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A new motion structure for a six-legged insect robot with Bluetooth remote-control

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ABSTRACT

This paper focuses on motion which is considered an important issue for insect robots, which consumes significant energy sources in general. We inspired the robot design structure from the challenges that crawling insects face in nature, especially a cockroach. The proposed robot configuration enhanced error scale such as energy modulation, computation, and mass. This paper presents the design and construction of six-legged robot with minimum number of trigger motors and the movement mechanisms used for the leg movements. The insect robot resembles a cockroach in shape and size (1.6 cm × 4 cm) and can move at rates of up to 3.5 cm per second. The robot can operate for up to 260 minutes. Additionally, it has a camera that can rotate more than 60 degrees in response to commands from a smartphone. The 160×120 pixels monochrome "first person" camera transmits video to a Bluetooth radio at a distance of up to 120 meters away at a frame rate of 1 to 5 per second.

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1. INTRODUCTION

Autonomous robots that resemble insects have various benefits over bigger robots due to their tiny size and low mass, including the ability to maneuver in small places, have great agility, and climb barriers and withstand crashes. Numerous applications are made possible by these qualities. They can be used, for example, to inspect hazardous areas where wheeled or large robots cannot operate, such damaged or destroyed structures, natural catastrophe sites, ruins, and areas of conflict. When fitted with the appropriate sensors, they can also find survivors, assist in rescue efforts by finding risks like chemical toxicity and temperature extremes, and do measurements to study surroundings more generally [1]–[9]. If these robots operated in a more efficient manner such as smart war fighting array of reconfigurable modules (SWARM) technology, the majority of these applications could be accomplished [10], [11]. Many insect robot receptors are installed to support and develop high visual acuity in small retinal regions and move their visual systems independently of their bodies through legs movement. Also, the changeover made by insect apparition programs and presentations in the contiguous environment, where a recovering structure for the robot can be planned on the insect scale in a way that balances energy, computation and mass, and through the range of the robot motion.

Building a cockroach mimic and wireless steerable control robot with least mechanical parts at this range is challenging in practice due to size, weight and extreme limitations. In addition to being small, insect robots have a severely restricted payload capacity. Several studies have been attended in this context by a lot of researchers to solve the apprehensions mentioned above.

Fuchiwaki [12] proposed a scheme to develop a comprehensive insect-sized robot with nano-meter precision. To offer stretchy and compact size miniscule processes, single drive machinery has been receptor involving of four piezoelectric motors and two U-shaped electromagnetic legs. Here, two legs are organized through each other and associated by four piezoelectric motors so that the machinery can change in any direction, i.e. in the two X directions and Y as well as revolution, at an exact point in an inch way. In the early tests, numerous acts such as repeatability, precision, and acceptable deftness were confirmed using a charge-coupled device (CCD) camera-based microscopic image tracker and capacitive distance instrument. The drawback of this robot is that it needs four motors and its size 5 cm^3 [12]. Swee and Al-Qudah [13] are improved a six legs robot structure inspired by ants and crickets. This robot is capable to impersonate creepy-crawlies in relations of step shape and bodily size. The robot is organized wirelessly via a Bluetooth xBee element and remote devices counting a mobile phone with android request, a personal computer with windows software, and a Bluetooth wireless manager made the Adriano progress stage. But this robot is not truly like crickets and the final dimensions of the robot is about (13×9×7) cm [13]. Simons and Tibbetts [14] introduced organized research on reasoning expansion in vertebrates and insects, exactly revealed latest improvements in vertebrate study related to insects. They focused on two key elements: i) the challenges of calculating cognizance, and ii) what issues to add for the expansion of cognizance. The claim of approaches such as comparative exploration and interactive cognizance dimension to insects is to be expected to arrange for significant insight into the development of animal intelligences [14]. Ma *et al*. [15] suggested the design and creation of a small, integrated leaping and running robot with passive self-righting and trajectory control. A revolutionary design approach that blends the mobility of soft-bodied animals (gall midge larvae) and hard-bodied animals (spring tails) was used to create the robot's leaping mechanism. With a load of 98.6 g, it could reach a height of approximately 1.5 m, and with a load of 156.8 g, it could reach a height of about 1.2 m. A clutch system with an adjustable height and launch time control was employed to increase the robot's leaping flexibility so that it could easily transition between different jumping heights. However, this robot has no camera and does not actually resemble any insects [15]. Song *et al*. [16] improved the gait method of a six-legged arthropod robot to ascent stages at altered altitudes, which allows the robot to ascent a stage 3.9 times its leg distance. The non-conformable legs are used to raise the center of mass (COM) of the body by raising the front and rear legs alternately until the front legs can reach the top of the step, then the front and middle legs are alternately raised to maneuver the COM up in the stride. The model and dynamic study of climbing strides are used to prove the viability of the better-quality gait. Finally, the experiences of climbing stairs at different heights are performed using the improved gait to compare with the current gait. Simulation and experimental results showed that the proposed gait is superior to the higher grades climb. But this robot does not simulate the real cockroach in shape [16].

