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Spidy: Hexapod Robot

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Abstract
This paper presents the details about the design of a hexapod robot powered using ESP32 which has the ability to operate and work in areas containing humans that are hard to reach. The robot has as well equipped with on board sensors and cameras that allow it to perform object searching by itself. Subsequently, it uses algorithms trained with machine learning to sort and recognize the targets. The robotic structure consists of six legs, allowing the robot to perform movement on different types of surfaces while keeping its stability intact. Once the object is found the robot uses an arm installed onboard to grab and secure the object, which makes it useful for various applications such as operations in search and rescue missions, environmental studies, and inspection purposes in factories. The system based on ESP32 provides the capabilities of processing the information in real time and moving and controlling the hexapod robot and its parts from a distance which makes the hexapod suitable for undergoing tasks which require accuracy and which are not able to be carried out by a human being.

Keywords: Firefighting Robots, Autonomous Navigation, Fire Detection, Extinguishing Technology, Robotics, Safety Systems, Artificial Intelligence, Real-Time Operations.

1. INTRODUCTION

The feature of this leg mechanism constructed for this robot is that it can adjust its length, angle and extent of stiffness in a dynamic manner, which allows the robot to master many kinds of different kinds of terrain. These changes allow the robot to adapt its legs to the ground even if the ground is rocky or sloped or there are irregularities on it instantaneously. For instance, on uneven rocky grounds, the mechanism is able to retract the legs in an attempt to increase stiffness in order to achieve a certain level of balance, conversely, if the ground is soft, they may extend outward and the angles may shift in order to maintain stability and succeed in passage. Such capability as adaptability in real-time greatly increases the retention of the robot and averts the risk of it falling or slipping and therefore greatly increasing the possibility of it being able to balance itself without falling on the ever-changing workspace. Therefore, such system is well suited for operations that require traversing through colonies or surface features such as rescues, farmlands or planetary bodies for instance Mars for example. In order to make mobility easier and more advanced, the robot employs a fully integrated suite of sensors which produce terrain maps while identifying and detecting obstacles and also aid in moving objects. With these sensors, the robot will be able to see where it is and what surrounds it, and will produce detailed terrain models that will help it in deciding the best and most optimal routes to take while avoiding physical structures. The sensors also allow for a better grip of objects and thus better handling of objects making it easy to manipulate them. In addition to these, the

robot has a sufficient communication network that provides the chances of working far away from the robot using remote monitoring and control Possibilities. The system also enables real-time patching and updates of the software meaning that if any problem were to occur, it would be easy to fix and the robot wouldn't have to stop working even if it was in a remote or hard to reach place. The combination of mobility, awareness and communication puts the robot at a higher rank when looking to use it in autonomous and semi-autonomous tasks that require the robot to operate in tough conditions.

2. LITERATURE REVIEW

Chuanqi Zheng, Siddharth Sane, Kangneoung Lee, Vishnu Kalyanram [1]: The robot α-WaLTR belongs to a new generation of mobile adaptative robots by this which aims at achieving a combination of the advantages of the legs and the wheels. Transformable wheels coupled with spring suspension which are able to reduce vibrations, enhancing robustness while crossing rough or even difficult terrains. The design is specifically aimed to ensure efficient obstacle climbing and traversing through complex terrains or stair systems become a hassle-free task. The robot has been tested through simulations and actual physical experimentation has been able to demonstrate autonomous spatial perception of stairs, and followed by climbing these stairs. These features and performance clearly indicate the areas where α-WaLTR can be potentially useful such as burdened mobility in disaster areas, urban constructions or industrial sites where the mobility over the boundaries and rough structures need to be applied for executing the goals set by the system**.**

Mariano Garduño-Aparicio, Juvenal Rodríguez-Reséndiz, Gonzalo Macias-Bobadilla [2]: The paper presents a robot prototype designed for an undergraduate laboratory program focused on teaching embedded systems and robotics, in accordance with ABET accreditation criteria. This is an emphasis on interdisciplinary learning, fostering the development of technical skills and the application of theoretical knowledge to practical, real-world problem-solving tasks. A digital electronics course at Universidad Autónoma de Querétaro, Mexico, exemplifies this initiative. Results showed that the prototype of the robot significantly enhanced the students' learning experiences as demonstrated by positive feed backs and better academic outputs. ABET criteria analysis also indicates that the project offers an integration of hands-on activities with theory teaching, benefiting students on both embedded systems and robotics.

