Grenze International Journal of Engineering and Technology, June Issue

Smart-Walker: A Two-Legged Robot with AI Superpowers

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***Abstract*— The paper proposes the development and construction of a bipedal walking mechanism with a focus on planar locomotion, incorporating advanced Artificial Intelligence (AI) concepts. The two-legged walking robot employs Machine Learning (ML) for Gait Optimization to adapt its walking pattern based on factors like speed, terrain and energy efficiency. Integration of multiple sensors with AI for improved balance, utilizing predictive analytics for obstacle avoidance and collision prevention. The study includes a GUI developed using Python to facilitate user interaction. A comprehensive literature survey on obstacle avoidance contributes to the understanding of existing approaches. In this paper, we explore the intersection of robotics and AI, discussing key technologies, challenges, and potential future developments. ML algorithms and computer vision play pivotal roles in enabling robots to acquire and apply knowledge etc..**

***Index Terms*— Two-legged walking robot, Bipedal, ML, AI, Robotics, GUI, Python, Sensors.**

I. Introduction

The fields of robotics and AI have witnessed significant advancements in recent years, revolutionizing various aspects of human life and industry. Robotics, characterized by the design and construction of intelligent machines capable of performing tasks autonomously or with minimal human intervention, has found applications in diverse domains such as manufacturing, healthcare, and exploration. The field of robotics continues to evolve, with ongoing advancements in AI contributing to more sophisticated and capable robotic systems. Emergence of the two-legged robots have represented a leap forward in the field of robotics, mimicking the human gait and balance. These robots, often equipped with advanced sensors and actuators, strive to emulate the intricate movements of human legs. This design not only enhances versatility in navigating complex environments but also opens up a realm of possibilities for applications ranging from disaster response to household helping. In addition to this, AI is used to increase the capabilities of these tools so that they can perform increasingly complex tasks, from soldering and assembling electronic components, to complex surgery with greater precision and control, and less invasive procedures for the patient. Obstacle detection and avoidance has been the primary and most important

Grenze ID: 01.GIJET.10.2.560

feature of any robot. This capability is particularly crucial in dynamic and unpredictable environments where obstacles can appear unexpectedly. Whether it's a mobile robot navigating through a cluttered space or an industrial robot working alongside human operators, obstacle detection and avoidance is fundamental for efficient operation [1][2].

This paper explores the convergence of AI and robotics, unveiling a transformative journey in the development of a two-legged walking mechanism. Rooted in AI concepts, our approach elevates the robot's stability and adaptability. Employing ML algorithms, the robot optimizes its gait dynamically based on speed, terrain, and energy efficiency. Learning paradigms enable the robot to adapt its walking pattern seamlessly. Sensor Fusion integrates accelerometers, gyroscopes, and vision sensors, refining the robot's balance across diverse scenarios. Predictive Analytics for Obstacle Avoidance augments navigation, foreseeing obstacles and steering clear and a user-friendly GUI for the demonstration of human-robot interaction. Through this exploration encompassing literature review, methodology, block diagrams, and outcomes, this report encapsulates the pioneering fusion of AI and robotics, envisaging a future where intelligent, adaptable two-legged robots navigate the world with unprecedented grace and also the integration of AI with robots enables them to perform a wide range of tasks more efficiently and adapt to dynamic environments [3][4].

II. Review Of Literatures

Dynamic modeling and walk simulation for a new four-degree-of-freedom parallelogram bipedal robot with sideways stability control - The paper introduces a minimalist mathematical model for a two-leg walking robot with a focus on efficient sensing and balancing. It proposes a novel semi-rigid ankle for precise instability measurement and a unique hip-mass carrying method, implementing control algorithms through four DC motors for continuous stability during forward motion, validated using MATLAB Simulink [5][6].

Master-Slave Bipedal Walking and Semi-Automatic Standing Up of Humanoid Robots - The paper introduces an approach for bipedal walking and standing in master-slave humanoid robots using affordable 3-DoF haptic master devices. It enables users to control leg and arm movements, ensuring stable locomotion and facilitating standing up in case of a fall with a semi-automatic motion planner [7][8].

