DESIGN AND DEVELOPMENT OS SCALABLE AND MODULAR ALL TERRAIN UNMANNED VEHICLE(ATUV)

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College : *Sahyadri College of Engineering & Management, Mangaluru*
Branch : *Department of Robotics & Automation*
Guide(s) : *Mr. Vinay B.U.*
Student(s) : *Mr. Amog*
Ms. Rithuparna K.S
Ms. Sahana Priya I P
Ms. Sanjana

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Introduction:

The Scalable and Modular All-Terrain Unmanned Vehicle (ATUV) is developed as an intelligent and robust robotic platform capable of operating independently in challenging outdoor environments. The system is designed to navigate through difficult landscapes and generate detailed maps without human intervention. While many traditional unmanned vehicles struggle on surfaces such as rocky hills, forest paths, sandy deserts or disaster-affected regions, the ATUV is specifically built to manage such conditions with far greater stability and confidence. A defining strength of the platform is its ability to adapt to a variety of terrains, making it a dependable choice wherever ground conditions are unpredictable.

The origins of unmanned ground vehicles (UGVs) can be traced back to the mid-twentieth century when they were first introduced for military surveillance and hazardous material handling. These early systems were primarily remote-controlled and were often constrained by communication limitations and terrain challenges. With advancements in computing power, sensor technology and intelligent control systems, modern UGVs have evolved into highly capable autonomous machines. The ATUV draws on this technological progression by integrating LiDAR-based mapping, adaptive control strategies and a modular mechanical structure to meet the demands of real-world environments.

One of the most distinctive features of the ATUV is its modular and scalable architecture. This design approach enables users to modify or expand the system based on the specific requirements of a mission. Components such as advanced sensors, upgraded navigation units or additional mechanical attachments can be incorporated with minimal changes to the core structure. This adaptability makes the ATUV suitable for diverse applications including search and rescue operations, environmental monitoring, industrial inspection and field exploration.

Figure 1: ATUV

Objectives:

1. To design and build a scalable and modular All-Terrain Unmanned Vehicle (ATUV) capable of adapting to various mission requirements and terrains.
2. To integrate mapping systems for effective movement and environmental awareness in challenging areas.

Methodology:

The development of the All-Terrain UMV follows a structured process that begins with the conceptual design phase during which the overall framework, mobility configuration and appropriate materials are selected. Once the design is finalized, the next stage involves hardware integration where motors, sensors and navigation components are assembled to enable autonomous functionality. A prototype is then constructed and tested across different terrain conditions to assess its movement capability, obstacle-handling performance and adaptability to uneven surfaces. Insights from these tests are used to refine the system by improving stability, enhancing navigation accuracy and increasing overall operational efficiency.

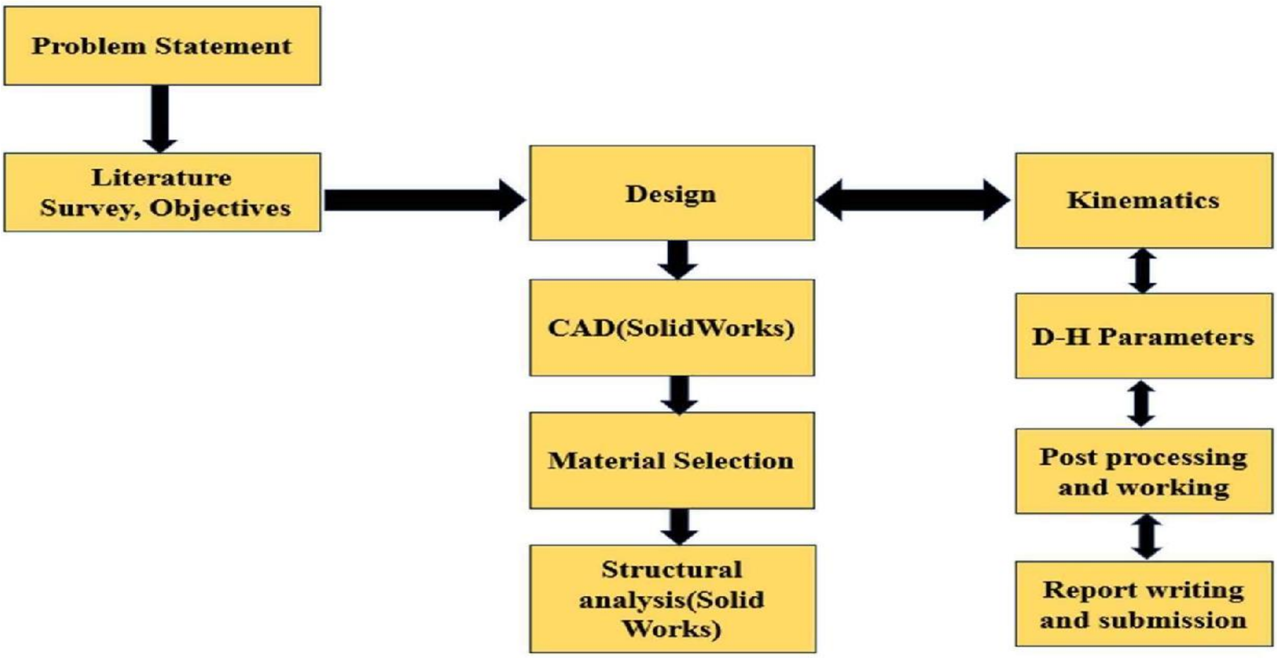

Figure 8: Methodology

This methodology outlines the systematic approach followed in the design and development of the project:

