InternPro Weekly Progress Update

Name	Email	Project Name	NDA/ Non-NDA	InternPro Start Date	OPT
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Progress

Include an itemized list of the tasks you completed this week.

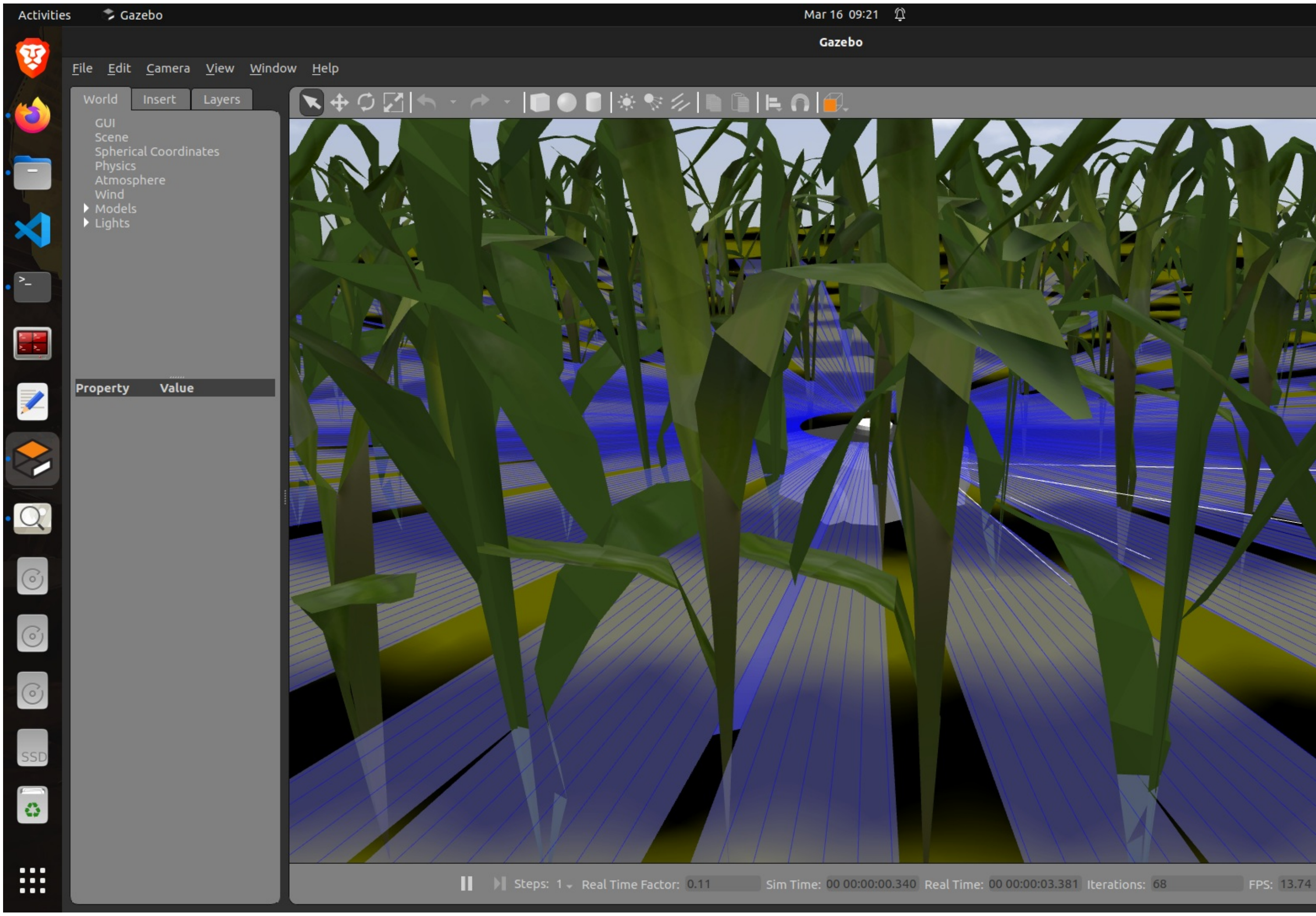
#	Action Item/ Explanation	Total Time This Week (hours)
1	Integration of TurtleBot3 Waffle into Virtual Farmland Simulation	3
2	Integration of Husky UGV into Virtual Farmland Simulation	3
3	Autonomous Rover Navigation in Virtual Farmland	3
4	Integration of GNSS Antennas into Virtual Agricultural Environment	3
5	Research Analysis for Agricultural Rover Simulation Enhancement	3
6	Autonomous Navigation of a Center-Articulated Hydrostatic Rover	3
7	Weekly Project Plan	1
8	Report Writing	1
	Total hours for the week:	20

Verification Documentation:

Action Item 1: Integration of TurtleBot3 Waffle into Virtual Farmland Simulation – 3 hour(s).