Body Trajectory Generation Using Quadratic Programming in Bipedal Robots - The paper innovates preview control for bipedal robots, shifting from traditional trajectory optimization to a quadruped-inspired approach. Prioritizing minimal body trajectory acceleration enhances real-time stability, reduces speed changes, and shortens computation time while maintaining ZMP constraints within a small support polygon [9][10].

Research on Automatic Navigation of a Bipedal Humanoid Robot - This research presents an automated navigation system for a bipedal humanoid robot, employing SLAM for 3D mapping and utilizing Dijkstra's algorithm and the Dynamics Window Approach for global and local path planning, respectively. The system's effectiveness is verified through simulation experiments [11][12].

Walking problem of bipedal humanoid robot: comparison between model-based and learning-based method - The paper explores stable bipedal walking in humanoid robots amidst external disturbances, comparing model-based and learning-based approaches.It concludes that the choice depends on specific cases, with the model-based method suitable in some instances, and the learning-based method proving more effective in others [13][14].

Innovative Design and Simulation of a Jumping Bipedal Robot with Leg-Wheel Transformation - The paper presents Lool, a versatile bipedal-wheeled robot seamlessly transitioning between wheel, creeping, and jumping modes with four motors. Its compact design, simple controls, and robust movement allow for effective navigation in dynamic environments, as demonstrated through detailed mechanical analysis, kinematics, and simulation experiments [15][16].

Modeling and MPC-based balance control for a wheeled bipedal robot - The paper explores recent advancements in wheeled bipedal robots, emphasizing their flexibility and performance in navigating diverse terrains. It addresses the challenge of maintaining balance on inclined surfaces by developing dynamic equations and employing a model predictive controller with input constraints and an extended state observer. Simulations demonstrate the proposed control method's effectiveness in preserving balance and adapting to external interference [17][18].

Design and Analysis of Feedback Controller for Underactuated 3D Bipedal Robots During the Single Support Phase - The paper focuses on underactuated 3D bipedal robots, addressing the design and analysis of a feedback controller for the single support phase. It provides a dynamic model, introduces a finite-time feedback controller, and demonstrates its stability through Lyapunov analysis. Numerical simulations show that the proposed controller achieves faster convergence compared to a classical PD feedback controller [19].

Dynamic Height Balance Control for Bipedal Wheeled Robot Based on ROS-Gazebo - The paper tackles speed, flexibility, and human affinity in mobile robots, spotlighting the SR600 bipedal wheeled robot. It introduces a height-changing method for dynamic balance, demonstrated in ROS Gazebo, showcasing advancements in human-like bipedal legged-wheeled robots for complex living environments through a simple prototype experiment [20][21].
Mechanical Design of Robot Lower Body based on Four-Bar Linkage Structure for Energy Efficient Bipedal Walking - This paper proposes a six-degree-of-freedom robot leg using a four-bar linkage mechanism to enhance energy efficiency. Placing actuators on the hip reduces mass and inertia, aiming to design a lower body for a bipedal walking robot with optimal dimensions. Simulation results guide the generation of a walking pattern, informing the detailed production of the actual robot lower body [22][23].
The Design of Bionic Leg and Motion Simulation on Passive Dynamic Bipedal Robot - The paper introduces a passive-dynamic bipedal robot with improved walking stability through the implementation of a four-linkage multiaxial bionic knee. A 3D dynamic simulation in MSC.ADAMS showcases the robot's smooth walking on a slope, providing insights into human walking dynamics and offering clues for enhancing the dynamic performance of bipedal robots. [24]
Bipedal robot walking strategy on inclined surfaces using position and orientation based inverse kinematics algorithm - This paper presents a strategy for bipedal robot walking on inclined surfaces using a position and orientation-based inverse kinematics algorithm. The approach systematically introduces inverse kinematics methodology, embedding positions and orientations into calculations. The proposed method utilizes a 3-D dynamics simulator for simulation and validation, distributing angles caused by inclined surfaces to appropriate robot joints, avoiding sole control at ankle joints [25].

