Tracked Robot with Blade Arms to Enhance Crawling Capability

Jhu-Wei Ji, Fa-Shian Chang, Lih-Tyng Hwang, Chih-Feng Liu, Jeng-Nan Lee, Shun-Min Wang, Kai-Yi Cho

***Abstract*—**This paper presents a tracked robot with blade arms powered to assist movement in difficult environments. As a result, the tracked robot is able to pass a ramp or climb stairs. The main feature is a pair of blade arms on both sides of the vehicle body working in collaboration with previously validated transformable track system. When the robot encounters an obstacle in a terrain, it enlists the blade arms with power to overcome the obstacle. In disaster areas, there usually will be terrains that are full of broken and complicated slopes, broken walls, rubbles, and ditches. Thereupon, a robot, which is instructed to pass through such disaster areas, needs to have a good off-road capability for such complicated terrains. The robot with crawling-assisting blade arms would overcome the obstacles along the terrains, and possibly become to be a rescue robot. A prototype has been developed and built; experiments were carried out to validate the enhanced crawling capability of the robot.

***Keywords*—**Tracked robot, rescue robot, blade arm, crawling ability, control system.

I. Introduction

In future, robots will be used to deal with some dangerous things instead of human being [1]-[4]. They are utilized to execute the difficult, dirty and dangerous works in the factory, stope, space exploration, farmland, security, rescue, and military. Robots work place is usually very complex or dangerous; this kind of robots should have many abilities, such as running on the mud, ditch, sands, and stairs quickly and steady. More and more researchers take interest in tracked mobile robot which can move in unstructured environment quickly and steady [5]-[8]. The main ability of overcome obstacles of the rescued robot is used of its legged or wheeled to adapt the stair or slope and to assist the robot passing the obstacle. [9]-[12]. Therefore, a robot can climb a slope and stairs which needs more force to enhance its slope climbing and upward lifting height. Thus the power of overcome obstacle of the rescued robot is also important issues of the action development of the robot. However, we think further by using better idea of the structure of adaptability to overcome the limitations brought on terrain. Many robots have been developed for rough terrain, such as rescue robots and observation robots. These robots are used instead of people to operate in locations that are dangerous or difficult for people to enter [4]. The robot must pass rough terrain; it should have the ability to move in multiple directions, and can have a simple mechanism to easy control.

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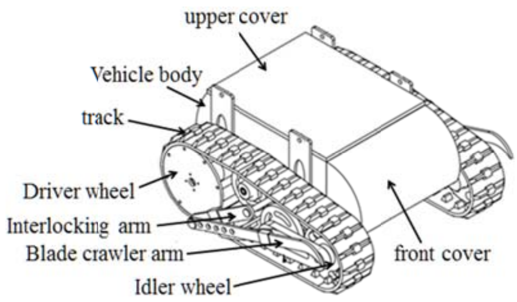
Some researchers have focused on improving the performance of robot movement for rough terrain by adjusting on other features [1]-[8]. However, due to the need to reduce costs and make functional restrictions. Accordingly, we attended to design a mechanism that can improve the robot performance to pass the rough terrain using effective institutions and feasible action. In order to improve the ability of overcome the difficult obstacle, some methods were developed, such as Wang's on board manipulator [1], Kumar's wheeled robot [9], Yamada's blade crawler [13], Edlinger's omni-crawler robot [14], and Zang's Jack robot [15]. They each presented a number of good ways to improve the problems. The studies proposed the good designs that provide great reference of our research which involves board manipulator, blade crawler, and Jack robot, etc. The creations can be integrated with the innovation for better climbing obstacle capability.

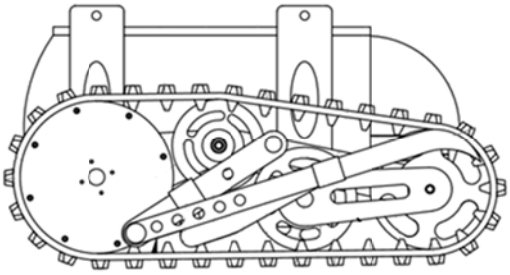
In this paper, we presented a prototype of unmanned ground vehicle; it has a blade crawler to assist walking mechanism that is to form the obstacle capability to overcome the sloping and uneven ground. In the design, we refer the characteristics of walking assistance of the insect. Recently, by using the characteristics of the insects as a reference, robots achieved high mobility on rough terrain [16]-[18]. In order to improve the rough terrain drivability with constrained structure type and size, it is necessary to inspire from the reptile insects, such as wharf roach, it has high mobility despite on the complex natural environment. Therefore, we integrate and increase the deformation travel agencies, which can help to support a set of blade crawler to improve the walking ability of the robot. Design and experimental results for the tracked robot is presented in the following sections.

