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New Hybrid Locomotion System Design

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ABSTRACT

Rescue, surveillance and bomb disposal are very hard and hazardous task to acheive by humans. Many victims are trapped inside the rubble in natural and man-made disasters. It is very difficult to locate those victims within short period of time by human source. Therefore, mobile robot offers an effective and alternate solution to this problem. In this study, a new design approach for a multi terrain-abilities mobile robot was presented. It consists the wheel and track type motion mechanism resulting as a hybrid mechanism. This changeover from wheel to track system or vice versa is done by track tensioner unit. Three wheeled mechanism helps the robot to move on flat path at high velocity and high maneuverability. The track system was designed for rough and unstructured path. This hybrid locomotion system robot gave the best performance for rescue and other hard operations in multi terrain environments.

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INTRODUCTION

Robot technology is moving through advance and matured level, where soon it would become potential to use strong and portable robots in various applications. In hazardous and unsafe environments for humans, the mobile robots may be used. Such robots are helpful in many tasks, to explore the affected area, trace and identify the fatalities from rubble, report their situation to control room and deliver first aid. The survival rate will be high, if survivors can be rescued and receive treatment immediately after the disaster occurred. In this regards, the rescue activities must be carried out as fast as possible to save the lives of victims. A mobile robot needs appropriate locomotion mechanisms that enable it to move unbounded throughout its environment. In order to enhance the work ability of robots, it becomes necessary to consider efficient locomotion mechanism, mainly for outdoor applications (Adachi and Koyachi, 2001). There are many possible ways, which makes the selection of a robot's approach to effective locomotion system for their design shown in Fig. 1. The hybrid locomotion mechanism seemed effective and efficient in all type of environments as compared to individual locomotion mechanism (Lacagnina, *et al*, 2003). The use of many locomotion modes would results an appropriate motion mechanism of robot for the persisting conditions in the work environment (Michaud *et al.*, 2005; Boxerbaum *et al.*, 2005; Crespi and Ijspeert, 2005).

In this paper the current development of Urban Search and Rescue (USAR) robots locomotion system was discussed and a new design of a hybrid locomotion system for robot was presented. The scope of study was to design and develop a hybrid motion mechanism for USAR mobile robot. In this system, robot can be able to work in wheel, track or wheel and track combined mechanism.

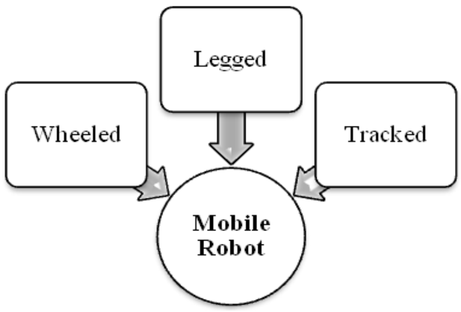

Fig. 1: Mobile robot

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2. Literature Review:

The research in the field of mobile robot is in high level, especially for rescue and urban search applications. A proper and appropriate mechanism, flexible mobility system is required to make the mobile robot more versatile and feasible. In some cases the working environment becomes very complicated and congested, that includes not only high obstacles but also narrow palisades and ground cluttered with rubble. Therefore, the robot should have the vital configurations that can be compatible with various tasks and complex environments.

In 2006, a shape shifting JL-I robot introduced which includes 3 modules and have rich configurations owing to the pose adjusting joints and the docking mechanisms (Zhang *et al*., 2006). The researcher designed many mobile robots for USAR task but still robots fails to perform rescue operation with high success. In 2006, a hybrid robot was presented with 2 modular mobile units, based on track and snake like motion structure. It is able to move in all type of terrains, narrow holes by changing the body shape (Ye and Lii, 2006). RAPOSA designed in 2007, with 2 units, main body and front flippers. The flippers help the robot to climb into stairs and high obstacles. It consists of camera, temperature and humidity sensors (Marques *et al*., 2007). The rescue robot should be small, light in weight and low cost, that can put in operation very fast after the disaster, because humans cannot work at dangerous place immediately. In 2008 a small spherical hybrid robot was presented, with abilities of hopping, bouncing, and rolling mechanism to move into deep spaces for search of victims (Dubowsky *et al*., 2008). By using high energy micro fuel cells combined with lightweight DEA's robot gains high flexibility and versatility. A track motion type robot was introduced in 2009 (Li *et al*., 2009); it has 3 modules, 2 link arms with 7 DOF, 2 pitch joints and 2 yaw joints. This robot can work on land surface and in water. It has ability to change the shape according to path and terrain.