The aim of this paper is to design and create a small size cockroach robot with a smaller number of motors and mechanical parts and fully wireless independent tools which provide less cost and energy consumption. Building a cockroach mimic and wireless steerable control robot at this range is challenging in practice due to size, weight and extreme limitations. In addition to being small, insect robots have a severely restricted payload capacity. For small robots, heavy loads require more energy to maintain speed, and reduce uptime. Likewise, adding a heavy load can limit the cockroach insect's ability to move.

2. DESIGN METHOD

The cockroach insect design technique depends on lengthening the internal design system steps and being homogenous and compatible in order to achieve the cockroach robot movement. Following is a description of the design process. The structure design is first presented as an outline. In the second section, we go over the exact steps we used to build the kinematics of the device that moves the leg horizontally. This section offers an operational alternative, describes the mono design, and explains how to best utilize it in the desired system. The mechanism that creates movement directions is then introduced as the robot movement for the leg is explained. Finally, the compatible mechanism that is associated with the vertical and horizontal movement of the robot is discussed through the internal design of the robot.

2.1. Structure design and stride mechanism

The structure of the robot is subdivided into several pieces of the main robot mechanisms, that is, the plane movement of the cockroach insect robot through which the movement will be carried out continuously through the six legs, which are represented in Figure 1. The legs in the proposed robot, simultaneously, make the movement in the straight plane, and they are in tune. This implies that, as illustrated in Figure 2. Figure 2(a) represents the forward step1 in which the left legs (L1 and L3) and the right hind leg (R2) move in phase opposed to the other three legs (R1, R3, and L2) which produces the forward step2, as shown in Figure 2(b). The elliptical movement can be divided into horizontal and vertical components when two distinct mechanisms are created. Each mechanism uses a single actuator to create the motion of all three legs. Thus, only two stepper motors are used to move the six legs of the proposed insect robot. They are combined with a coupling mechanism and driven by a 90-degree phase difference for elliptical movement. A tripod-style robot gait is programmed, and then transferred from a computer to the Arduino NANO. The stepper motors are controlled by this software using mechanical switching signals.

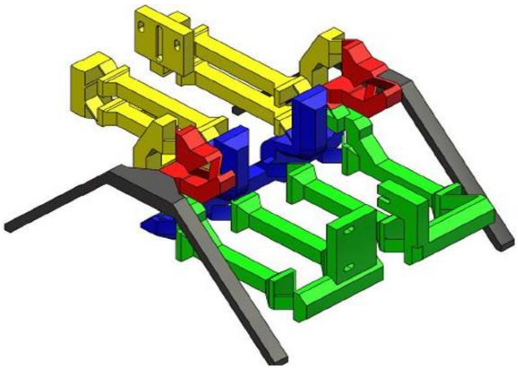
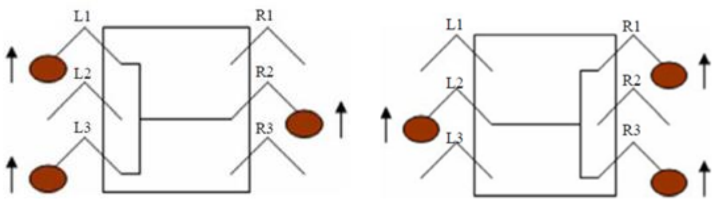