Project Work Summary

- Burger turtlebot model has limitations like small and fewer sensors and hence prioritized the Waffle variant for its enhanced 360° LiDAR, higher payload capacity, and modular design better suited for uneven terrain of the farmland.
- Updated the current Burger model in the Gazebo world file by updating the <uri> tag to turtlebot Waffle’s 3D mesh and adjusted coordinates to avoid collisions with crop rows during initialization.
- Visualized and verified the Waffle’s RGB-D camera and LiDAR to align with maize farm land which could be eventually used for accurate crop health scanning and mainly for motion planning and navigatio.
- The Waffle’s compatibility and ability to be controller with ROS2 set the base for the simulation for upcoming tasks like motion planning, navigation and eventually swarm coordination.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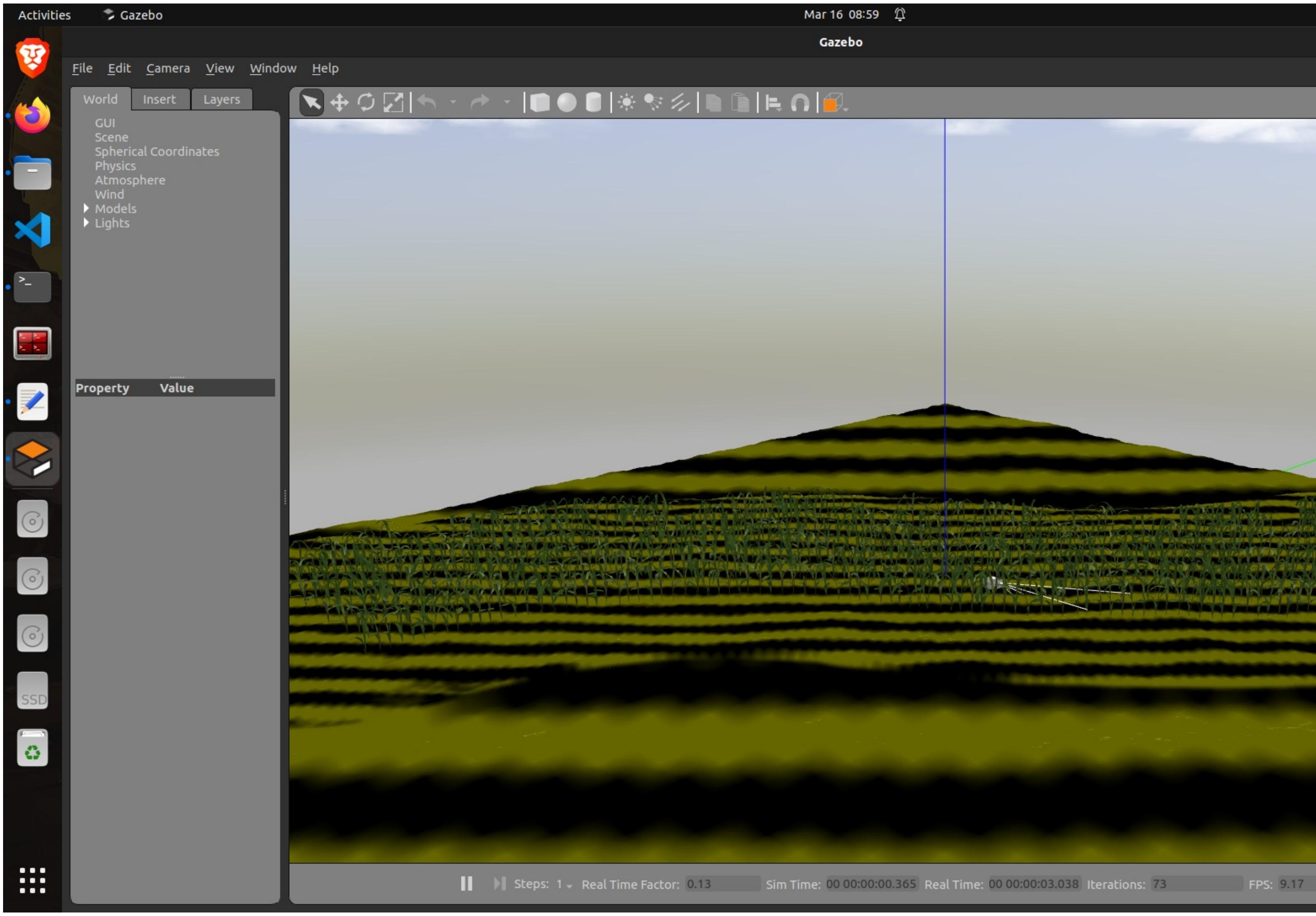
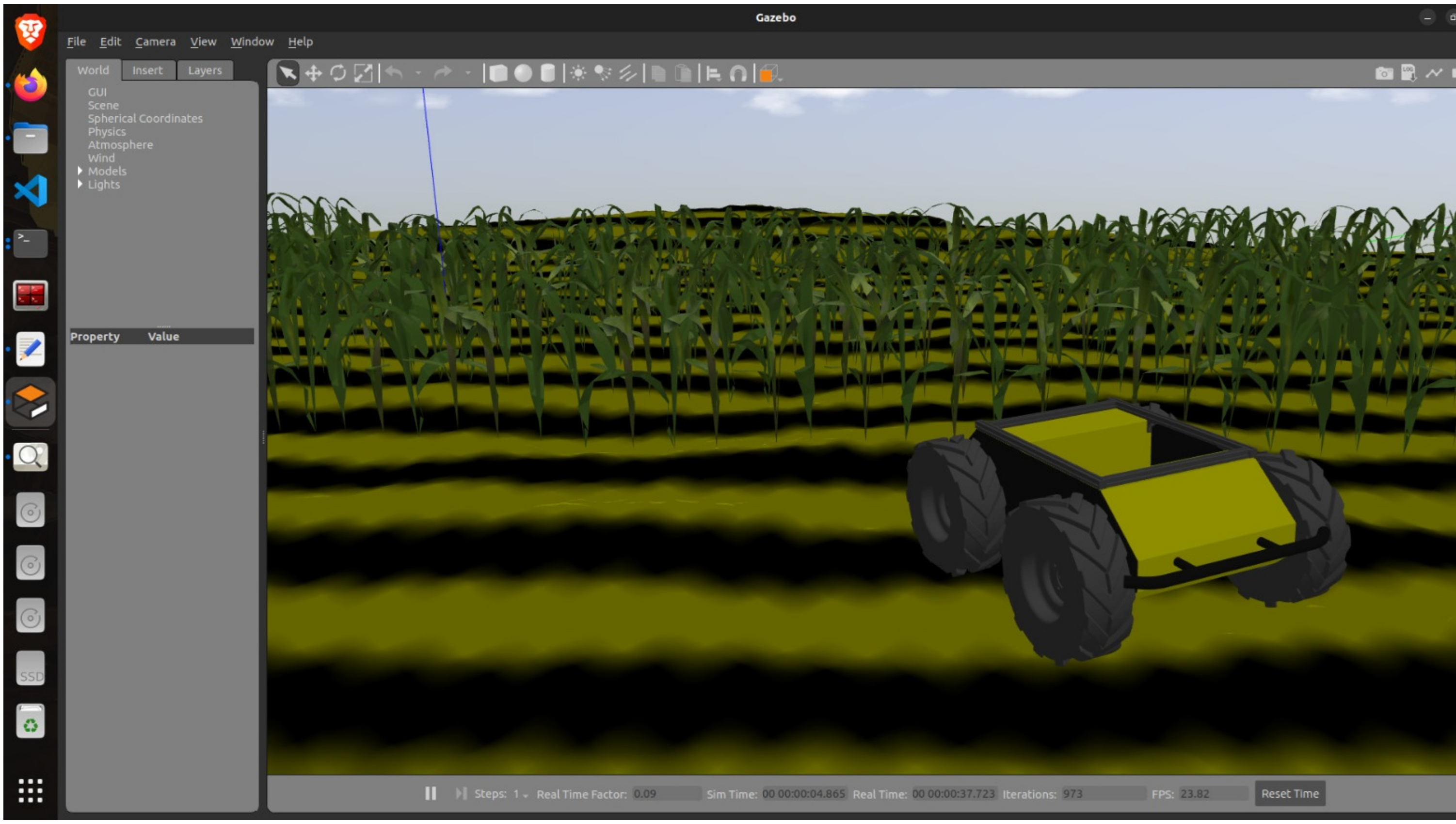
Iterations: 68
FPS: 13.74