Hybrid system with track and wheel mechanism designed in year 2009, its locomotion may be in track, wheel or both (Bayar *et al*., 2009). In 2010, a rocker type robot was presented for coal mine rescue application, which consists 4 wheels drive with bevel gear mechanism. The rocker suspension provides the stable mechanism for drive in all type of terrains (Li *et al*., 2010). Hybrid mechanisms with the locomotion platform and manipulator arm introduced in 2010, this robot supports both locomotion and manipulation interchangeably. Only one motor used for manipulation DOF and mobile platform DOF (Ben-Tzvi *et al*., 2010) it can work in track, leg and hybrid motion mechanism. In 2010, a Track locomotion robot presented with 2 front flippers and a manipulator arm. To increase the rescue and victim identification activities, it is rich with cameras, lights and sensor (Miro and Dissanayake, 2010). To avoid the slippage of robot, while moving on various terrains, a double track system on both sides was introduced in 2011. By using backstepping method combined with scaling technique, robot become more stable on multi environments (Zhou *et al*., 2011).

In 2011, a climbing type robot was introduced with 4 legs designed in 4-DOF (Sintov *et al*., 2011). The claws attached to each leg, gripping device at the tip of each leg with 12 fishing hooks and it can move freely on the wall's surface. Small rescue robot with 2 side arms and crawl motion mechanism was designed in 2011. In which force applied by arms on contacting surface, which cause the robot body moves. The arms consists 4 bar links, work in quick return mechanism (Richardson *et al*., 2011). In 2011, a multi track mechanisms robot introduced with additional arms on both sides (Enayati and Najafi, 2011), which helps the robot to gain better maneuverability on rough terrains. A shape shifting tracked robotic vehicle (STRV) for rescue operation introduced in 2012, which can be able to move in all type of obstacles, paths at constant nominal propulsion speed (Vincent and Sun, 2012). In 2012, a Rocker-bogie mechanism (Kim *et al*., 2012), by all wheels is contact with ground during climbing stairs and this enhance its locomotion abilities and flexibility.

3. System Design Approach:

To design mechanical systems, the designer should be proficient in the design of individual elements and components that embrace the system. The parameters which commonly need to consider while design any mechanical component, such as part dimensions, shape, material, load and type of application. The design of virtual model for small hybrid mobile robot was done in Solidworks. The designing covers the individual part design and then assembly of full system. The detail of model design, component description and dimension are given in Fig. 2, 3, 4 and Table 1 respectively. In this system, robot can be able to work in hybrid locomotive mechanism (wheel and track). The wheel and track system will work within interchangeable phenomena and it gives the additional flexibility to mobile robot in its motion mechanism. The hybrid systems are more effective and versatile as compared to the individual mobility systems (Bakhsh *et al*., 2013).

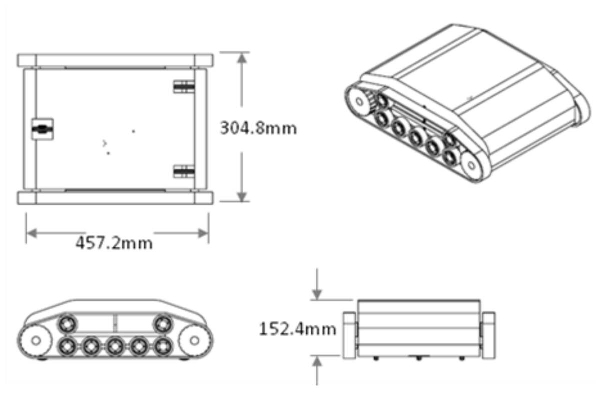
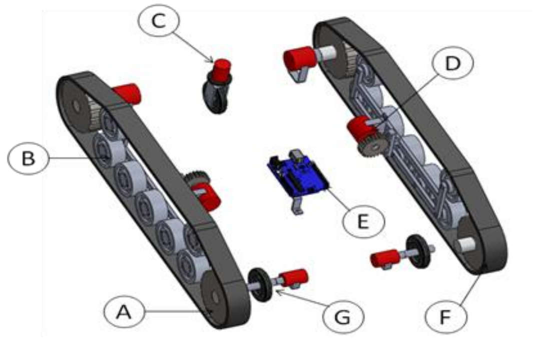