1. The process begins with the problem statement, where the key objectives and challenges of the system are clearly defined. This is followed by a literature survey and objective setting, where existing research and technologies are analyzed to understand current solutions and identify gaps.
2. Based on these insights, the design phase is initiated, forming the core of the methodology. The design is developed and refined using CAD tools (SolidWorks), allowing precise modeling of the system components. Once the model is created, material selection is carried out to ensure the structure meets requirements such as strength, weight, and durability. This is followed by structural analysis, also performed in SolidWorks, to verify that the design can withstand expected loads and operating conditions.
3. Parallel to the design process, kinematic analysis is conducted to study motion and mechanical behavior. This involves the use of Denavit–Hartenberg (D-H) parameters to mathematically model joint and link movements. The results are then applied in post-processing and working, where the system is evaluated and refined for practical implementation.
4. The methodology concludes with report writing and submission, documenting all stages of design, analysis, and outcomes.

Result and Conclusion:

1. The physical assembly of the All-Terrain Unmanned Vehicle (ATUV) successfully transformed the computer-aided design into a fully functional prototype. The chassis, fabricated using transparent acrylic sheets, achieved an optimal balance between rigidity, low weight, and ease of manufacturing. Precision cutting ensured that all components matched the CAD dimensions, eliminating the need for post-fabrication adjustments and resulting in high dimensional accuracy. The dual-track system was carefully implemented using aligned mounts and reference jigs, enabling smooth motion with minimal side play. The structure demonstrated strong resistance to bending and twisting forces, supporting both static and dynamic loads encountered during operation. Internal mounts for electronics, battery, and processing units were strategically positioned to maintain proper weight distribution, contributing to overall stability. Manual testing confirmed correct track tension and sprocket alignment, preventing derailment and validating the robustness of the mechanical design.
2. The ATUV's mobility system is powered by four RPM geared DC motors, arranged across the left and right tracks to provide distributed traction. These motors were selected for their balance of torque, speed, and durability, and were securely mounted using vibration-resistant fasteners. Initial no-load testing confirmed uniform motor performance, while load testing demonstrated minimal speed variation, ensuring even torque distribution and reducing mechanical stress. This multi-motor configuration enabled the vehicle to generate sufficient tractive force for navigating uneven terrain. During testing, the ATUV successfully traversed obstacles, gravel, and grassy surfaces without significant slippage or instability. The integration of

motors with the track system functioned efficiently during both straight and turning maneuvers. Overall, the drive system delivered reliable and consistent performance, meeting the operational requirements of an all-terrain robotic platform.

3. The power and control system of the ATUV was centered around a 12V Li-Po battery and a Raspberry Pi-based processing unit, ensuring efficient energy delivery and computational capability. The battery was centrally positioned to maintain balance, while pre-integration testing confirmed stable voltage output during operation. All electrical components, including motor drivers, camera, and LiDAR sensor, were integrated with careful wiring management to prevent interference and enhance durability. The Raspberry Pi effectively handled sensor data processing, video streaming, and communication tasks without performance issues. Virtual validation using a URDF model in ROS confirmed accurate kinematic behavior, proper alignment, and collision-free operation. Additionally, a web-based dashboard enabled real-time video streaming with minimal delay, providing clear visibility for remote monitoring. Together, the electrical and software systems demonstrated reliable performance, supporting both manual and semi-autonomous functionalities.

