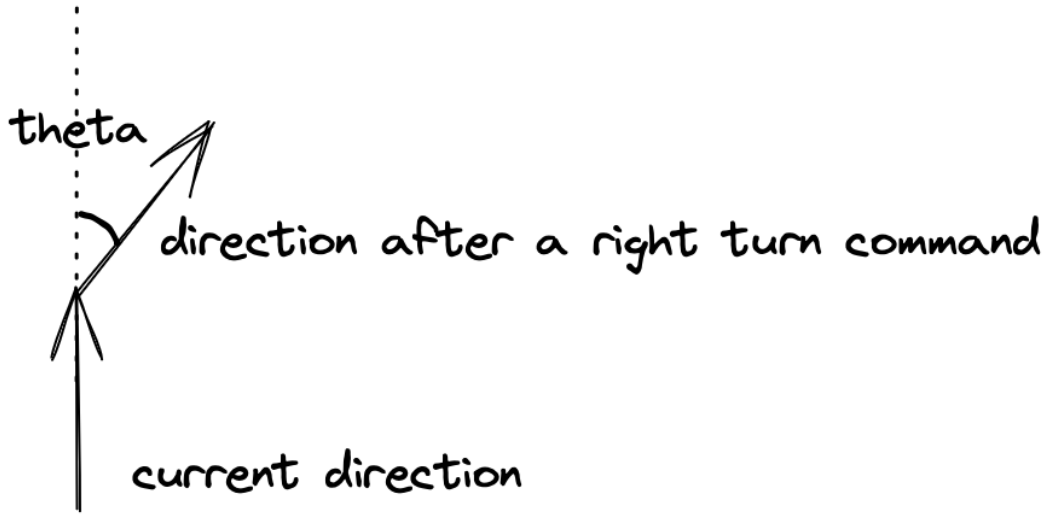
A Discussion on Digital Twin Mapping.

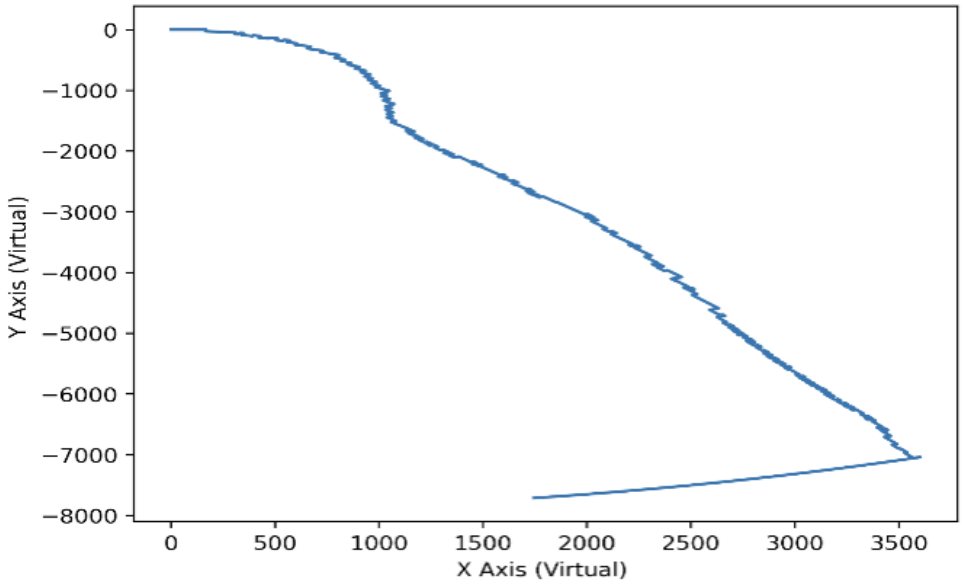
An initial thought was to use the Heading Vector obtained using the IR sensor data.



However, an important issue was the lack of feedback on degree of rotation taken by the bot was unknown, thus the rotation given to the bot in the virtual world was an empirical value.

Algorithm:

