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Exploring BEAM Robotics for Adaptive and Energy-Efficient Solutions

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Abstract:

In the rapidly evolving landscape of robotics, engineers and roboticists continually strive to develop intelligent robots capable of versatile tasks. BEAM robots represent a unique class designed with inspiration from biological principles of artificial intelligence. This innovative approach seeks to emulate the functionality of biological organisms, differentiating itself by eschewing microcontrollers and software in favor of simple electrical circuits. The BEAM philosophy centers around crafting uncomplicated mechanisms to address intricate problems, resulting in robots with distinct advantages over their traditional counterparts. This paper explores the ongoing developments in BEAM robots, emphasizing their energy-efficient nature, minimalist design, and adaptability to the environment. Notably, some BEAM robots exhibit self-organization, demonstrating the potential for collaborative problem-solving without centralized control. The practical implementation of BEAM robotics involves careful component selection. The schematic diagram illustrates the assembly of a BEAM robot, emphasizing the importance of mechanical design to ensure autonomy. Looking ahead, the paper outlines future enhancements for BEAM robots, including the implementation of an energy analysis system. This system will enable the robot to autonomously transition into a sleep mode during periods of insufficient energy, contributing to prolonged autonomy in varying environmental conditions.

Key words: BEAM Robotics, Biological principles, Energy efficiency, Autonomous robots, Adaptability, Sustainable technologies.

Introduction

The modern world is full of technological advances, and robotics is no exception. Engineers and roboticists are working tirelessly to create new intelligent robots capable of performing various tasks. Currently, many researchers are creating a variety of robots. At the same time, they use a wide variety of approaches, each of which has its own advantages and disadvantages, use different methods and theories [1]-[17].

Among all approaches, we can highlight BEAM robotics. BEAM (Biology, Electronics, Aesthetics and Mechanics) robots are a class of robots designed with biological principles of artificial intelligence in mind. This approach to robot design is inspired by biological systems and aims to create robots that can function like biological organisms. It is based on the idea of designing simple mechanisms to solve complex problems, and its main feature is the absence of microcontrollers and software. Instead, BEAM robots control their actions using simple electrical circuits. This approach turns them into "living" robots with interesting advantages over traditional robots.

Related works

The direction of BEAM robotics is very promising. Many scientists see it as very promising for the development of robotics [18]-[21].

In [22] authors note that inflated continuum robots are promising for a variety of navigation tasks, but controlling their motion with a small number of actuators is challenging.

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Researchers in [23] also use BEAM robots. Their study showed the intriguing finding that participants displayed more fear of and competed slightly more against robots that matched their number.

Papers by Boya-Lara, C. and co-authors [24]-[26] propose to use BEAM robotics to enhance the STEM knowledge and skills of engineering students in the electrical, electronic, and mechanical domains.

Conference materials [27] present an optimized solution to solve the existing defects of the product and complete the solution that meets the modern market demand, aesthetic patterns, and production methods. This solution uses BEAM concept.

Scientists in [28] developed an extremely simple quadruped robot, which is able to walk with no form of software or controller. Instead, individual leg movements are triggered directly by switches on each leg which detect leg loading and unloading.

In [29] researchers consider an area of humanoid robots. They note this area is an emerging topic in the world of robotic research owing to their usefulness in replacing humans in various tasks. They write that solar PV cells have been frequently used in BEAM (Biology, Electronics, Aesthetics and Mechanics) robotics.

So, we see that the use of BEAM robotics is an extremely interesting direction in the development of robotics. Furher we will consider our exploring beam robotics for adaptive and energy-efficient solutions.

BEAM approach to robot development

BEAM (Biology, Electronics, Aesthetics and Mechanics) robots are an exceptional class of robots that sophisticatedly incorporate the principles of biological intelligence. This cutting-edge approach aims to emulate the functionality of living organisms, moving away from the traditional use of microcontrollers and software. The philosophy of BEAM robotics focuses on creating simple mechanisms to solve complex problems.

Unlike conventional robots, BEAM robots achieve autonomy and functionality through sophisticated electrical circuits. This approach, which differs from the standard dependence on complex electronic components, leads to the creation of a unique category of robots that can be compared to living organisms. The absence of microcontrollers and software makes BEAM robots particularly promising.