Rabia Jafri, Rodrigo Louzada Campos, Syed Abid Ali, and Hamid R. Arabni [3]: The paper introduces an innovative obstacle detection system designed for visually impaired users, utilizing both visual and infrared sensor data from the Google Project Tango Tablet Development Kit. The system tracks the user's motion and orientation in 3D space and reconstructs the surrounding environment using the Unity engine. By associating a Unity collider with the user, it detects interactions with obstacles in the reconstructed environment and gives audio warnings of potential dangers to alert users. Empirical testing has shown promising results, indicating the system's effectiveness and potential for further development to improve navigation assistance for visually impaired individuals.

Yan Dong, Haotian Yang, Shanliang Liu, Guangshuai Gao, Chunlei Li [4]: The paper introduces a one-stage object detection network for optical remote sensing images, addressing complex backgrounds and weak object visibility. Some of the key innovations include the localization attention mechanism that is integrated into deep feature maps and the small object compensation strategy that enhances the detection of weak objects through fusion operations. The proposed background separation strategy also effectively distinguishes foreground objects from background noise. The model shows strong performance across three public datasets, obtaining mean Average Precision (mAP) scores of 94.2% on NWPU VHR10, 70.7

% on DIOR and 80.5% on the DOTA dataset.

Shujie Ji, Wu Wei, Xiongding Liu, Junqi Wu[5]: This paper talks about making hexapod robots more stable on rough terrains using a new control method. The method combines reinforcement learning with foot impedance control and a special reward system to improve how the robot walks. By planning the robot's steps and using feedback from its feet and body position, the robot can optimize its movements automatically. The approach uses a model to transform the walking problem into a sequence decision-making issue, which can be tackled using a Markov decision process. The reward system helps the robot adapt its gait, making it more stable and efficient in moving over rough ground. This method also reduces the need for complex internal sensors, making the robot more practical. Simulation tests show that this new method performs much better than older techniques, especially in terms of stability and distance traveled.

Jingang Du; Hongde Qin; Zhongchao Deng; Zhongben Zhu; Xiaojian Cao; Xiaokai Mu[6] : This paper focuses on designing an amphibious crab-like robot that can navigate tough environments like the seabed and narrow spaces near walls. It delves into essential design aspects, such as the robot's body shape, leg proportions, and the ratio of body width to overall width, which are crucial for its efficient operation in these challenging areas. The researchers have developed two main leg postures to improve the robot's performance: a walking posture that helps it sense and navigate its surroundings more effectively, and a standing posture that ensures high stability. They also optimized the foot landing points in the surf zone, allowing the robot to move smoothly and securely on uneven, dynamic surfaces. These design enhancements aim to create a versatile and highly functional robot capable of performing complex tasks in harsh aquatic environments.

3. PAPER COMPARISON

Paper Title	Authors	Comparative Study
Adaptive wheel and leg to transformable robot for versatile multi terrain locomotion	**Chuanqi Zheng, Siddharth Sane, Kangneoung Lee, Vishnu Kalyanram**	In this paper a new generation robot that is adaptive that combines the advantages of legs and wheels, featuring transformable wheels with spring suspension for enhanced robustness on rough terrains. Designed to efficiently climb obstacles and navigate complex terrains, including stairs, it has demonstrated autonomous spatial perception and stair-climbing abilities in both simulations and physical tests. α-WaLTR's capabilities make it potentially useful in disaster areas, urban construction, and industrial sites where navigating boundaries and rough structures is essential.

