S.R.B Team Description Paper

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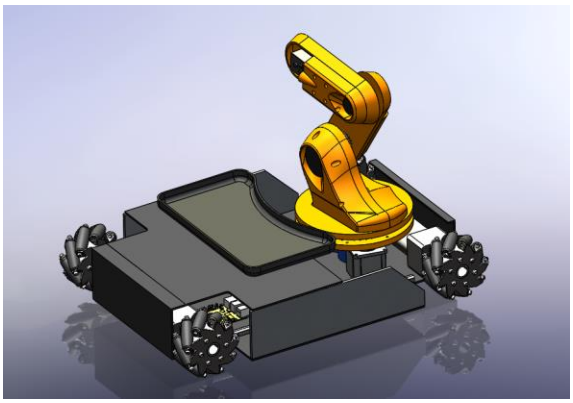
Abstract. This paper presents the design and implementation of S.R.B team's industrial robot from Tehran Azad University, focusing on its innovative mechanical design, hardware system, navigation using Robot Operating System (ROS), and image processing techniques. Featuring an omnidirectional moving mechanism and a versatile robotic arm, the robot is optimized for competition tasks. The hardware system ensures precise actuator control and sensor integration, while ROS enables adaptive navigation. Image processing, employing OpenCV in Python and planned integration of YOLO v8, enhances perception capabilities. This interdisciplinary effort underscores the team's commitment to excellence in competitive robotics.

Introduction

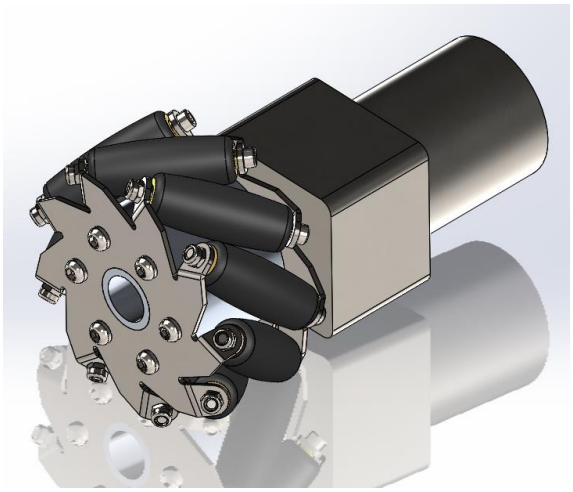
The S.R.B team, hailing from Tehran Azad University, comprises adept students specializing in diverse fields such as electrical engineering, hardware design, mechanical engineering, and software development. Since its inception in 2022, the team has embarked on a journey of innovation and excellence in the realm of robotics. This commitment culminated in our participation in the prestigious Iran Open RoboCup competition in 2023, marking a significant milestone in our pursuit of engineering prowess and competitive spirit. Through collaborative efforts and interdisciplinary expertise, we strive to push the boundaries of technological advancement and make impactful contributions to the field of robotics.

Mechanical Design

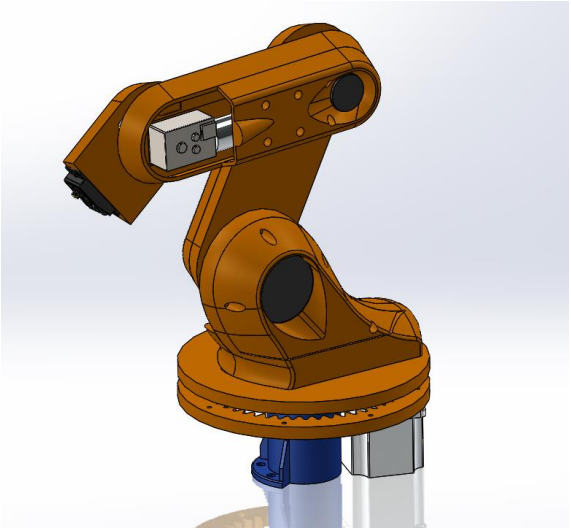
The mechanical design of our robot commenced with meticulous planning and modeling using SolidWorks software, ensuring precision and feasibility in every aspect. Translating our conceptualizations into tangible reality, we embarked on constructing the main platform utilizing aluminum material, leveraging the capabilities of CNC machines for unrivaled accuracy and consistency. This approach not only fortified the structural integrity of the robot but also facilitated optimal weight distribution and maneuverability. With the foundation laid, we strategically positioned our motors and wheels, aligning them in accordance with the omnidirectional moving mechanism envisioned for seamless mobility. The integration of these components symbolizes the synergy between design ingenuity and practical engineering, culminating in a robust and agile platform poised to excel in competitive arenas. A visual representation of our design and 3D model will further elucidate the intricacies of our mechanical craftsmanship, highlighting the attention to detail and precision inherent in our approach. [1]