II. Architecture of the Robot

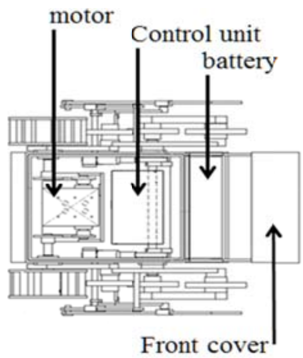
The illustrations and photos of the structure of the presented robot system are shown in Figs. 1, 2; it consists of a tracked robot and a control box. Using the modularity, the robot device is composed of several modules which are vehicle body, motion mechanism, drive element, control unit, MCU (Microcontroller Unit), and battery. The size of the robot is 85 cm (L) × 80 cm (W) × 55 cm (H), weight is about 150 kg, the body is welded of high carbon steel. The body of the vehicle is used the strengthening brackets to provide the necessary body strength. Particularly, it is designed to achieve good waterproof properties; the body adopted a similar hull design.



(a) A perspective view of the vehicle



(b) Side view



(c) Top View

(d) Control box

Fig. 1 Construction of the proposed tracked robot: (a) perspective view of the vehicle; (b) side view of the vehicle; (c) top view of the vehicle; and (d) the control box

(a) Front View

(b) Side View

Fig. 2 The photos of the proposed tracked robot with a pair of blade arms: (a) the front view of the vehicle; (b) the side view of the vehicle

III. Tracked Deformation Mechanism

This article presents a high mobility tracked vehicle; the main feature is the combination of the deformation mobile mechanism and a support arms which on both sides of the vehicle body. There is a pair of support arms which is on both sides of the mobile apparatus, the support arm can be connected so that deformation of the vehicle body, so that the vehicle driving apparatus can be changed in different terrain, the terrain change brought a lot of resistance of the vehicle drive, that the support arms can enhance carrier the ability to walk of the tracked vehicle. The support arms are called of a blade crawler arm for the tracked robot. The blade crawler arm can be changed according to different terrain, it is interlocking means associated change track contact area and improve the operational efficiency of the vehicle. So the interlocking device comprises a track structure will be deformed and a blade crawler arm. The interlocking mechanism can deform vehicle in climbing obstacle to lift the blade crawler arm, so that the front end of the vehicle also can raise, and the front end of the blade crawler arm resembles a pawl which can as a support, when the front end of the vehicle be raised that the tracked vehicle can be stable passing the obstacles.

The tracked robot has tracked transformation structures of the motion mechanism; it was given the deformation ability. The variable kinematics structure of the tracked system has a compensating idler wheels deformation structure that can be used to roam adaptively the mutative terrains. The compensating idler wheels deformation structure is used an electric drive pusher to move the connecting bar which is connected the idler wheels, and it adjusts the position

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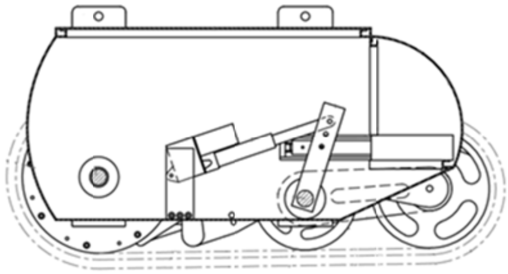
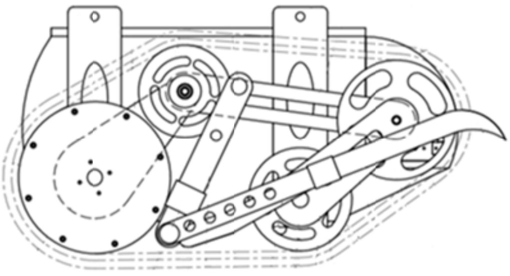
conversion of the idler wheel in between the high and low position, thereby they change the inclination angle of the front end of the blade crawler arm and the track, the structures are shown in Fig. 3.

The analysis of vehicle obstacle capability, the vehicle pass barrier depends on the combination of both to own good motion ability and to make a correct operation. The across obstacle capabilities of the tracked robot are provided mainly with climb the incline and stair. The stair climbing of the robot is related to center of gravity, climbing power and operation skills. The processes of through the vertical plane have static method and dynamic method.



