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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University u/s 3 of the UGC Act, 1956)

To whomsoever it may concern

This letter is written to express appreciation for Mr. Manveer Singh's recent contributions to the development of an autonomous food delivery robot (*Bibot*). Throughout the past year, we have served as his faculty advisor, and witness firsthand his remarkable dedication, technical brilliance, and innovative spirit. He did not merely contribute to this project; he played a pivotal role in its very conception and subsequent development. His experience in robotics and sensor technology was evident from the outset as he consistently demonstrated a deep understanding of algorithms.

More than just technical brilliance, Manveer's visionary leadership and planning captained the robot project to swift success. His orchestration of resources and unwavering determination defied deadlines, turning a vision into reality. The project consisted of multiple phases and milestones; they are summarised as:

- Choosing perception sensors, leading to the selection of a 2D LiDAR (*RP LiDAR A2M8*) and an RGBD camera (*Xbox Kinect V2*) for enhanced feature extraction. Furthermore, it entailed the creation of a mechanical 4WD structural prototype of the robot which included sensor housing and compartments.
- Constructing the electronic circuitry of the robot with reliable connections and ensuring safety measures alongside maintaining robustness of the system.
- Development of entire *Robot Operating System (ROS)* framework from the ground up to enable seamless integration of sensors with the system, teleoperate the robot, sensor data fusion, *Simultaneous Localization and Mapping (SLAM)*, localization and navigation. In addition, the algorithms and system were initially tested on Gazebo using a model created by defining its URDF.
- Initial testing steps involved successfully interfacing the hardware and teleoperating the real robot. Implementing and optimizing 2D LiDAR based mapping (*Hector SLAM*) and 3D SLAM using RGBD camera for comparison. Implementing a sensor fusion based mapping technique called *RTAB-Map*, involving optimizing the parameters through rigorous testing.
- Utilizing *Adaptive Monte Carlo Localization (AMCL)* for localization, optimized further for accurate pose array predictions. The last step involved implementing point to point navigation which incorporated *A** as global planner and *Timed Elastic Band (TEB)* based local planner.

The entire robot developed showcased a highly accurate mapping and efficient autonomous navigation between two locations with minimal deviation from the intended destination while evading dynamic obstacles. Overall, Manveer's contributions to the project have been nothing short of extraordinary. His technical expertise, innovative spirit, and leadership qualities have not only shaped the success of this project, but also hold immense promise for the future of robotics and automation. We have no doubt that he will continue to achieve great things in his academic and professional pursuits, and we wholeheartedly recommend him for any opportunity.

Please feel free to contact us if you require any further information or wish to discuss his work in greater detail.

Sincerely,

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