Fig. 2: New design of hybrid mobile robot



(A) Track Sprocket (B) Guider drum (C) Motor (D) Rack & pinion (E) Control board (F) Track belt (G)Wheel

Fig. 3: Detailed view of new model

Fig. 4: Assembled model

Table 1: Component description

Name	Quantity	Detail
Wheel	3	1 steering, 2 drive
Track sprocket	4	2 driver, 2 follower
Guider drum	14	7 each unit
Floating unit	2	1 each side
Spur gear	2	1 each track tensioner unit
Bearing	21	4 sprocket, 3 wheel, 14 tensioner unit
Brushless motor	4	2 sprocket drive, 2 wheel drive
Steeper motor	3	2 Tensioner unit, 1 steering wheel
Control board	1	To control whole system

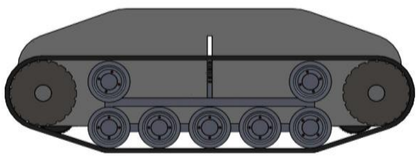
4. Practical Working Approach:

The working of this robot depends upon the locomotion mechanism, it consists two interchangeable mobility systems. The robot can work on wheel, track or wheel and track combined. These multi locomotion mechanisms are helping the robot to work in all type of terrains with interchangeable motion mechanism. Wheel mechanism is easy to design and control as compared to other locomotion types. It is simpler and small in terms of descriptions, but to work only on flat and smooth surface is the main disadvantage. They are unable to work or move on unstructured or uneven terrains.

Beside this, it has number of advantages on smooth surfaces such as; high velocity, energy efficient, high maneuverability and simple mechanical design. The robot moves on smooth path as wheel robot, the three wheels would be in contact with the ground. The front wheel work as a steering system and two rear wheels are for drive/propulsion. The wheeled mechanism can work, while it moving on flat inclined plan but up to a limited height. Then, locomotion mechanism of robot switched over from wheel to track by means of track tensioner unit, shown in Fig 5. The track tensioner unit is controlled by rack and pinion mechanism, which helps the loading and unloading of track locomotion. When the robot need to move on rough or unstructured path and steps its mechanism would be track system, because it is more flexible on rough surfaces with high stability.

Mode 1 *Wheeled sytem*

Mode 2 *Tracked system*



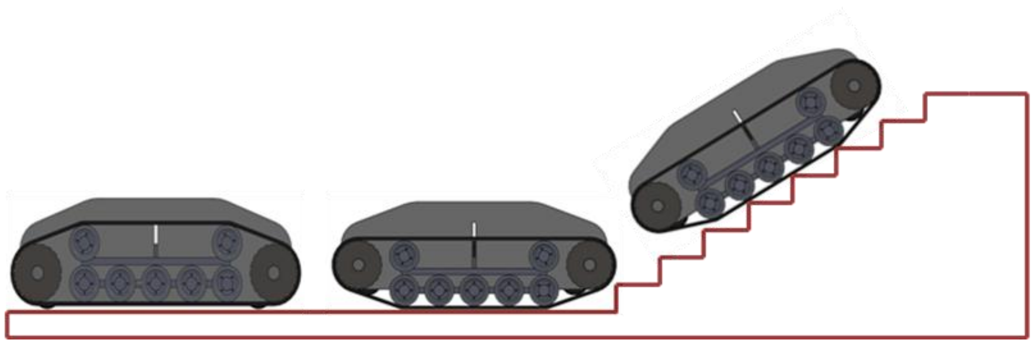


Fig. 5: Modes of operation

5. Comparative Study:

Mechanical design, energy consumption, velocity and flexibility are important factors for consideration while designing a hybrid locomotion system for mobile robot. Fig. 6 shows the comparison between existing hybrid (wheel and track) mobile robot named as CoMoRAT (Bayar *et al*., 2009) with the new proposed design for hybrid (wheel and track) locomotion system. In Fig 6(A) it shows that the wheel of robot touches the obstacle but track unit is on the space and it would be difficult to pass through such steps or obstacles, while wheel start slipping. This is because the diameter of wheel is 10cm and diameter of track pulley is 9cm. There is no fully steerable wheel in this system, therefore it has low maneuverability.