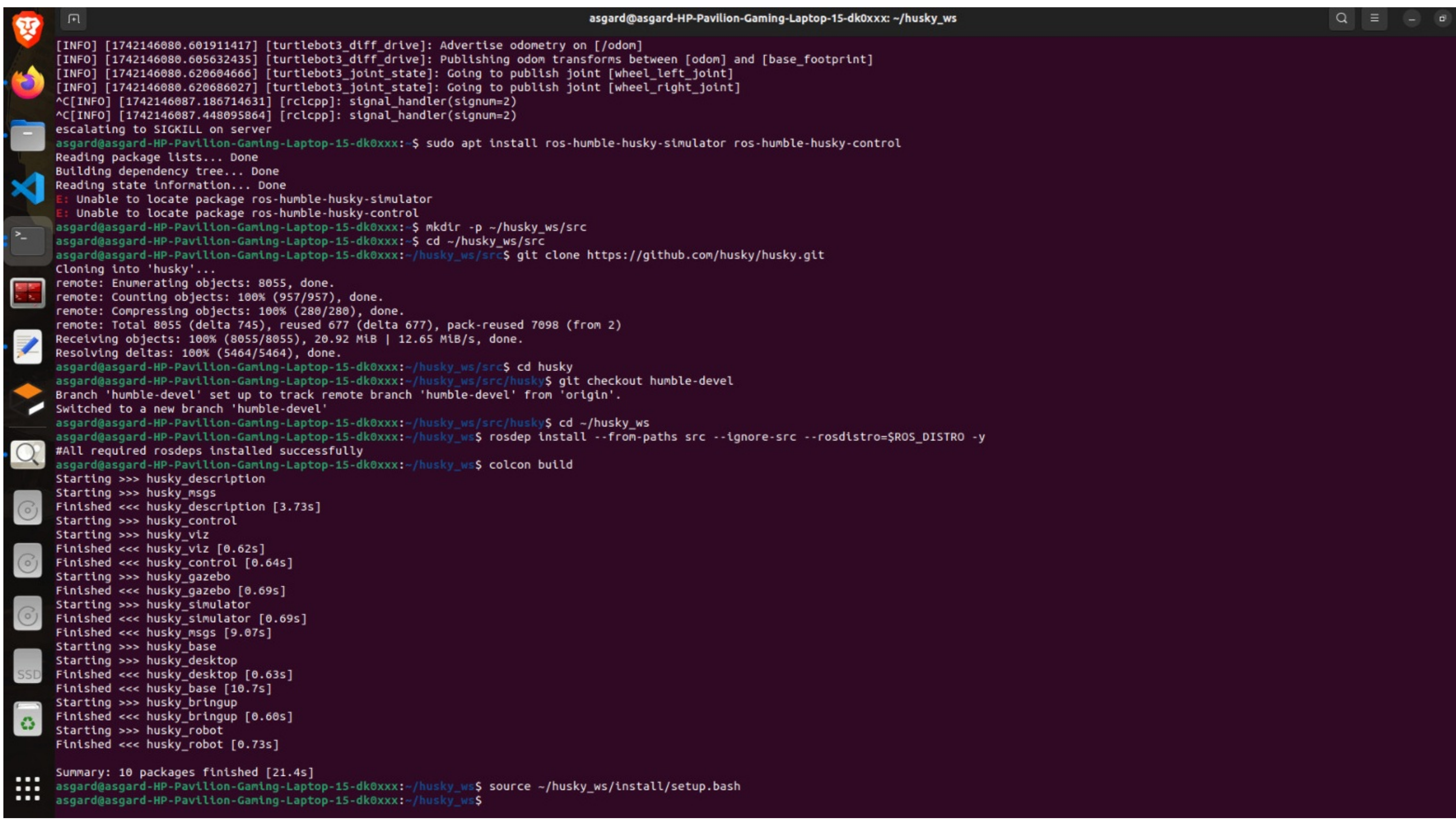


Action Item 2: Integration of Husky UGV into Virtual Farmland Simulation – 3 hour(s).