(a) Idler modulation mechanism

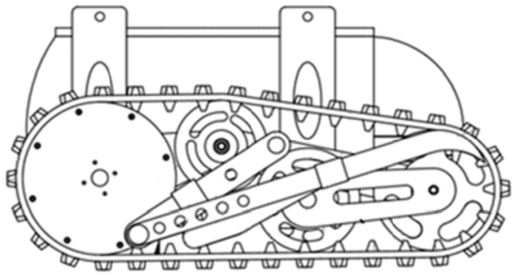


(b) Support blade crawler arm modulation mechanism

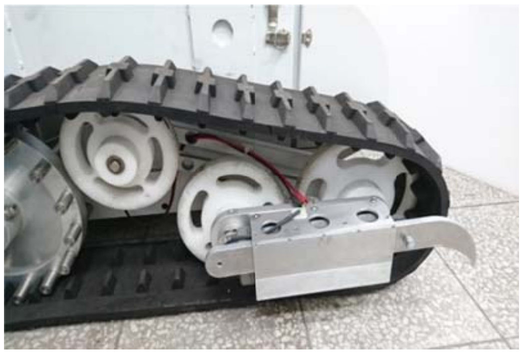
Fig. 3 The kinematics structure of the tracked wheel

The static method is passing the inclined plane or vertical plane by low speed. The slope tilt angle for vehicle passing is restricted by the stability loss of vehicle; the method considers the possibility of vehicle passing slope or stair, and that is mainly dependence on the tilt angle of the track front end or the vehicle climbing ability. In this paper, we presented a track system; it has available idler modules that can vary the level of the idler positions. When the idler in a high position, the front end of track have a high inclination, it can provide enough climbing ability. Further, when the idler in a low position, the front end of the track is down to the plane, that increases the length of the track, it can provide sufficient capacity to through the ditch, the track action shown in Fig. 4.

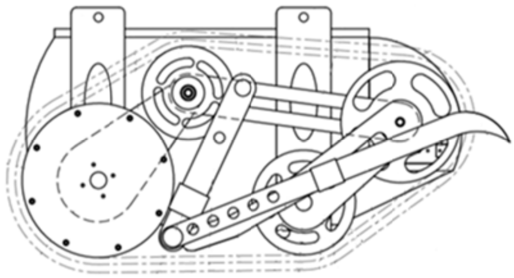
The dynamic method of the vehicle passing slope or stair is with higher speed, it will increase the angle of climb of vehicle passing capacity. When the vehicle passes slope or stair, the first idler wheel leaves support surface, the body begins to raise the tilt angle of the track front end. If the speed is higher, at the same distance, the vehicle can increase the angle of climb, and passing more complex terrain. Adoption dynamics method to pass slope or stair has great relationship on both edges of mutual position and shape.



(a) Illustration of track posture in the lower position



(b) A photo of track posture in the lower position



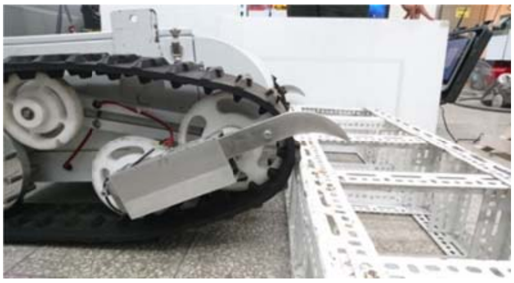
(c) Illustration of track posture in the higher position

(d) A photo of track posture in the higher position

Fig. 4 Various track and crawler arm configurations

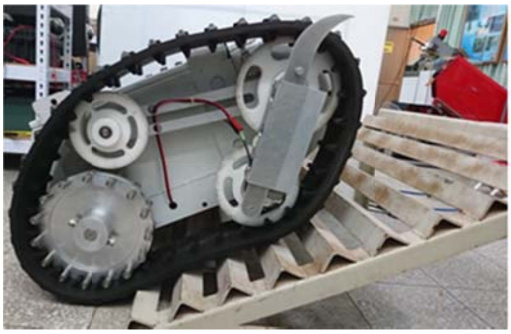
For inclined plane and stair climbing ability, the vehicles pass is related to the shape of the track front end, driving force and driving methods, especially we also use the blade crawler arm to help improve climbing ability. Usually, the vehicle track has a high rake angle; it will have the better climbing ability.

Good climbing ability contains the inclined plane passing, also contains overcoming the building stairs. In addition, another important factor for the abilities of the terrain obstacles passing, that can be adjusted to use the blade crawler arm to tow the vehicle body, and gets a booster to drag vehicle forward. The experiment of the presented robot which has overcome the slope and stair are shown in Fig. 5.