III. BLOCK-DIAGRAM

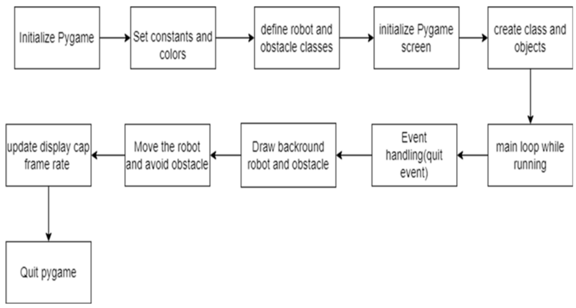

Figure 1. Block-Diagram

The block diagram shown in the Fig. 1 depicts the steps involved in creating a two-legged walking robot using the Pygame library file, a cross-platform set of Python modules designed for showing interactive features. The first step is to initialize Pygame and create a screen to display the robot. Next, you need to define the robot and obstacle classes and set constants and colors for the robot and its environment. Once the basic elements are in place, the robot starts to move in the background. You can use the event handling block to check for user input, such as keyboard presses, and adjust the robot's movement accordingly. When an obstacle is encountered, it diverts its path and continues moving in the directed trajectory. The main loop block ensures that the program continues to run until the user quits. Within the main loop, you should update the display cap and frame rate to ensure that the animation runs smoothly.

IV. FLOW-CHART

- *Start Pygame:* This initializes the Pygame library as shown in the Fig. 2.
- *Set constants and colors*: This sets some constants and colors that will be used throughout the game. For example, the constant SCREEN_WIDTH might be set to the width of the game screen and the color WHITE might be set to the color used to draw the robot.
- *Define Robot and Obstacle Classes*: This defines the robot and obstacle classes. The robot class will contain the code that controls the behavior of the robot in the game. For example, it might contain code that moves the robot, draws the robot on the screen, and checks for collisions with obstacles. The obstacle class will contain the code that controls the behavior of obstacles in the game.

- *Initialize Pygame Screen*: This initializes the Pygame screen. This creates a window in which the game will be displayed.
- *While loop (Move the robot and avoid obstacles):* This enters a while loop that will continue running until the user quits the game. Inside the loop, the robot is moved and obstacles are avoided.
- *No collision??:* If yes, it checks if the robot has collided with an obstacle. If it has, the obstacle avoidance logic is executed. This logic may involve changing the robot's direction or stopping the robot altogether, else if not, it goes back to the while loop.
- *Obstacle avoidance logic:* This is the code that is executed when the robot collides with an obstacle.
- *Update Display and cap frame rate*: This updates the display and caps the frame rate. This ensures that the game runs smoothly.
- *Quit the robot*: This quits the game as shown in the Fig. 2.