The benefits of this approach are energy efficiency, as BEAM robots consume less power due to the minimised use of electronics. The absence of complex electronic components makes BEAM robots more reliable and easier to maintain. Facilitate the study and reproduction of biological principles, offering insight into robotics and biology.

Thanks to its minimalist design, BEAM robots are lightweight and compact compared to more traditional robots, reducing the complexity of the design.

Adaptable to the environment, BEAM robots are highly adaptable to environmental changes and make efficient use of natural energy sources such as solar panels.

Some BEAM robots can self-organise, collaborating to solve problems or coordinate actions without central control.

They show potential for use in nature studies and interaction with living organisms.

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As with any approach, there are disadvantages to the BEAM approach, such as the limited use of electronics limits the ability of BEAM robots to perform complex tasks and algorithmic computations.

As with any approach, there are drawbacks to the BEAM approach, such as the limited use of electronics limits the ability of BEAM robots to perform complex tasks and algorithmic computations.

The basic concept of microkernels in BEAM robotics involves the development of small, simple mechanical components that can be coordinated to perform complex actions. Similar to neurons in biological systems, these micro-core components, such as Nv (visual neurons) that respond to changes in light or Nu (motor neurons) that are responsible for movement, are based on mechanical sensors and control mechanisms rather than traditional electronic components.

Ongoing research and development in the field of BEAM robots is making a significant contribution to the understanding of biological principles. This enhanced understanding, in turn, can contribute to the development of new methods in fields as diverse as medicine and biology. The significant energy efficiency inherent in BEAM robots makes them useful for environmental monitoring and solving environmental problems. In addition, they can serve as educational tools, inspiring students and researchers studying the intersection of robotics and biology.

As for the future, the development of BEAM robotics promises even deeper advances in both biology and robotics. They can become the basis for creating complex and adaptive systems that use biological principles to optimise responses in unpredictable conditions.

BEAM robotics, as an innovative direction in the world of robotics, successfully combines natural inspiration with technological efficiency. It acts as a catalyst for understanding the intricacies of natural processes, which ultimately contributes to the creation of sustainable and adaptive systems. Despite the inherent limitations of BEAM robots, their capabilities and benefits are breathtaking in their innovation and potential, providing compelling evidence of the transformative power of this exciting technological direction.

Determining the choice of components for creating a BEAM-robot

The creation of a BEAM robot is one of the first tasks that requires careful selection of components that optimally combine biological principles, technical solutions and pricing. Determining the right combination of components was crucial to achieving maximum efficiency and reliability.

In general, the entire robot was assembled according to the scheme (see Figure 1).

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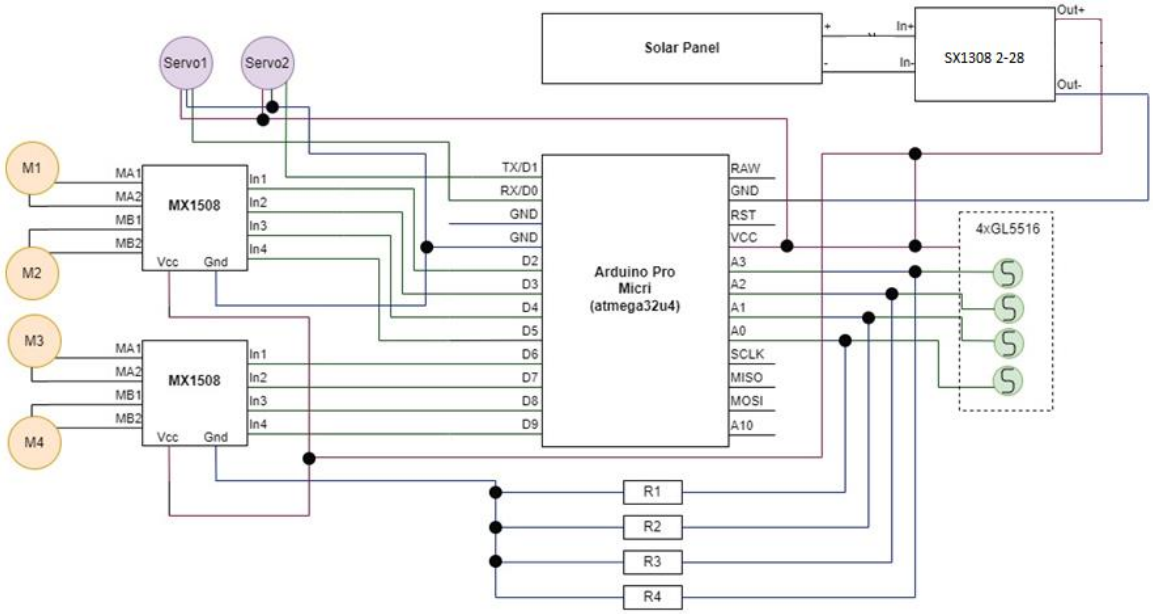