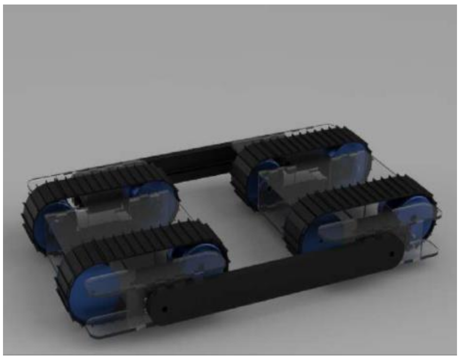

Figure 1: ATUV

Figure 1: Rendering

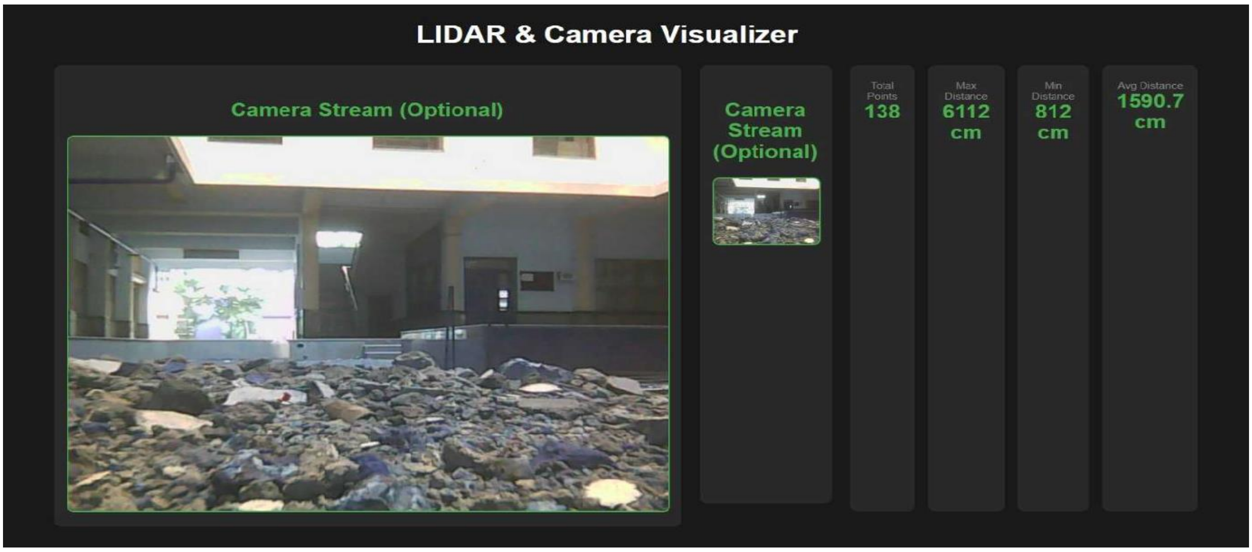

Figure 1: Lidar & Camera Visualization

References:

1. [1] L. Bruzzone, S. E. Nodehi, and P. Fanghella, "Tracked Locomotion Systems for Ground Mobile Robots: A Review," Machines, vol. 10, no. 8, p. 648, Aug. 2022.
2. [2] W. Guo, J. Qiu, X. Xu, and J. Wu, "TALBOT: A Track-Leg Transformable Robot," Sensors, vol. 22, no. 4, p. 1470, Feb. 2022.
3. [3] C. Jin, C. Wang, K. Tang, C. Jiao, and Y. Wang, "Research and Application of a Coupled Wheel-Track Off-Road Robot Based on Separate Track Structure," Advances in Mechanical Engineering, vol. 16, no. 1, Jan. 2024.
4. [4] L.-W. Lee, Y.-C. Cheng, rP.-J. Chen, and T.-H. Lin, "Design and Implementation of Transformable Tracked Robots," International Journal of iRobotics, vol. 6, no. 1, 2023
5. .[5] A. Kabanov and V. Kramar, "Modeling and Control of Tracked Mobile Robot," presented at the 50th Anniversary Technical University of Varna, 2012.
6. [6] Z. Sun et al., "BIT-DMR: A Humanoid Dual-Arm Mobile Robot for Complex Rescue Operations," IEEE Robotics and Automation Letters, vol. 7, no. 3, pp. 802– 809, Jul. 2022.
7. [7] S. Hong, M. Wu, J. Xiao, X. Xu, and H. Lu, "Kylin: A Transformable Track- Wheel Hybrid Robot," presented at the International Conference on Advanced Mechatronic Systems (ICAMechS), Zhengzhou, China, Aug. 2018.
8. [8] T. Sasaki and T. Fujita, "Gap Traversing Motion via a Hexapod Tracked Mobile Robot Based on Gap Width Detection," Journal of Robotics and Mechatronics, vol. 33, no. 4, pp. 665–675, Aug. 2021.
9. [9] S. You, H. Zhu, M. Li, and Y. Li, "A Review of Visual Trackers and Analysis of its Application to Mobile Robot," arXiv preprint arXiv:1910.09761, Oct. 2019.
10. [10] J. Weng, Z. Wu, Y. Cho, and S. Lee, "Locomotion and Motion Control Design of a Hybrid Mobile Robot with Wheels and Tracks," Journal of Mechanical Science and Technology, vol. 29, no. 12, pp. 4945–4955, Dec. 2015.

Future Scope:

The future scope of this project includes:

1. Incorporate advanced positioning systems combined with connected technologies to enable smarter remote operation and data-driven insights.
2. Introduce intelligent algorithms to improve navigation, adaptability, and overall system responsiveness.
3. Strengthen system robustness to ensure consistent performance under demanding and variable operating conditions.
4. Expand the platform’s capability to function efficiently in larger and more complex environments with multiple control access points.
5. Optimize energy usage and refine power systems to support longer operational cycles and improved sustainability.
6. Design a more user-friendly interface with enhanced accessibility features and customizable controls for better user experience.
7. Perform comprehensive field trials in diverse environments to validate reliability, safety, and practical effectiveness.