Figure 1. The structure design of the cockroach insect robot; green denotes the horizontal movement, yellow the vertical movement, blue the main body, red the two coupling mechanisms, and black the pairs of legs



(a) (b)

Figure 2. The structure of walking pattern (a) forward step1 and (b) forward step2

2.2. Internal design of robot gear

The structure of the robot gears for right or left side is given in Figure 3. The movement of the robot is designed through the axial movement of the gear, which works through the rotation of the small rotating motor, which will be explained in the next section; when the first gear is rotated from the left, a rotation begins with the effect of the second gear from the left and so on until the mechanisms are automatically moved to operate the robot when turning first gear clockwise, the robot will move forward, but if it is turned counterclockwise, the robot will travel backward, and so on. This process is also done similarly on the other side, which works on the movement of the robot in the four directions through an integrated movement in the four directions.

2.3. Limbs and drive design for insect robot

A 3D printer is used to design the limbs of the robot as shown in Figure 4. The components are created by utilizing computer programs to divide their 3D drawings into extremely small layers, which are then printed one layer at a time until the desired shape is achieved using 3D printers [17], [18]. Compared to alternative shaping technologies, this design doesn't waste as much materials during production. Designing a hexapod insect robot is inspired by the cockroach creature. That is, the proposed robot legs design is similar to the cockroach leg's mechanism and has one gear for lifting, and each gear consists of a salient which is responsible the leg's swing.

The 3D design of the gears used in the robot is shown in Figure 5, and the 3D printed gear is shown in Figure 6. The body size and joint dimensions are determined from the maximum swing and lift angles. Each part is created by entering the figure and reference coordinates. The internal robot body structure which was printed from the 3D printer is given in Figure 7.

The number of motors and the movement mechanism employed for the leg motions are the key distinctions between the proposed design and prior six-legged robot research. The usage of at least one motor for each leg's rolling action is suggested by related studies [19]–[21]. In contrast, the proposed robot uses a single stepper motor to rotate the left and right camshafts in the same direction, as opposed to utilizing distinct motors for each leg, to achieve the up/down movements of the tripod legs. The system's control is made simpler by using a single stepper motor to complete all required tasks for the up and down movement. The robot's motor structure is depicted in Figure 8. One of the major components of the suggested design is the camshaft. It permits tripod gait with just one stepper motor and lifts three legs while grounding the other. Additionally, it makes control issues simpler. The same stepper motor powers two camshafts, one for each of the left and right legs. These camshafts spin concurrently, as seen in Figure 8.