Figure 1: Schematic diagram of the robot design

First of all, the mechanical design of the robot was carefully developed, taking into account the ability to "survive" without intervention.

The use of a solar panel was a key solution for providing power to the robot. This panel converts solar radiation into electrical energy, which is used to power and charge the batteries. This not only provides the energy to find light, but also allows the robot to operate in low-light mode.

The BEAM robot receives energy from 80x45 mm solar panels with a voltage of 5 V, which is fed to the SX1308 2-28 module. This module is used to efficiently convert the energy from the solar panel and supply it to the battery. The SX1308 module is designed to work with energy sources such as a solar panel as well as DC power sources.

The use of servo motors allows the robot to optimally position the solar panel vertically and horizontally to maximise solar energy collection.

The selected sensors determine the robot's ability to interact with its environment. The use of photoresistors to respond to light creates opportunities for the robot to respond to external stimuli, i.e. they are used to determine the illumination around the perimeter of the panel, transmit the information to the Arduino, which analyses the information to decide on the degree of rotation of the servo motors. The optimal placement of these sensors allows the robot to interact effectively with the world around it and perform its intended tasks (see Figure 2).

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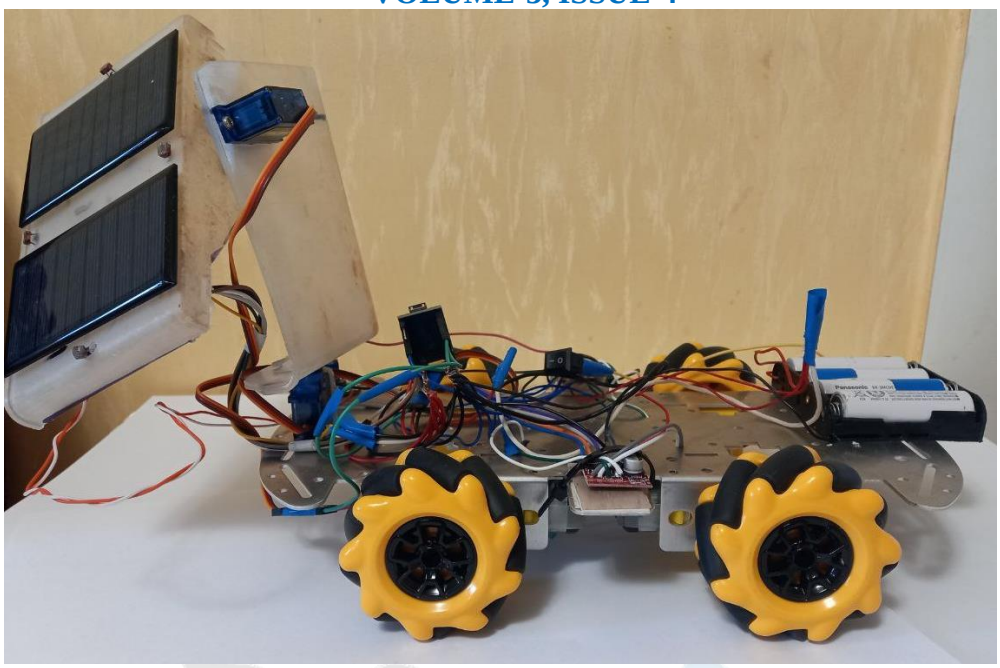

Figure 2: Real prototype of the constructed BIEM robot

The decision to incorporate the Arduino Micro Pro board is a strategic one. This board simplifies software development for controlling the robot, processing input from sensors such as photoresistors. It utilizes this information to make decisions, precisely controls servo motors, contributing to optimal task-solving and efficient energy use. Furthermore, it provides accurate and flexible control of the robot's movements and chassis functions.