Project Work Summary

- Replaced the TurtleBot3 completely due to ground clearance and low torque of the bot, causing navigation failures on simulated farm terrain with height variations. Better option was to go with the Husky UGV with better ground clearance, traction suitable for outdoor agricultural environments.
- Installed and cloned the ROS 2 Humble workspace with Husky rover package, including in-built controllers and SLAM packages, ensuring compatibility with mobility over the crop field.
- Then updated the Gazebo generation world code file to spawn the Husky at field entry coordinates (5, 5), for better visibility in the farmland. Adjusted the position to avoid collision with the maize row.
- Created ROS 2 gazebo file readily available for future integration of implements navigation, ploughing, sensor fusion and path planning and health monitoring applications.

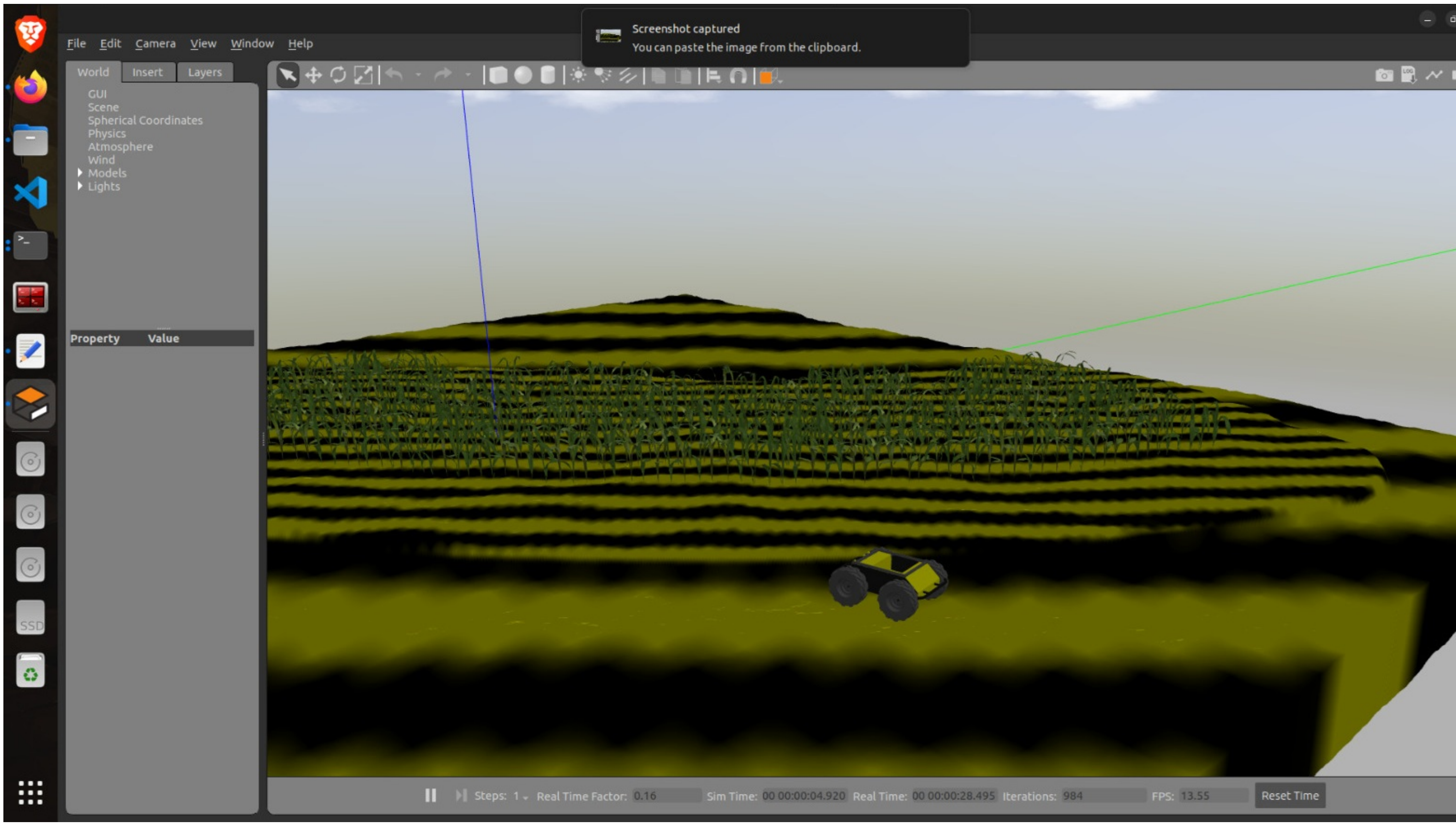
- 



Action Item 3: Autonomous Rover Navigation in Virtual Farmland – 3 hour(s).