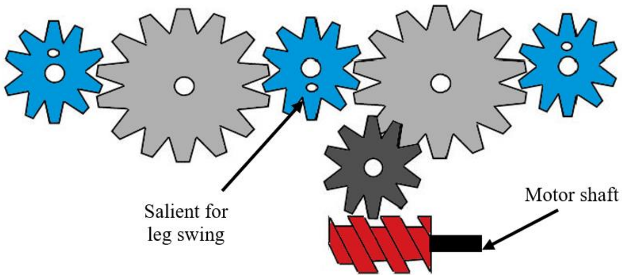


Figure 3. The construction of the inner robot gears for right or left side

Figure 4. Design and printing of the six legs of the cockroach robot insect

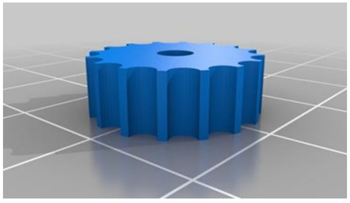


Figure 5. Three-dimensional design of the gears used in the robot

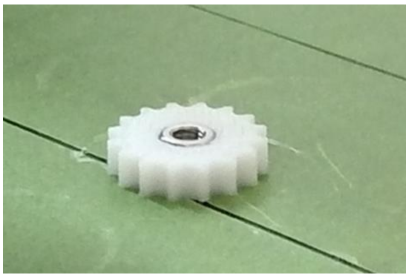


Figure 6. Gear design following the 3D printing used in the robot

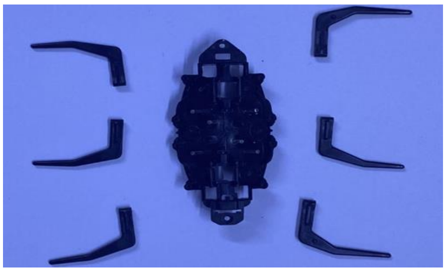


Figure 7. Internal robot structure

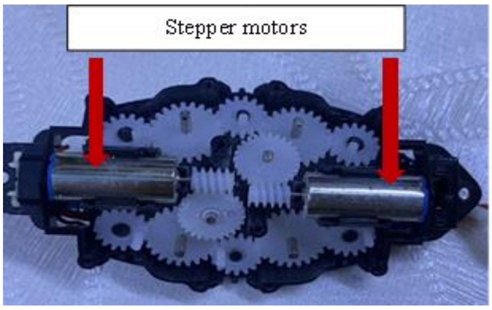


Figure 8. Internal robot structure

Every time the first stepper motor is initiated and moved forward one step, the left and right tripod legs move one step (0.098 m), respectively. Subsequently, other pulses are supplied to drive the second stepper motor forward one step, and so on. The second stepper motor drives the camshaft one turn, which causes the tripod legs to move up and down. As a result, the ladder diagram develops the walking motion.

3. THE CONTROL CIRCUIT DESIGN

Arduino NANO is used in the control circuit design as it is very small and light. Figure 9 shows the design and programming of the robot system controller which is based on the Arduino NANO, which in turn gives the movement action, connection and programming through the system tools [22]–[24]. The program flowchart that organizes and controls the robot motion is shown in Figure 10.

Figure 9. Arduino NANO control circuit

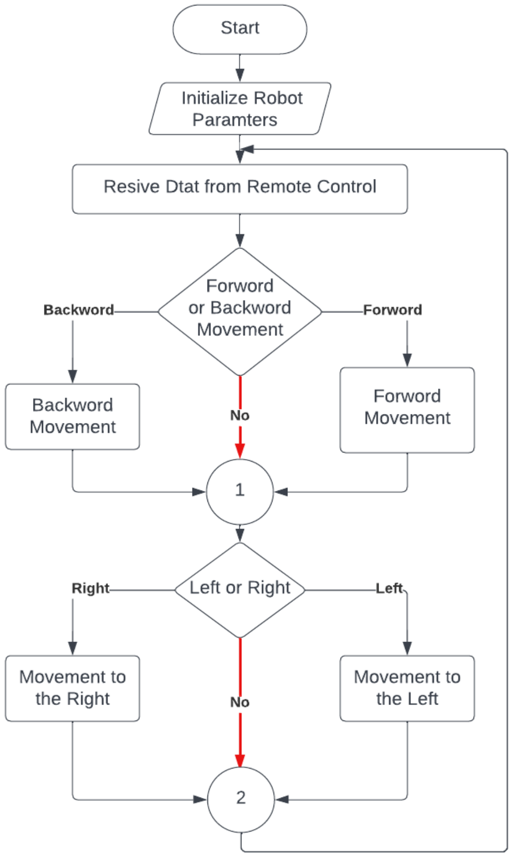


Figure 10. The robot control algorithm flowchart

4. MATHEMATICAL PROBLEM DESCRIPTION

The mathematical formula for the divergence between the intended observed frequency and the frequency of a given set of parameters is given in (1). According to (1) serves as both a nonlinear equality constraint for the motion algorithm as well as an objective function for sensitivity analysis. It is derived to enable application in a negative blank form for an optimal system, such as the axial movement of the cockroach robot [25].

$$f_{dif}(x) = \frac{\sqrt{(f(x)-f_{des})^2}}{\sqrt{(f(x_0)-f_{des})^2}} \quad (1)$$

Where, x stands for the whole set of physical elements, x_0 denotes the starting set of elements provided to the algorithm, f represents the Eigen frequency in Hertz, f_{des} represents the desired Eigen frequency and f_{dif} denotes the difference's normalized value. According to (1) is used as an objective function in sensitivity analysis. The objective function's partial derivative with respect to each parameter at the designing point x_d, as provided in (2), is used to determine the objective function's sensitivities at a particular design point.

$$S_i(x_d) = \frac{\partial f_{obj}}{\partial x_i}|_{x_d} \quad (2)$$

Where i takes the values 1–n, S_i represents the physical element's sensitivity value x_i, and n denotes the total number of elements.