Central to our robot's agility and versatility are the 12-volt DC motors paired with Mecanum wheels, embodying the essence of omnidirectional mobility. These meticulously chosen components empower our robot to navigate seamlessly in any direction within a two-dimensional space while enabling precise rotational movement. The ingenious design of Mecanum wheels, featuring a series of rollers set at strategic angles, facilitates omnidirectional motion by allowing each wheel to independently drive and steer.[9] This holistic approach to locomotion not only enhances maneuverability but also enables our robot to traverse complex terrains and navigate intricate environments with unparalleled ease. The integration of these cutting-edge technologies exemplifies our commitment to pushing the boundaries of robotic capabilities, ultimately positioning our team for success in competitive endeavors. [6]

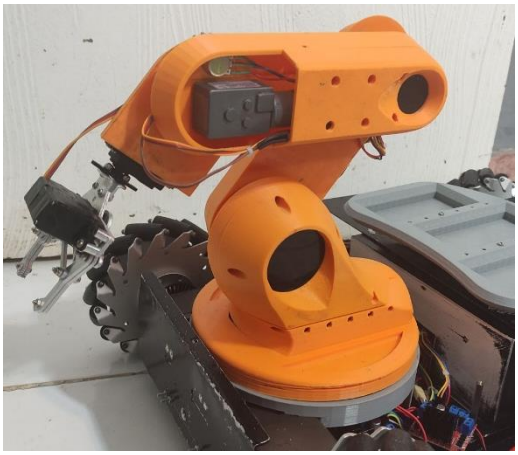


Our robotic arm, meticulously crafted using SolidWorks software, stands as a testament to precision engineering and strategic design. With six degrees of freedom, it boasts unparalleled flexibility and agility, capable of reaching any object within a radius of 70 centimeters. The first joint, facilitating the rotation of the entire arm around itself, employs a stepper motor, while subsequent joints are powered by DC motors equipped with feedback systems for enhanced control and accuracy. To orchestrate seamless movement and coordination, each joint is governed by a PID controller, ensuring precise positioning in accordance with input from high-level software. At the extremity, our gripper mechanism utilizes servo motors, providing dexterity and adaptability for handling various objects with finesse. This culmination of advanced mechanics and intelligent control systems underscores our dedication to engineering excellence and innovation in robotic design.

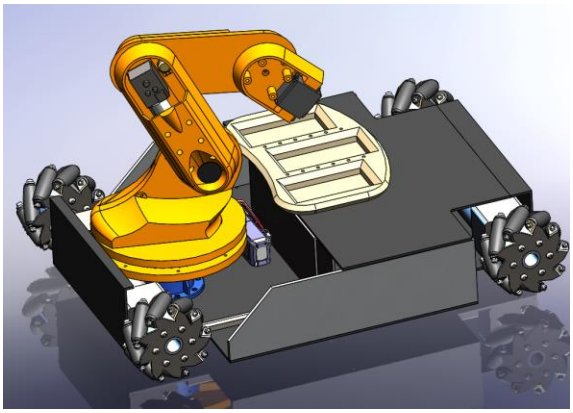


From initial design to physical realization, our robotic arm epitomizes precision and innovation. Conceptualized in SolidWorks, each component was meticulously crafted to exacting standards. Through collaborative effort and unwavering dedication, digital designs were transformed into tangible reality. The result? A six-degrees-of-freedom arm, engineered for precision and agility within a 70-centimeter radius. This journey from