Project Work Summary

- Now that husky is imported to the farmland, we then started to experiment with rover movements in the farmland one by one.
- Firstly the rover was programmed to follow a combining straight-line along the farm. But the problem with the movement was that direct forward motion collided with crops and the land
- To avoid collision from the crops we did many trial runs with various locations as the start point and finally identified an optimal start point at (5.0, 3.8) that was at a safe distance from the first crop row .
- Then the sensors attached to the rover was used to find any obstacle on the way and on encountering obstacles, the rover was subject to change directions.
- By doing so we implemented basic movement navigation command, to move along a designated direction and towards a target location.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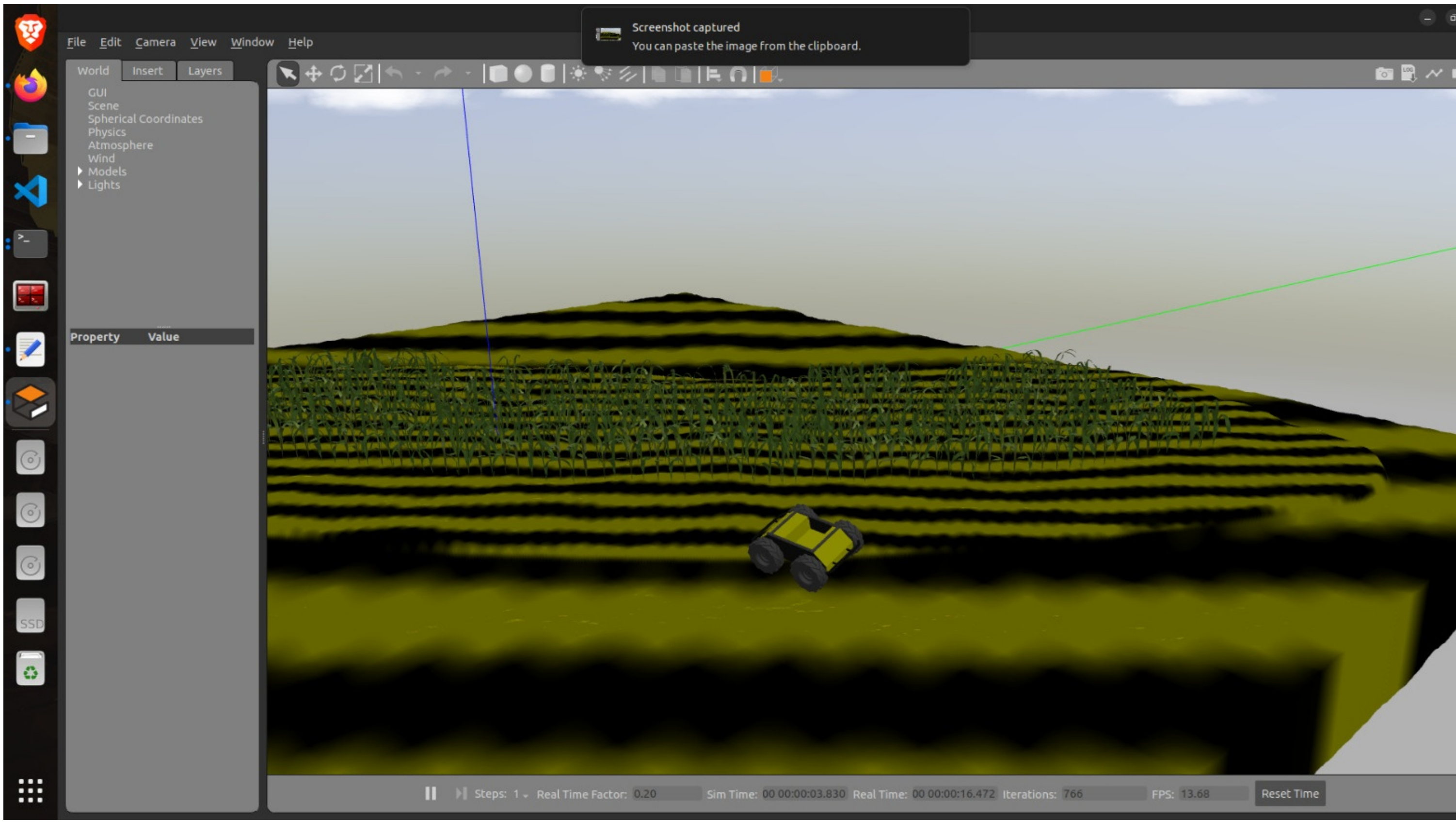
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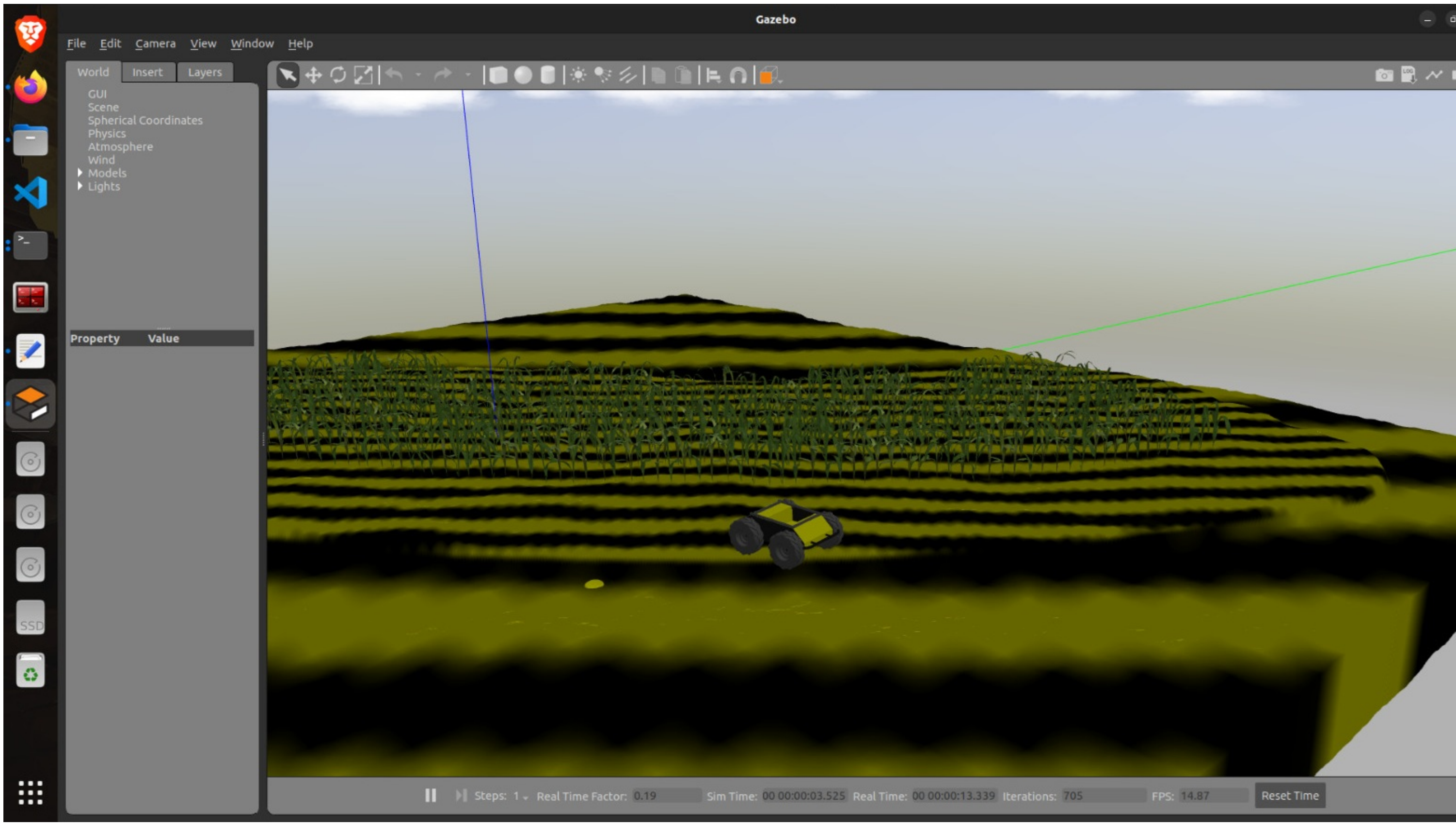
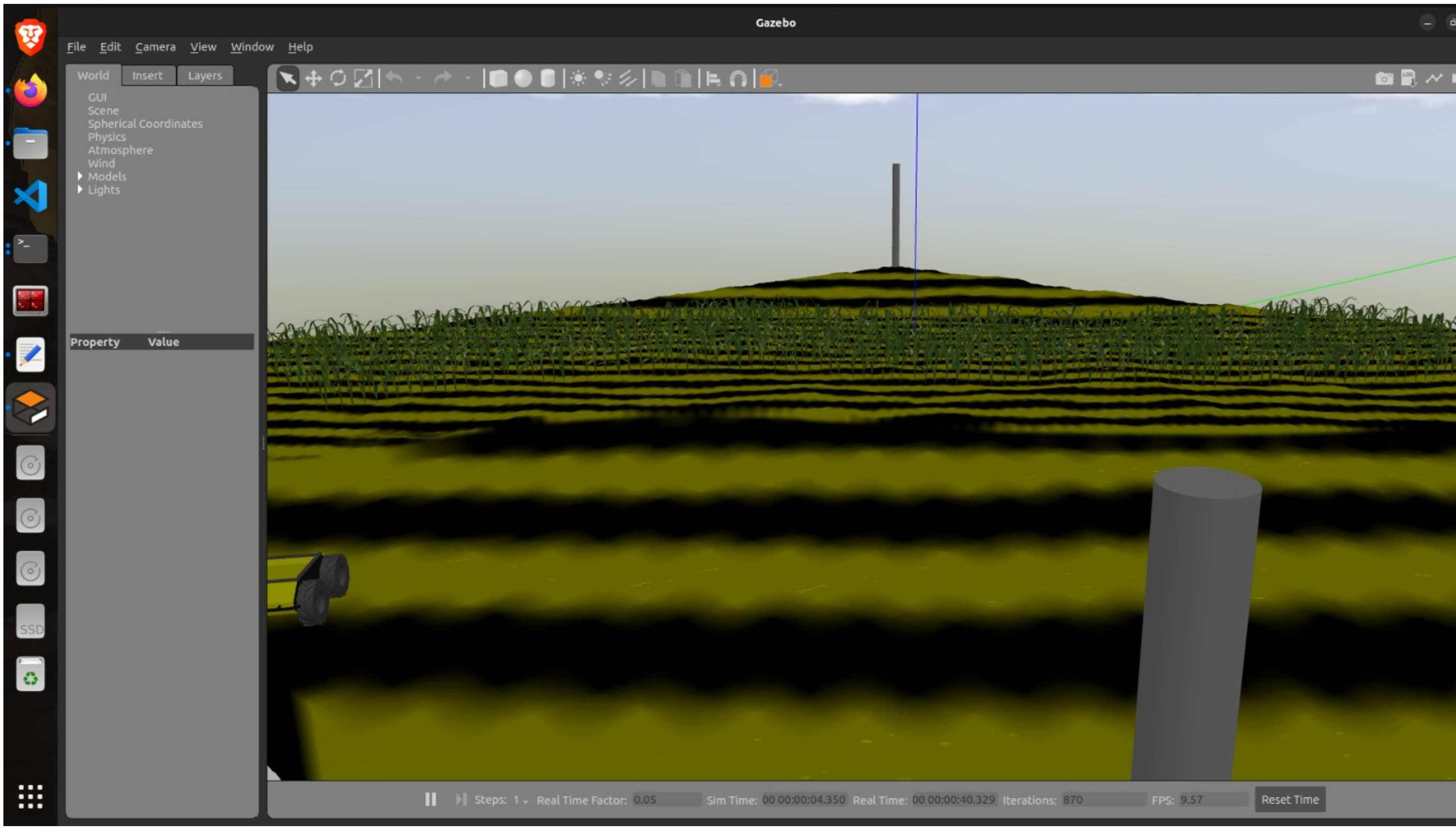
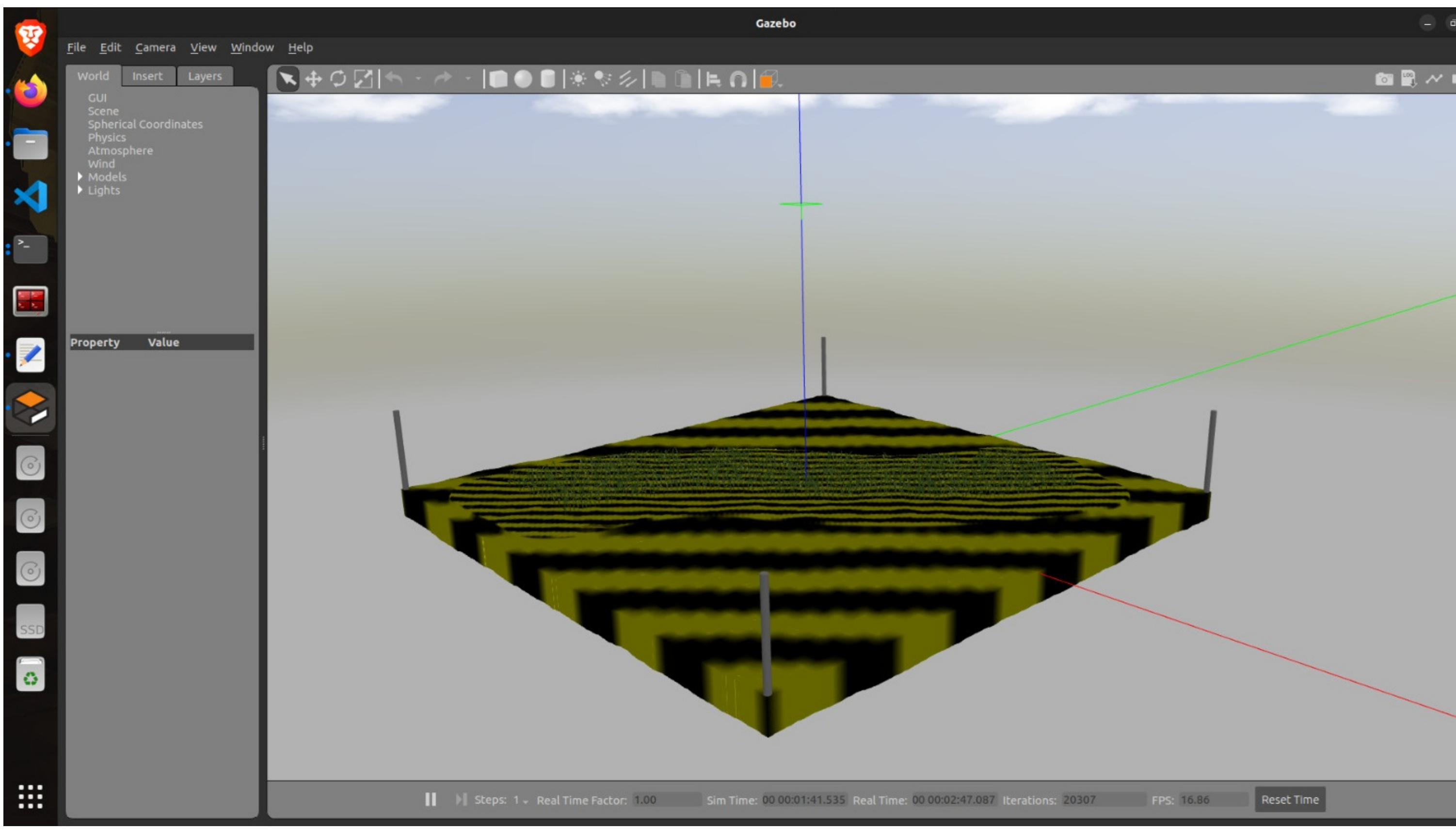