(a) The front end of the vehicle will pass the stair obstacle

(b) The vehicle is crossing the stair obstacles



(c) The vehicle utilized a high angle to through ramp

(d) The vehicle utilized a low angle to through ramp

Fig. 5 Robot under experimental tests

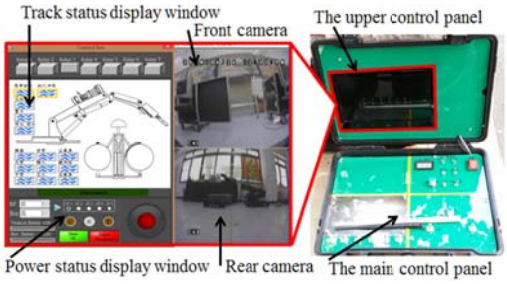


Fig. 6 The control box

IV. Implementation

Robot control contains a controller built into the robot and a set of wireless remote control box. The controller has been made to install it inside the robot structure. Also, two micro camera and LED lighting group are designed for spatial identification. At the same time, we use MCUs (The main control unit (MCU) is designed on the techniques which used the TMS320F281X DSP chip; it is used to control motor for each axis of motion control and transmission the system data or signal). The DSP chip calculates the angular velocity of the control box interface and linear velocity of the robot. The TMS320F281X DSP chip calculates the motor speed by producing a PWN signal. It can control all of the DC motors. The control box is shown in Fig. 6. All the motor driver and MCUs are embedded in an internal control unit as shown in Fig. 7. Fig. 7 shows the different control units' architecture of the MCUs. When an order of the device controller is given by control box, it is transferred to the robot by wireless communications. The view of the robot is provided to use the Micro CMOS cameras. The cameras are mounted at the front and rear of the robot body. The vision module makes the robot possible to easily movement in difficult terrain. The vision module of the robot is made with two cameras, the cameras have LED light ring group and radio device.

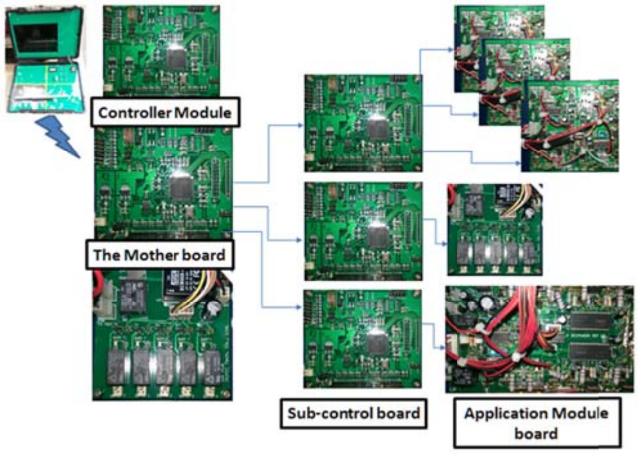


Fig. 7 Architecture of the main control unit

The control box uses TMS320F2801PZA-50 DSP chip; its control transfers are set in wireless modes. The controller provides a simple setting method to set the instruction and to get the operational position, and it has 24 buttons on the maximum extent, they allow user to meet their operation mode. We use virtual control panel vision to connect with control panel, it can use simple commands to communicate with a buttons and knobs; also can get the information to produce exclusive application instructions.

V. Conclusions

We have successfully developed a tracked robot with transformable movement mechanisms and a pair of crawling assisting blade arms to enhance the robot's off-road capability in a difficult terrain. It is capable of overcoming barriers of different shapes and sizes, such as stairs and slope of the complex environment. Most of the robots designed have only fixed track movement mechanism; therefore, they are less adaptive to complex environments. The presented design with transformable track movement mechanism was able to roam adaptively over mutative terrains. The features of transformable track movement system include modular, hull type body, waterproof and dustproof design. The track movement mechanism of the robot is designed to deform when it encounters uneven grounds or a soft ground. Thus, the robot can be operated in various types of terrain.

The variable kinematics structure of the tracked system has a compensating idler wheels deformation structure that can be used to roam adaptively over mutative terrains. The kinematics structure of the tracks has several good features, just to name a couple: To raise the track front-end angle, which effectively helped vertical wall climbing; to adjust the track length adaptive to the road surface, which enhances the ability to speedy travel.