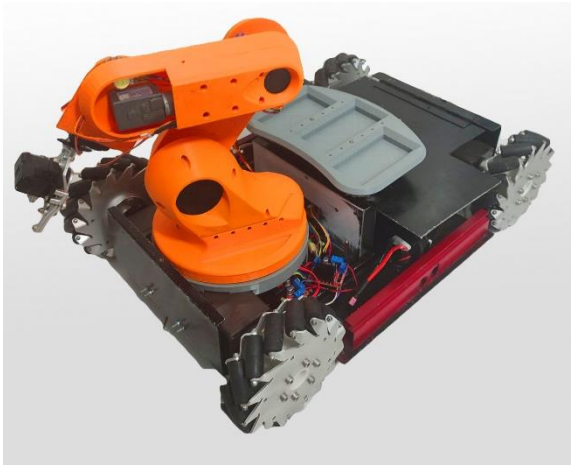
conception to creation underscores our commitment to excellence in robotics. [2]



Adjacent to the robotic arm lies a meticulously designed loading plate, strategically crafted to facilitate seamless object manipulation in alignment with competition regulations. Featuring three square-shaped compartments, each tailored to accommodate specific objects, the loading plate adheres to precise dimensions mandated by competition guidelines. These compartments serve as designated stations for loading and unloading objects, ensuring efficient and organized task execution. The thoughtful integration of the loading plate enhances the robot's versatility and adaptability, underscoring our meticulous attention to detail and commitment to compliance with competition standards.



With the culmination of precise design, meticulous planning, and skilled craftsmanship, our team brings forth the tangible embodiment of innovation: the fully realized robotic system. From conceptualization to execution, every aspect of its construction reflects our dedication to engineering excellence. As we unveil the culmination of countless hours of labor and ingenuity, the crafted robot stands as a testament to our team's unwavering commitment to pushing the boundaries of robotics. This pivotal moment marks not only the fruition of our collective efforts but also the beginning of a new chapter in our journey toward technological advancement and competitive success.



Hardware Integration

Every component of our robotic system boasts its own meticulously designed hardware, meticulously engineered to fulfill specific functions seamlessly. From the movement system comprising motor drivers, accelerometer sensors, and motor encoders for speed feedback, to the intricate control mechanisms governing the robotic arm's precision, each element embodies precision and reliability. What truly sets our system apart is its seamless integration facilitated by wireless connectivity. Utilizing WiFi modules, each hardware unit communicates effortlessly with the main computer, ensuring real-time data exchange and synchronized operation. This interconnectedness not only enhances the robot's responsiveness but also streamlines its functionality, underscoring our commitment to engineering excellence in every aspect of our design. The PCB is

designed in Altium Designer software and then printed and the components are soldered using hot air stations.

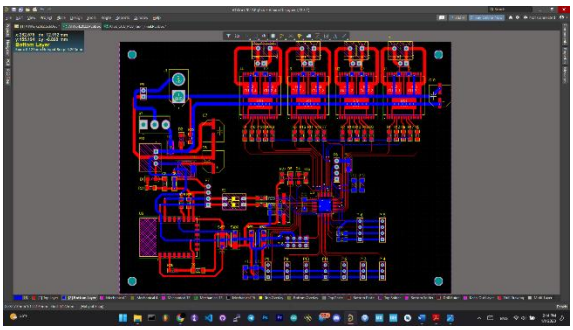
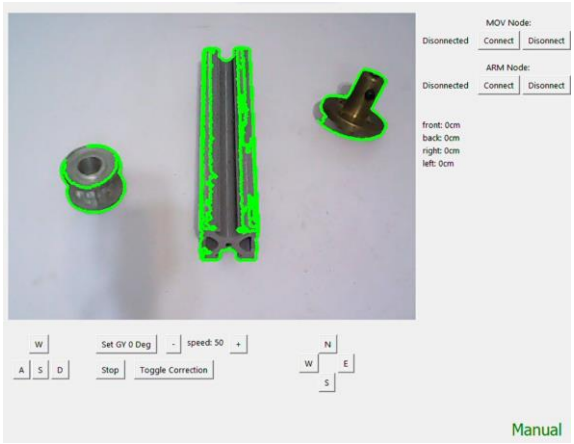


Figure 5 Hardware Design with Altium Designer

Within the robotic arm subsystem, a sophisticated array of hardware components ensures precise and fluid motion. This includes step motor drivers and DC motor drivers, meticulously calibrated to synchronize the movement of each joint. Complementing these drivers are feedback sensors, primarily potentiometers, strategically positioned to detect the angle of each joint accurately. This intricate feedback mechanism enables the arm to maintain precise positioning and execute complex maneuvers with finesse. Through the seamless integration of these hardware elements, our robotic arm embodies a harmonious fusion of mechanical precision and electronic sophistication, poised to meet the demands of intricate tasks with unwavering reliability and efficiency.