Action Item 4: Integration of GNSS Antennas into Virtual Agricultural Environment – 3 hour(s).

Project Work Summary

- Designed a 3D model of a GNSS antenna for positioning the rover by creating a separate Gazebo's SDF format for the gazebo model, incorporating realistic dimensions and visual properties to simulate a GNSS base station antenna.
- Created the model within the Gazebo's model directory (~/.gazebo/models) for the GNSS antenna for future use and easy access, including files like (model.config and model.sdf) following the general procedure.
- Updated the GAZEBO_MODEL_PATH environment with GNSS antenna model directory and sourced it making it available in the bash and easily accessible for future usage/
- Edited the generation farm world SDF file to add a single instance of the GNSS antenna model, positioning at one corner of the simulated agricultural land.
- Then duplicated the GNSS antenna model four times within the world file using different names, over all the corners of the farmland to created a distributed network of base stations across the virtual farmland, increasing a structured and full coverage with the sensor.
- This task put forth the proper foundation to build a robust GNSS infrastructure within the virtual farm environment, laying the groundwork for future navigation in the farmland.





Action Item 5: Research Analysis for Agricultural Rover Simulation Enhancement – 3 hour(s).

Project Work Summary

- https://journals.sagepub.com/doi/10.1177/1729881420904526
- Integration of RTKLIB with ROS for Centimeter-Accurate GNSS Navigation
- Summary of Report
  - The paper explains how they developed rtkrcv_ros, a ROS package that acts as a middleware between RTKLIB's RTKRCV module and ROS.
  - It explains how it translates RTKLIB's raw GNSS data (observation and navigation messages) into ROS-compatible topics (/gnss/obs and /gnss/nav), enabling real-time correction streaming.
  - They have Implemented triple-antenna configurations to estimate not only measure the position but also the vehicle (roll, pitch, yaw) using carrier-phase differential GNSS. This is critical

    - for agricultural rovers to maintain alignment with crop rows.
    - Introduced the ros2 concepts like ROS services (/gnss/restart, /gnss/pause) to manage signal disruptions.
- Relation to Project
    - The paper helps in understanding the Gazebo setup with virtual base stations (antennas) simulated RTCM correction data to the rover via ROS topics, imitating real-world RTK networks.
    - The idea of adding multiple GNSS antennas to the rover model (e.g., front/rear) has helped improve the precision positioning of the rover in open fields.
    - The service node -based approach allows testing recovery protocols, such as failure in the sensor fusion back to wheel odometry during GNSS outages,
- Motivation for Research
    - Crop spacing in maize fields often vital and requires proper alignment to avoid plant damage during mechanical weeding or harvesting, so we were looking for ways of creating a better realistic farm land. .
    - Crops taller than rover in the farm can block satellite signals, hence we need robust error-handling workflows and multiple sensor fused together for better positioning.
    - Since RTKLIB is open-source we do not have to license the costs, aligning with the medium scale agricultural robotics’ need for affordable solutions.

Action Item 6: Autonomous Navigation of a Center-Articulated Hydrostatic Rover – 3 hour(s).

Project Work Summary

- https://pmc.ncbi.nlm.nih.gov/articles/PMC7472308/
- Autonomous Navigation of a Center-Articulated and Hydrostatic Transmission Rover using a Modified Pure Pursuit Algorithm in a Cotton Field
- Summary of Report
    - The rover uses a hydrostatic transmission along with the jointed chassis geometry, allowing good tractional along turns without skid-steering (which damages soil structure). Physics parameters like articulation angle (0–30°) and hydraulic pressure were modeled in Gazebo.
    - They have modified the pure-pursuit algorithm to adjust look-ahead distance based on terrain roughness. In smooth terrain, they have used 3m look-ahead; in uneven heights, this reduces to 1m for cautious steering.
    - Combined RTK-GNSS, IMU, and wheel encoders with the help of an Extended Kalman Filter (EKF) they have achieved a 0.06 m lateral error in straight rows and 0.24 m error during turns for precise positioning.
- Relation to Project
    - The adaptive pure-pursuit method proposed in the paper can be used to our rover for better navigation along the simulated farmland (e.g., furrows, irrigation channels).
    - Found that avoiding skid-steering reduces soil compaction, a critical factor for crop yield. Our simulation can model wheel-terrain interaction forces to validate this.
    - The paper proposes error margins are very less and could be helpful for our application and acceptable performance range for our rover’s navigation problem.
- Motivation for Research
    - The paper provided methods to minimize lateral deviation that will ensure the rovers to stay away from the plants and safe movement through the spacing, preventing crop damage.
    - The Hydrostatic transmissions are standard in tractors but complex to simulate even though we do not use that for our application particularly. But they provide Gazebo models as a template for simulating hydraulic dynamics and that could be used for our application with much less complexity.
    - The paper demonstrates that RTK-GNSS paired with low-cost IMUs can better perform than LiDAR-based navigation in open fields and hence for our navigation purpose in simulation and perhaps for the full scale real world application we can go with the same combination of sensors for the sensor fusion and get best of accuracy for positioning.
    - We could also bring those sensors into simulation and use it in gazebo environment for our own applications.

Action Item 7: Weekly Project Plan – 1 hour(s).

Project Work Summary

- Terrain height smoothening - Refine farmland heightmaps to create smoother and surface, ensuring proper significant wheel traction. Integrate soil compaction physics via Gazebo plugins to simulate realistic wheel-terrain interaction.
- Farm Map enhancements - Add more details to the farmland with crop rows, realistic surface channels, and sensor.
- GNSS Receiver Integration - add a simulated RTK-GNSS sensor into the rover’s URDF with noises. Establish ROS 2 topics for more realistic GPS data and RTCM corrections.
- Waypoint Navigation Setup - Implement a grid-based path planner for row-to-row transitions for health monitoring, irrigation and other agricultural processes.
- Sensor Fusion - Develop an EKF extended kalman filter for sensor fusion of GNSS, IMU, and wheel encoder data. Calibrate filter parameters to maintain cm-level accuracy in positioning of the rover in the field.

Action Item 8: Report Writing – 1 hour(s).

Project Work Summary

- Created word document layout to write contents of the weekly progress.
- Created relevant subsections in the epicspro website and documented 20 hours of weekly progress.
- Collected relevant documents research papers, relevant links and company's objective from their portal.