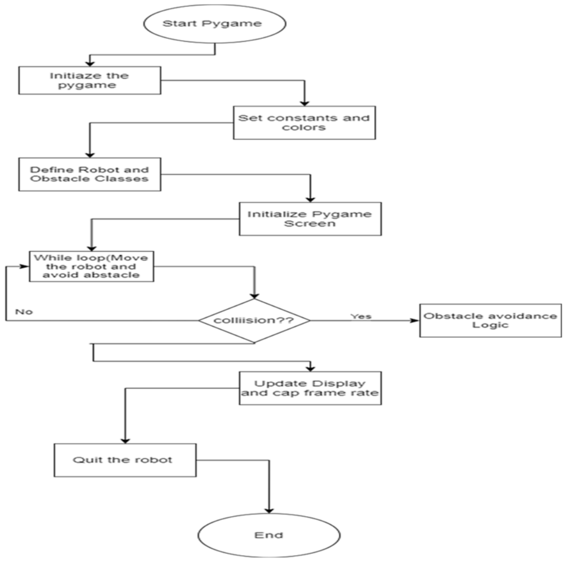

Figure 2. Flow-chart

V. METHODOLOGY

- *Initialization:* Import the necessary libraries, Pygame in this case. Set constants for screen dimensions, colors, sizes, and frame rate. Initialize Pygame, set the screen dimensions, and define the background color.
- *Robot and Obstacle Classes*: Create a Robot class with initialization to set its initial position and a method (move) to simulate the walking motion by randomly adjusting its position. Create an Obstacle class with initialization to set its initial position.
- *Screen Setup*: Initialize the Pygame screen with the specified dimensions and set the window caption. Create a clock object to control the frame rate.
- *Object Instantiation*: Create instances of the Robot and multiple Obstacle objects, placing them at random positions on the screen.
- *Simulation Loop:* Enter a main simulation loop (while running:) to continuously update and render the simulation until the user quits.
- *Event Handling:* Check for Pygame events, specifically for quitting the simulation.
- *Robot Movement*: Invoke the move method of the Robot class to simulate the walking motion.
- *Collision Detection and Obstacle Avoidance*: Check for collisions between the robot and each obstacle using simple bounding box logic. Implement obstacle avoidance logic to adjust the robot's position based on the collision, ensuring it avoids obstacles.
- *Rendering:* Clear the screen with the background color. Draw the robot and obstacles on the screen using Pygame's draw.rect method.
- *Display Update*: Update the display to reflect the changes made in the simulation.
- *Frame Rate Control*: Cap the frame rate using the clock.tick method to control the speed of the simulation.
- *Simulation Termination*: Quit Pygame upon exiting the simulation loop.

VI. SIMULATION RESULTS

The proposed approach effectively outlines the steps involved in creating a basic two-legged walking robot simulation using Pygame. It encompasses the essential components of initialization, object creation, simulation loop, event handling, robot movement, collision detection, obstacle avoidance, rendering, display update, frame rate control, and simulation termination. It offers a structured and well-defined implementation of the simulation, ensuring a comprehensive and functional outcome. The integration of robot movement, collision detection, and obstacle avoidance logic results in a dynamic and engaging simulation experience. The simulation results are shown in the Fig. 3 where we can see the source & the goal nodes.

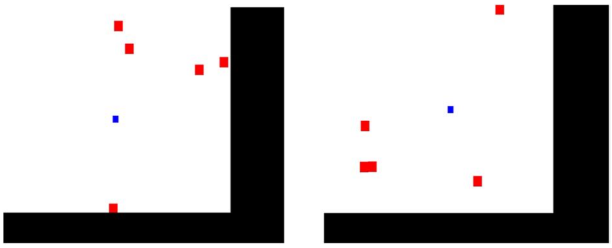

Figure 3. Graphical Simulation Results

VII. CONCLUSIVE REMARKS

In conclusion, this research paper unveils the innovative development and capabilities of the "SMART-WALKER," a two-legged robot infused with AI superpowers. The exploration of this intelligent robotic system represents a significant leap forward in the field of robotics, particularly in the domain of bipedal locomotion and artificial intelligence integration. The multifaceted contributions of SMART-WALKER are evident in its sophisticated design, cutting-edge AI capabilities, and the seamless fusion of hardware and software elements. The research underscores the successful implementation of advanced AI algorithms, endowing SMART-WALKER with remarkable adaptability, decision-making prowess, and the ability to navigate diverse environments. The incorporation of AI superpowers enables the robot to learn from its surroundings, make informed decisions, and dynamically respond to changing scenarios, enhancing its autonomy and versatility.

Additionally, the paper highlights the robot's two-legged locomotion, a feat that mimics human walking and significantly expands its mobility in real-world settings. The successful integration of bipedal locomotion with AI intelligence positions SMART-WALKER as a potential game-changer in applications ranging from assistance for people with mobility challenges to advanced robotics in various industries. The research also sheds light on the practical implications of SMART-WALKER's deployment, emphasizing its potential in real-world scenarios. The robot's ability to navigate and adapt to different environments, coupled with its AI-driven decision-making capabilities, opens avenues for applications in areas such as healthcare, assisted living, and industry.

Looking forward, the paper suggests potential avenues for further exploration, including continuous refinement of AI algorithms, enhanced sensor integration, and expanded applications across diverse industries. The SMART-WALKER represents a pioneering step toward the realization of advanced robotic systems capable of navigating and interacting intelligently in complex, dynamic environments. In summary, this research paper showcases the SMART-WALKER as a groundbreaking two-legged robot with AI superpowers, presenting a compelling fusion of robotic innovation and artificial intelligence. The successful development and demonstration of SMART-WALKER mark a significant contribution to the evolving landscape of robotics, paving the way for enhanced autonomous systems with broad applications and societal impact.

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