In the future, additional functionalities are planned to enhance the robot's capabilities. One such feature involves implementing an energy analysis system for the energy obtained from the solar panel. This system will enable the robot to assess its energy intake and, in case of insufficient energy, autonomously transition into a sleep mode to conserve power. This sleep mode will be activated when the battery charge falls below a certain threshold. This forward-looking approach aims to optimize energy utilization and enhance the robot's autonomy in varying environmental conditions.

Conclusion

BEAM robotics is at the intersection of biological inspiration and technological innovation, offering a paradigm shift in robot design. The absence of microcontrollers and software, combined with a minimalist approach, distinguishes BEAM robots as autonomous objects capable of mimicking the adaptability and efficiency inherent in biological organisms.

Ongoing research and development in the field of BEAM robotics not only deepens our understanding of biological principles, but also paves the way for revolutionary applications in medicine, biology and environmental monitoring. The energy efficiency and reliability of BEAM robots make them valuable tools for solving real-world problems.

Looking to the future, the trajectory of BEAM robotics promises progress in both biology and robotics. These robots, with their adaptive systems guided by biological principles, are able to effectively navigate unpredictable environments.

The practical implementation of the BEAM robot illustrated in this article highlights the careful selection of components and the integration of innovative features such as an energy analysis system. These additions contribute to long autonomy and efficient energy use, increasing the robot's viability in a variety of environmental conditions.

References:

1. Shcherbyna, V., & et al. (2023). Mobile Robot for Fires Detection Development. Journal of Universal Science Research, 1(11), 17-27.
2. Basiuk, V., & et al. (2023). Mobile Robot Position Determining Using Odometry Method. Multidisciplinary Journal of Science and Technology, 3(3), 227-234.
3. Nevliudov, I., & et al. (2023). Development of a Mobile Robot Prototype with an Interactive Control System. Системи управління, навігації та зв'язку. Збірник наукових праць, 3(73), 128-133.
4. Nevliudov, I., & et al. (2023). Mobile Robot Navigation System Based on Ultrasonic Sensors. In 2023 IEEE XXVIII International Seminar/Workshop on Direct and Inverse Problems of Electromagnetic and Acoustic Wave Theory (DIPED),IEEE, 1, 247-251.
5. Yevsieiev, V., & et al. (2023). A Small-Scale Manipulation Robot a Laboratory Layout Development. International independent scientific journal, 47, 18-28.
6. Yevsieiev, V., & et al. (2022). Software Implementation Concept Development for the Mobile Robot Control System on ESP-32CAM. In Current issues of science, prospects and challenges: collection of scientific papers «SCIENTIA» with Proceedings of the II International Scientific and Theoretical Conference, 2, Sydney, Australia: European Scientific Platform, 54-56.
7. Baker, J. H., & et al.. (2021). Some interesting features of semantic model in Robotic Science. SSRG International Journal of Engineering Trends and Technology, 69(7), 38-44.
8. Abu-Jassar, A. T., Al-Sharo, Y. M., Lyashenko, V., & Sotnik, S. (2021). Some Features of Classifiers Implementation for Object Recognition in Specialized Computer systems. TEM Journal: Technology, Education, Management, Informatics, 10(4), 1645-1654.
9. Al-Sharo, Y. M., Abu-Jassar, A. T., Sotnik, S., & Lyashenko, V. (2021). Neural Networks As A Tool For Pattern Recognition of Fasteners. International Journal of Engineering Trends and Technology, 69(10), 151-160.
10. Sotnik, S., & et al.. (2020). Some features of route planning as the basis in a mobile robot. International Journal of Emerging Trends in Engineering Research, 8(5), 2074-2079.
11. Mustafa, S. K., & et al.. (2020). Interesting applications of mobile robotic motion by using control algorithms. International Journal of Advanced Trends in Computer Science and Engineering, 9(3), 3847-3852.
12. Al-Sharo, Y. M., Abu-Jassar, A. T., Sotnik, S., & Lyashenko, V. (2023). Generalized Procedure for Determining the Collision-Free Trajectory for a Robotic Arm. Tikrit Journal of Engineering Sciences, 30(2), 142-151.
13. Nevliudov, I., Yevsieiev, V., Baker, J. H., Ahmad, M. A., & Lyashenko, V. (2020). Development of a cyber design modeling declarative Language for cyber physical production systems. J. Math. Comput. Sci., 11(1), 520-542.
14. Sotnik, S., Matarneh, R., & Lyashenko, V. (2017). System model tooling for injection molding. International Journal of Mechanical Engineering and Technology, 8(9), 378-390.