A Multidisciplinary Industrial Robot Approach for Teaching Mechatronics	**Mariano Garduño-Aparicio, Juvenal Rodríguez-Reséndiz, Gonzalo Macias-Bobadilla**	The paper introduces a robot prototype used in an undergraduate laboratory program to teach embedded systems and robotics, meeting ABET accreditation standards. This initiative, exemplified by a digital electronics course at Universidad Autónoma de Querétaro, Mexico, emphasizes interdisciplinary learning and practical problem-solving. The results showed significant enhancements in students' learning experiences and academic performance, with the ABET criteria analysis highlighting the project's effective integration of hands-on activities and theoretical teaching.
Visual and Infrared Sensor Data-Based Obstacle Detection for the Visually Impaired Using the Google Project Tango Tablet Development Kit and the Unity Engine	**Rabia Jafri, Rodrigo Louzada Campos, Syed Abid Ali, and Hamid R. Arabni**	The paper presents a novel obstacle detection system for visually impaired users, leveraging visual and infrared sensor data from the Google Project Tango Tablet to track motion and reconstruct the environment in 3D using the Unity engine. By associating a Unity collider with the user, the system detects obstacle interactions and provides audio warnings of potential dangers. Empirical tests have shown promising results, highlighting the system's effectiveness and potential for enhancing navigation assistance for visually impaired individuals.
Optical Remote Sensing Object Detection Based on Background Separation and	**Yan Dong, Haotian Yang, Shanliang Liu, Guangshuai Gao, Chunlei Li**	The paper introduces a one-stage object detection network for optical remote sensing images, featuring innovations like a

Small Object Compensation Strategy		localization attention mechanism and a small object compensation strategy to enhance detection of weak objects. It also employs a background separation strategy to effectively distinguish foreground objects from background noise. The model demonstrates strong performance with mean Average Precision (mAP) scores of 94.2% on NWPU VHR10, 70.7% on DIOR, and 80.5% on the DOTA dataset.
Optimization Control of Attitude Stability for Hexapod Robots Based on Reinforcement Learning	**Shujie Ji, Wu Wei, Xiongding Liu, Junqi Wu**	This paper introduces a new control method for enhancing the stability of hexapod robots on rough terrains by combining reinforcement learning with foot impedance control and a specialized reward system. By optimizing the robot's steps through feedback from its feet and body position, the approach transforms the walking problem into a sequence decision-making issue, addressed via a Markov decision process. Simulation tests demonstrate that this method significantly outperforms older techniques in terms of stability and distance traveled, while also reducing the need for complex internal sensors.
Structural and Kinematic Analysis of an Amphibious Crab-Like Robot for Nearshore Environmental Applications	**Jingang Du; Hongde Qin; Zhongchao Deng; Zhongben Zhu; Xiaojian Cao; Xiaokai Mu**	This paper details the design of an amphibious crab-like robot optimized for tough environments like seabeds and narrow spaces near walls. Key design aspects include the robot's body shape, leg proportions, and body-to-width ratio, enhancing its performance and stability. The researchers developed walking

		and standing leg postures, and optimized foot landing points for secure movement on uneven surfaces, making the robot versatile for complex tasks in harsh aquatic environments.

4. CONCLUSION

Hexapod robots, inspired by insect locomotion, are one of the most important advances in robotics, offering stability and versatility on diverse terrains unmatched by any other type of robot. Their six-legged configuration allows for complex movement patterns, enabling these robots to navigate environments that would be difficult or impossible for wheeled or bipedal robots. From search and rescue missions in disaster-stricken areas to the exploration of extraterrestrial surfaces, hexapod robots have applications in a wide range of fields. Their ability to adapt to uneven and unpredictable surfaces makes them invaluable for tasks that require robust and reliable mobility. Moreover, the evolution of hexapod robots continues to expand the possibilities of what can be achieved with robotics. Improvements in sensor technology, artificial intelligence, and material science are making hexapod robots more capable and autonomous. The integration of advanced navigation systems, developed on the basis of machine learning algorithms, allows hexapod robots to make decisions and avoid obstacles in real time. As research continues to advance, hexapod robots will become even more integrated into a variety of sectors, transforming industries and enhancing human capabilities in ways never thought possible. The future of hexapod robots promises exciting developments and transformative impacts on both technology and society.

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