The measured sensitivity values are necessary for element comparison. The logarithmic sensitivity is derived using the partial derivative of the objective function's logarithm with respect to the element's logarithm, as given in (3). Because these derivatives cannot be calculated analytically, they are tackled using the finite center difference method, that is, dependent on Taylor series, as given in (4).

$$S_{i,log}(x_d) = \frac{\partial \log f_{obj}}{\partial \log x_i}|_{x_d} = \frac{\partial x_i}{f_{obj}} \frac{\partial f_{obj}}{\partial x_i}|_{x_d} \quad (3)$$

$$\frac{\partial f}{\partial x_i} \approx \frac{f(x_i+h)-f(x_i-h)}{2h} \quad (4)$$

Where, the perturbation step size is denoted by h. The sensitivity levels for the center difference approach are determined by the magnitude of the perturbation step.

5. PROTOTYPE

In this paper, a prototype cockroach robot is built to test remote control system. The mechanism of horizontal movement is both functional and kinetic. This prototype is used to test the robotic motion mechanism, to verify design methodology and parametric modeling and for experimental operation as shown in Figure 11. The prototype is powered by an internal rechargeable battery power source 3.7 V 100 mA, the motors operate at an operating voltage 1.5 V - 2.1 V. By using an accelerometer that achieved run time of 6 hours. The motor's electrical input is a mass wave with a frequency that the user may regulate using Arduino. The Arduino is used as a simple microcontroller circuit. Figure 12 shows the general structure with the positioned battery of the cockroach insect robot, which contains the components of the robot's movement, whereby the process of interaction with the surrounding environment takes place through it. The final design of the cockroach robot with the remote control is given in Figure 13.

Figure 11. The final structure cockroach shape of the robot used

Figure 12. The position of the battery on the robot

Figure 13. Control the movement of a robot through the remote control

6. RESULTS AND DISCUSSION

Figure 14 shows the position of the camera display controller on the back of the cockroach robot. The camera displaying data through the robot is also connected by Bluetooth technology. A compact Bluetooth transceiver allows the near operator to control the visual display of the cockroach's surrounding environment via a regular mobile phone. In the environment lobe on the left or right side of the insect. The video data of camera is transmitted using Wi-Fi technology to be viewed on the smartphone screen as shown in Figure 15. Figure 16 shows the camera interface application used in the proposed insect robot design. Additionally, in response to the commands from the used smartphone, may tilt the camera beyond 60 degrees. The monochrome "first person" camera shoots in the 160×120 pixels range and broadcasts video at 1–5 frames per second. Figure 17 shows the camera video display of the insect robot environment surroundings on the smartphone. Table 1 lists the result features and characteristics after testing the proposed robot.

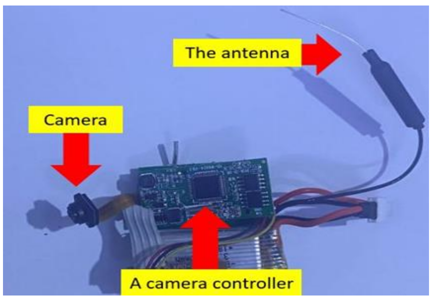


Figure 14. The camera display controller

Figure 15. The application's network name with the contact address of the camera display application