Vision System

In our pursuit of advanced perception capabilities, our current vision system harnesses the power of OpenCV in Python, providing robust object detection and recognition functionalities. However, as we continue to evolve, our sights are set on integrating YOLO v8, anticipating heightened efficiency and accuracy in object identification. Our algorithmic approach begins with segmenting objects based on color ranges, followed by contour detection within the camera's image frame. Through meticulous labeling, each object is identified by its name, culminating in a comprehensive list of objects within the robot's visual field. Leveraging this data, our AI application autonomously determines the optimal object for manipulation, transmitting precise positional and orientational commands to the robotic arm. This streamlined process epitomizes our commitment to harnessing cutting-edge technology to enhance the robot's perception and decision-making capabilities, paving the way for seamless interaction with its environment. [4]



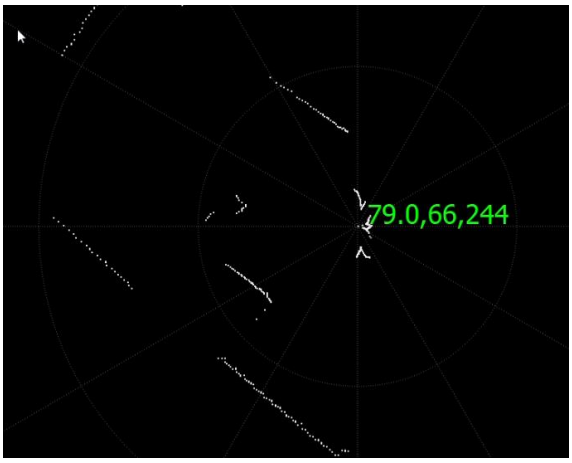
The figure above illustrates the processed camera frame with delineated lines around each object on the table.

For the transition to YOLO v8, we've curated an extensive dataset for each object, capturing images and meticulously labeling them for identification. [5] This dataset serves as input for a machine learning algorithm trained to discern subtle differences between objects, ensuring enhanced object detection accuracy.[10]

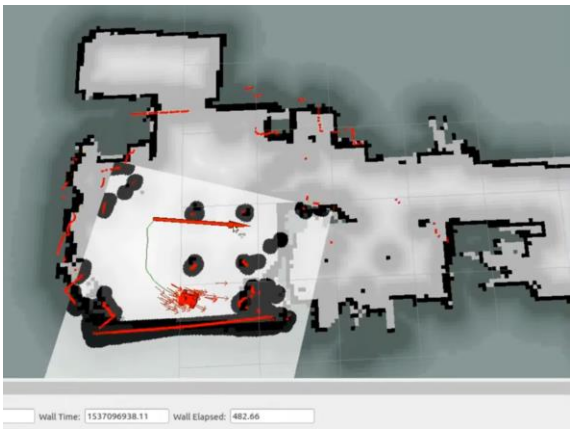
Navigation

In our navigation framework, we rely on the robust capabilities of the ROS (Robot Operating System) [3] ecosystem. A pivotal component in our navigation system is the LD19 LiDAR sensor by "LDRobot," which diligently scans the two-dimensional space surrounding the robot.[7] This scan data is then processed by our program, facilitating the creation of a dynamic map through localization of the robot's position and

merging of all scanned data over the course of the test run. Leveraging simultaneous localization and mapping (SLAM) algorithms, we can seamlessly guide the robot to designated positions on the map while actively avoiding collisions with obstacles, ensuring safe and efficient navigation in diverse environments.[8]



The figure below showcases the Rvis output, presenting the merged map generated by processing LiDAR data, illustrating the comprehensive spatial understanding achieved through the integration of scanned information.



Conclusion

In conclusion, our robotic team, S.R.B from Tehran Azad University, has endeavored to push the boundaries of innovation and excellence in robotic design. Through meticulous mechanical engineering, sophisticated hardware integration, and advanced software development, we've crafted a formidable industrial robot capable of excelling in competitive environments. Our commitment to continuous improvement is evident in our adoption of cutting-edge technologies such as YOLO v8 for enhanced object recognition and ROS for seamless navigation. As we navigate the ever-evolving landscape of robotics, we remain dedicated to driving progress, pushing limits, and making impactful contributions to the field.

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