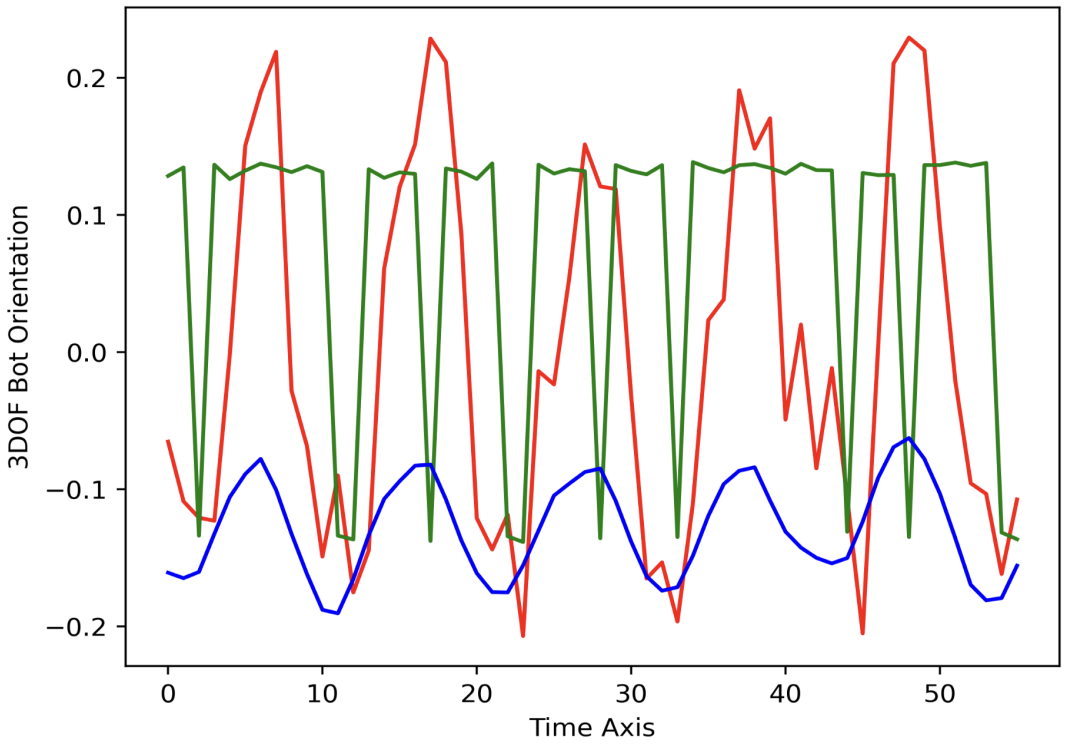




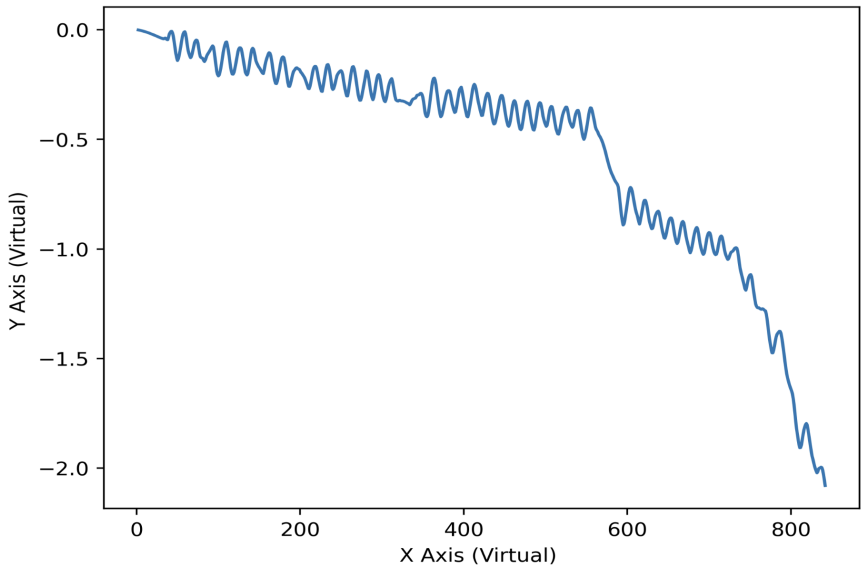
Path Mapping (IR decision based)

This issue was resolved by adding an IMU sensor on the bot.

A minor tweak was made to the path mapping algorithm, this time the degree of rotation made by the bot was inferred from the gyro data.



Gyroscope Data



Path Mapping (Gyro decision based)

It is clear from the path mapped that the gyro based decisions are more accurate.

VR Concept - SLAM (simultaneous localization and mapping) is a method used for autonomous vehicles that lets you build a map and localise our vehicle in that map at the same time. SLAM algorithms allow the vehicle to map out unknown environments. The map information to carry out tasks such as path planning,sensor fusion, object tracking, and obstacle avoidance.

Conclusion -

From this Project we saw that adding PWM to the motor can control the speed of the motor, IR sensor has low latency than Ultrasound sensor and thus, is better at path mapping . Finally, we saw that the path mapped using the gyroscope data was more accurate.

Future Scope

- Improved Robot Stability.
- Multi-sensor fusion for better path mapping and texture sensing surface data.
- Better autonomous navigation of robots.
- Reduced latency.

References

[1] Real-Time Localization and Mapping Utilizing Multi-Sensor Fusion and Visual–IMU–Wheel Odometry for Agricultural Robots in Unstructured, Dynamic and GPS-Denied Greenhouse Environments Yaxuan Yan 1 , Baohua Zhang 1,* , Jun Zhou 2 , Yibo Zhang 2 and Xiao'ang Liu 1

[2] Kuts, V., Otto, T., Tähemaa, T., & Bondarenko, Y. (2019). Digital Twin based synchronised control and simulation of the industrial robotic cell using Virtual Reality. *Journal of Machine Engineering*, *19*(1), 128–145.