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2023-5.384 ResearchBib IF: 8.848 / 2023

15. Lyashenko, V., Mustafa, S. K., Belova, N., & Ahmad, M. A. (2019). Some features in calculation of mold details for plastic products. International Journal of Emerging Trends in Engineering Research, 7(11), 720-724.

16. Lyashenko, V., Matarneh, R., & Sotnik, S. (2018). Defects of Casting Plastic Products: Causes, Recurrence, Synthesis and Ways of Elimination. International Journal of Modern Engineering Research (IJMER), 8(2), 1–11.

17. Hani Attar, & et al. (2022). Zoomorphic Mobile Robot Development for Vertical Movement Based on the Geometrical Family Caterpillar, Computational Intelligence and Neuroscience, 2022, 3046116.

18. Do, B. H., & et al. (2020). Dynamically reconfigurable discrete distributed stiffness for inflated beam robots. In 2020 IEEE International Conference on Robotics and Automation (ICRA), IEEE, 9050-9056.

19. Yevsieiev V. Some aspects of the development of the BEAM robot control scheme. In IV International Scientific and Theoretical Conference,Singapore, Republic of Singapore, 79-81.

20. Stetsenko, K. (2023). BEAM Robotics: Combining Biological Principles and Technological Solutions for More Adaptive and Energy-Efficient Robots / K. Stetsenko. In Manufacturing & Mechatronic Systems, Proceedings of VIIst International Conference, Kharkiv, 30–32.

21. Yevsieiev, V. (2023) Modeling of the BEAM robot control systemon the basis of a microcircuit L293D. Manufacturing & Mechatronic Systems 2023: Proceedings of VIIst International Conference, Kharkiv, 12-14.

22. Yevsieiev V. (2023). Beam scheme development work based on arduino pro micro c using solar panel. Матеріали III Всеукраїнської науково-технічної конференції молодих вчених, аспірантів і студентів, Одеса, 155-158.

23. Do, B. H., & et al. (2020). Dynamically reconfigurable discrete distributed stiffness for inflated beam robots. In 2020 IEEE International Conference on Robotics and Automation (ICRA), IEEE, 9050-9056.

24. M. R. Fraune, & et al. (2020). Is Human-Robot Interaction More Competitive Between Groups Than Between Individuals?, In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Daegu, Korea (South), 2019, 104-113.

25. Boya-Lara, C., & et al. (2023). A course based on BEAM Robotics for the valorization of WEEE through the development of STEAM skills. In 2023 IEEE World Engineering Education Conference (EDUNINE), IEEE, 01-06.

26. Boya-Lara, C., & et al. (2022). A STEM Course for Computational Thinking Development with BEAM Robotics. In 2022 IEEE 40th Central America and Panama Convention (CONCAPAN), IEEE, pp. 1-6.

27. Boya-Lara, C., & et al. (2022). Development of a course based on BEAM robots to enhance STEM learning in electrical, electronic, and mechanical domains. International Journal of Educational Technology in Higher Education, 19(1), 1-23.

28. Yang, H., & Kim, C. (2022). Research related to the Appearance Design of Water Surface Cleaning Robot based on Bionics. In IOP Conference Series: Earth and Environmental Science, 1011(1), 012019.

29. Smith, B. J., & Usherwood, J. R. (2020). Minimalist analogue robot discovers animal-like walking gaits. Bioinspiration & Biomimetics, 15(2), 026004.