The new proposed system for hybrid locomotion is shown in Fig 6(B), which gives the clear concept of wheel and track systems. When robot need to work on wheel system, the track unit would be idle and while it works on track system then wheels are on space. This changeover from one locomotion system to other is done by automatically according to the nature of environments, it increase robots flexibility for multi terrains. One front wheel is fully driven by separate motor for steering mechanism. This steering system would enhance the robot maneuverability without slowdown its velocity.

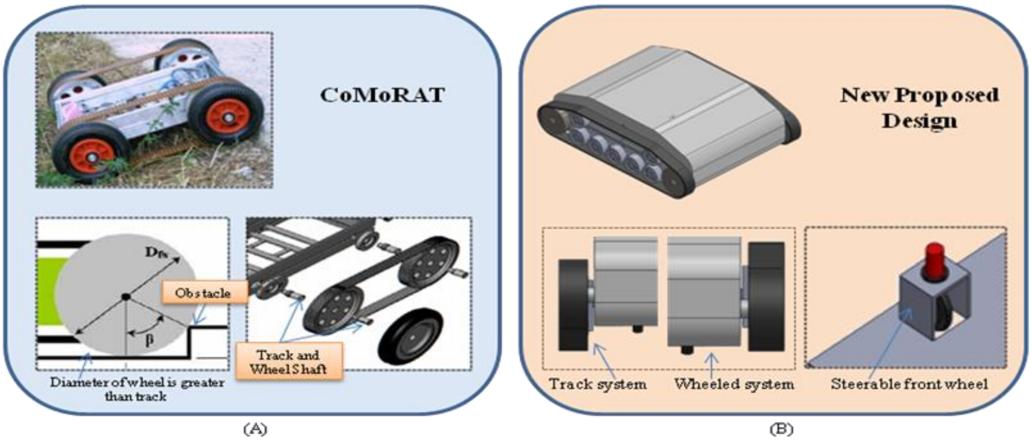


Fig. 6: Comparison between CoMoRAT and New Proposed System

Discussion:

As the urban search and rescue task is very difficult and covers complex workplace. Therefore, the rescue robots should be rich in locomotion mechanism, so that it can moves easily through various steps, gaps and obstacles to reach at destination. It should be strong enough and capable of survive in all weather platforms such as desert, mud, snow, sedge or scrubby terrain. Beside all this, it is also necessary that USAR robots be small in size, stable, portable, energy efficient, high velocity, versatile and light weight. Through the study, it is clear that, the hybrid locomotion mechanisms are good for complex environments. Robot will be able to work in all harsh and hostile environments, if in the system the track locomotion combined with other type of mechanisms. The main advantages of this robot is wheel type locomotive mechanism because of this type, robot will be good enough in dynamics, kinematics nature and also with high motion velocity on smooth path. Wheel type locomotion system is more easy to design, control and maneuverable, but it is limited only to plain and smooth terrains. In the combination of tracked locomotion, it would be effective for rough and unstructured path.

Conclusion:

It gives the clear figure that new design of locomotion system for mobile robot would enhance the flexibility, versatility and stability in kind of environments. With the additional front wheel, which enhance its maneuver quality for all type of terrains. It is concluded that, the new design of hybrid locomotion system of mobile robot, will be more effective and efficient in all kind of applications.

REFERENCES

Adachi, H. and N. Koyachi, 2001. "Development of a leg-wheel hybrid mobile robot and its step-passing algorithm." In the Proceeding of 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems, Expanding the Societal Role of Robotics in the Next Millennium, 2: 728-733.

Bakhsh, Q., K. Hasnan, A. Ahmed, 2013. "Comparative study between wheeled and tracked mobility system for mobile robot." Applied Mechanics and Materials, 363: 538-543.