The performance of the presented tracked robot system with a pair of blade arms was verified through experiments under a test-platform where stairs and slopes were present. We gained valuable experience in the actual performance verification. In particular, a pair of blade crawler arms with power were added on both sides of the mobile apparatus, thus, further enhancing its off-road capability. The blade crawler arm can tow the robot vehicle forward or raise the body; along with deformed track movement mechanism, the vehicle moved smoothly over the hostile terrains. The presented robotic system could be further demonstrated in field rescue missions in the event of disasters.

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References

[1] W. Wang, L. Zhou, Z. Du, and L. Sun," Track-Terrain Interaction Analysis for Tracked Mobile Robot," *Proceedings of the 2008 IEEE/ASME, International Conference on Advanced Intelligent Mechatronics*, July 2008, pp.126-131.

[2] C. R. Weishin, J. Blitch, D. Lavery, and E. Krotkov, "Miniature Robots for Space and Military missions," *Robotics & Automation Magazine*, vol.6, no.3, 1999, pp.9-18.

[3] D. Calisi, A. Farinelli, L. Iocchi, and D. Nardi, "Autonomous navigation and exploration in a rescue environment," *IEEE International in Safety, Security and Rescue Robotics Workshop*, June 2005, pp. 54–59.

[4] J. Casper and Robin R. Murphy," Human-Robot Interactions During the Robot-Assisted Urban Search and Rescue Response at the World Trade Center," *IEEE Trans on Systems, Man., and Cybernetics, Part B: Cybernetics*, vol.33, no.3, June 2003, pp.367-385.

[5] C. R. Weishin, D.B. Lavery, and G. Rodrigncz," Robots in space: U.S. missions and technology requirements into the next century," *J. Autunomous Robots*, vol. 4, May 1997, pp. 159-173.

[6] J. A. Okello, M. Watany, and D. A. Crolla," A Theoretical and Experimental Investigation of Rubber Track Performance Models," *Journals of Agriculture Engineering*, vol.69, 1998, pp.15-24.

[7] James H. Lever, Daniel Denton, and Gary E. Phetteplace," Mobility of a Lightweight Tracked Robot Over Deep Snow," *Journals of Terramechanics*, vol.43, 2006, pp.527-551.

[8] W. Lee and S. Kang," Rough Terrain Negotiable Mobile Platform with Passively Adaptive Double-Tracked and Its Application to Rescue Missions," *Proceeding of International Conference on Robotics and Automation*, 2005, pp.1591-1596.

[9] K. N. Kumar, A. Gopichand, M. G. Anjaneyulu, and B. G. Krishna," Design and Development of Adjustable Stair Climbing Robot," *International Journal of Research in Engineering and Technology* (IJRET), vol.2, no.4, Apr. 2013, pp.470-475.

[10] G. Bekker," Introduction to Terrain-Vehicle Systems," Ann Arbor: University of Michigan Press; 1969.

[11] Helmick, D. M. et al.," Multi-Sensor, high Speed Autonomous Stair Climbing," *Proceeding of International Conference on Intelligent Robots and System*, 2002, pp.733-742.

[12] S. Odedra, S. D. Prior, and M. Karamanoglu," Investigating the Mobility of Unmanned Ground Vehicles," *Proceedings of International Conference on Manufacturing and Engineering Systems*, 2009, pp.380-385.

[13] Y. Yamada, G. Endo, and E. F. Fukushima," Blade-Type Vehicle Bio-inspired by a Wharf Roach," *IEEE International Conference on Robotics & Automation* (ICRA), June 2014, pp.806-812.

[14] R. Edlinger, M. Zauner, and W. Rokitansky," Intelligent Mobility – New Approach of Robot Mobility Systems for Rescue Scenarios," *IEEE International Symposium on Safety, Security, and Rescue Robotics* (SSRR), Oct. 2013, pp.1-5.

[15] X. Zang, Y. Liu, and Y. Zhu," Structure Design of a Mobile Jack Robot," *Proceeding of the IEEE International Conference on Information and Automation* (ICIA), Aug. 2013, pp.1218-1223.

[16] Bram G. A. Lambrecht, Andrew D. Horchler, and Roger D. Quinn," A small, Insect-Inspired Robot that Runs and Jumps," *Proceedings of the IEEE International Conference on Robotics and Automation*, 2005, pp.1240-1245.

[17] P. Birkmeyer, K. Peterson, and R. S. Fearing," DASH: A Dynamic 16g Hexapedal Robot," *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems,* 2009, pp.2683-2689.

[18] S. Kim, JE. Clark, and MR. Cutkosky," iSprawl: Design and Tuning for High-Speed Autonomous Open-Loop Running," *The International Journal of Robotics Research*, vol.25, no. 9, Sep. 2006, pp. 903-912.