Figure 16. Camera interface application

Figure 17. Camera video display on smartphone

Table 1. The specifications and features of the proposed robot

Robot parameters	Value
The insect robot size	1.6 cm × 2 cm
Robot and tools weigh	170 g
Internal voltage source	3.7 V, 100 mA
Robot work time	163 to 260 minutes
The step-size of left and right tripod legs	0.098 m
Robot movement rate	up to 3.5 cm per second
Bluetooth radio from a distance	up to 120 meters
Camera movement point	more than 60 degrees
The camera delivers monochrome	120p - 160p "single" video at 1 to 5 frames per second

7. CONCLUSION

In this paper, a simpler, more insect-like robot is created using an intelligent biological model as inspiration. The proposed legged robot is loosely developed that mimics the cockroach leg mechanism. Only two stepper motors are needed to achieve a tripod gait. Reducing the number of thrust motors results in a lighter chassis and simpler handling. The cockroach robot is characterized by a completely wireless, energy-independent, and mechanically steerable software system that simulates the movement of an insect in a small shape (1.6×4 cm) enough to be very similar to a live cockroach. Our electronic devices and actuators weigh 200 g that can move at speeds of up to 3.5 cm per second, and work for 160 to 300 minutes. And can point the camera over 60 degrees based on requests from a smartphone. The 160×120 pixels monochrome "first person" camera broadcasts video at 1 to 5 frames per second to a Bluetooth radio from a distance of up to 120 meters to identifying the surrounding environment and transmitting data through the tools of the user system.

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REFERENCES

[1] R. T. Yunardi, A. A. Firdaus, and E. I. Agustin, "Robotic leg design to analysis the human leg swing from motion capture," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 6, no. 3, pp. 256–264, 2017, doi: 10.11591/eei.v6i3.645.

[2] N. S. Ali, H. A. Kadhim, and D. M. Abdulsahib, "Multi-function intelligent robotic in metals detection applications," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 17, no. 4, pp. 2058–2069, 2019, doi: 10.12928/TELKOMNIKA.V17I4.11822.

[3] M. A. Muslim, M. Rusli, A. R. Zufaryansyah, and B. S. K. K. Ibrahim, "Development of a quadruped mobile robot and its movement system using geometric-based inverse kinematics," *Bulletin of Electrical Engineering and Informatic (BEEI)*, vol. 8, no. 4, pp. 1224–1231, 2019, doi: 10.11591/eei.v8i4.1623.

[4] A. Bendimrad, A. El Amrani, and B. El Amrani, "Design and implementation of line follower and obstacle detection robot," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 11, no. 1, pp. 160–168, 2020, doi: 10.11591/ijpeds.v11.i1.pp160-168.

[5] M. Rivai, D. Hutabarat, and Z. M. J. Nafis, "2D mapping using omni-directional mobile robot equipped with LiDAR," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 3, pp. 1467–1474, 2020, doi: 10.12928/TELKOMNIKA.v18i3.14872.

[6] A. Hassan, R. M. Asif, A. U. Rehman, Z. Nishtar, M. K. A. Kaabar, and K. Afsar, "Design and development of an irrigation mobile robot," *IAES International Journal of Robotics and Automation (IJRA)*, vol. 10, no. 2, pp. 75-90, 2021, doi: 10.11591/ijra.v10i2.pp75-90.

[7] Y. Gunardi, J. N. Jumadril, and D. Hanafi, "A smart guidance navigation robot using petri net, database location, and radio frequency identification," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 10, no. 4, pp. 1874–1883, 2021, doi: 10.11591/EEI.V10I4.3077.

[8] M. H. Salman, A. J. Abid, and A. A. Obed, "Robotic dry cleaner for photovoltaic solar panels: an implemented design that evaluated in iraq's weather," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 19, no. 6, pp. 2050–2058, 2021, doi: 10.12928/TELKOMNIKA.v19i6.20505.

[9] M. Polishchuk, M. Tkach, I. Parkhomey, J. Boiko, and O. Eromenko, "Design and modeling industrial intelligent robot flexible hand," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 11, no. 1, pp. 111–118, 2022, doi: 10.11591/eei.v11i1.3304.

[10] M. Schranz, M. Umlauft, M. Sende, and W. Elmenreich, "Swarm robotic behaviors and current applications," *Frontiers in Robotics and AI*, vol. 7, no. April, 2020, doi: 10.3389/frobt.2020.00036.

[11] M. Al-Obaidy and R. Al-Azawi, "Cluster-based algorithm for energy optimization of swarmed robots using swarm intelligence," in *ITT 2019 - Information Technology Trends: Emerging Technologies Blockchain and IoT*, 2019, pp. 202–207, doi: 10.1109/ITT48889.2019.9075119.

[12] O. Fuchiwaki, "Insect-sized holonomic robots for precise, omnidirectional, and flexible microscopic processing: Identification, design, development, and basic experiments," *Precision Engineering*, vol. 37, no. 1, pp. 88–106, Jan. 2013, doi: 10.1016/j.precisioneng.2012.07.004.

[13] S. K. Swee and A. Al-Qudah, "Wireless control system for six-legged autonomous insect robot," *7th International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2016), MATEC Web of Conferences*, vol. 54, 2016, doi: 10.1051/matecconf/20165402001.

[14] M. Simons and E. Tibbetts, “Insects as models for studying the evolution of animal cognition,” *Current Opinion in Insect Science*, vol. 34, pp. 117–122, Aug. 2019, doi: 10.1016/j.cois.2019.05.009.
[15] Y. Ma, Y. Wei, and D. Kong, “A biologically inspired height-adjustable jumping robot,” *Applied Sciences (Switzerland)*, vol. 11, no. 11, 2021, doi: 10.3390/app11115167.
[16] X. Song, X. Zhang, X. Meng, C. Chen, and D. Huang, “Gait optimization of step climbing for a hexapod robot,” *Journal of Field Robotics*, vol. 39, no. 1, pp. 55–68, Jan. 2022, doi: 10.1002/rob.22037.
[17] S. A. Rios, A. J. Fleming, and Y. K. Yong, “Miniature resonant ambulatory robot,” *IEEE Robotics and Automation Letters*, vol. 2, no. 1, pp. 337–343, 2017, doi: 10.1109/LRA.2016.2614837.
[18] J. Werner, M. Aburaia, A. Raschendorfer, and M. Lackner, “MeshSlicer: a 3D-printing software for printing 3D-models with a 6-axis industrial robot,” in 1*4th CIRP Conference on Intelligent Computation in Manufacturing Engineering*, *Procedia CIRP*, 2021, vol. 99, pp. 110–115, doi: 10.1016/j.procir.2021.03.018.
[19] M. S. Erden, “Six-legged walking machine,” Thesis, Middle East Technical University, 2006.
[20] T. Karakurt, A. Durdu, and N. Yilmaz, “Design of six legged spider robot and evolving walking algorithms,” *International Journal of Machine Learning and Computing*, vol. 5, no. 2, pp. 96–100, Apr. 2015, doi: 10.7763/ijmlc.2015.v5.490.
[21] L. Fang and F. Gao, “Type design and behavior control for six legged robots,” *Chinese Journal of Mechanical Engineering (English Edition)*, vol. 31, no. 3, pp. 1–12, 2018, doi: 10.1186/s10033-018-0259-9.
[22] I. K. Mohammed and A. I. Abdulla, “Balancing a Segway robot using LQR controller based on genetic and bacteria foraging optimization algorithms,” *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 5, pp. 2642–2653, 2020, doi: 10.12928/TELKOMNIKA.v18i5.14717.
[23] H. M. Ariza, F. H. S. Martinez, and F. S. Martinez., “Design of a controller for wheeled mobile robots based on automatic movement sequencing,” *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 18, no. 6, pp. 3088–3095, 2020, doi: 10.12928/TELKOMNIKA.v18i6.16431.
[24] H. Wang, J. Zhang, and J. Shen, “Body balancing control of a six-legged robot SiLVIA,” SEAS UCLA, 2018.
[25] J. K. Schonebaum, “Challenge the future Department of Precision and Microsystems Engineering the design of a monolithic, compliant, resonant running robot at insect scale,” Master of Science Thesis, Department of Precision and Microsystems Engineering, Delft University of Technology, 2019.

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