Bayar, G., A.B. Koku, E. Konukseven, 2009. "Design of a Configurable All Terrain Mobile Robot Platform." International Journal of Mathematical Models and Methods in Applied Sciences, 3: 366-373.

Ben-Tzvi, P., A.A. Goldenberg, J.W. Zu, 2010. "Articulated hybrid mobile robot mechanism with compounded mobility and manipulation and on-board wireless sensor/actuator control interfaces." Mechatronics., 20: 627-639.

Boxerbaum, A.S., P. Werk, R.D. Quinn and R. Vaidyanathan, 2005. "Design of an autonomous amphibious robot for surf zone operation: part I mechanical design for multi-mode mobility." In the Proceeding of 2005 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, pp: 1459-1464.

Crespi, A., and A.J. Ijspeert, 2005. "Swimming and Crawling with an Amphibious Snake Robot." In the Proceeding of 2005 IEEE International Conference on Robotics and Automation Barcelona, Spain., pp: 3024-3028.

Dubowsky, S., S. Kesner, J.S. Plante, P. Boston, 2008. "Hopping mobility concept for search and rescue robots. Industrial Robot" An International Journal, 35: 238-245.

Enayati, N., and F. Najafi, 2011. "Design and manufacturing of a tele-operative rescue robot with a novel track arrangement." Industrial Robot: An International Journal., 38: 476-485.

Kim, D., H. Hong, H.S. Kim, J. Kim, 2012. "Optimal design and kinetic analysis of a stair-climbing mobile robot with rocker-bogie mechanism." Mechanism and Machine Theory, 50: 90-108.

Lacagnina, M., G. Muscato and R. Sinatra, 2003. “Kinematics, dynamics and control of a hybrid robot Wheeleg.” Robotics and Autonomous Systems, 45: 3–4. 161-180.

Li, B., S. Ma, J. Liu, M. Wang, T. Liu, Y. Wang, 2009. “AMOEBA-I: A Shape-Shifting Modular Robot for Urban Search and Rescue.” Advanced Robotics, 23: 1057-1083.

Li, Y., S. Ge, H. Zhu, H. Fang, J. Gao, 2010. “Mobile platform of rocker-type coal mine rescue robot.” Mining Science and Technology (China). 20: 466-471.

Marques, C., J. Cristovao, P. Alvito, P. Lima, J. Frazao, I. Ribeiro, R. Ventura, 2007. “A search and rescue robot with tele-operated tether docking system. Industrial Robot.” An International Journal., 34: 332-338.

Michaud, O.I.S., D.L. Etourneau, M. Arsenault, Y. Bergeron, R. Cadrin, F.R. Ed, M. Legault, M. Millette, M. Tremblay, P. Lepage and Y.A.N. Morin, 2005. “Multi-Modal Locomotion Robotic Platform Using Leg-Track-Wheel Articulations. Autonomous Robots.” 18: 137-156.

Miro, J.V., G. Dissanayake, 2010. “Automatic Fine Motor Control Behaviours for Autonomous Mobile Agents Operating on Uneven Terrains.” In the Proceeding of 3rd International Symposium on Practical Cognitive Agents and Robots, Toronto., pp: 33-40.

Richardson, R.C., A. Nagendran, R. Scott, 2011. “The sweep-extend mechanism: A 10-bar mechanism to perform biologically inspired burrowing motions.” Mechatronics, 21: 939-950.

Sintov, A., T. Avramovich, A. Shapiro, 2011. “Design and motion planning of an autonomous climbing robot with claws.” Robotics and Autonomous Systems, 59: 1008-1019.

Vincent, I., Q. Sun, 2012. “A combined reactive and reinforcement learning controller for an autonomous tracked vehicle.” Robotics and Autonomous Systems, 60: 599-608.

Ye, C., B. Lii, 2006. “Design and Basic Experiments of a Shape-shifting Mobile Robot for Urban Search and Rescue.” In the Proceeding of 2006 IEEE/RSJ International Conference on Intelligent Robots and Systems, Beijing, China, pp: 3994-3999.

Zhang, H., W. Wang, Z. Deng, G. Zong, J. Zhang, 2006. “A Novel Reconfigurable Robot for Urban Search and Rescue.” International Journal of Advanced Robotic Systems, 3: 359-366.

Zhou, B., J. Han, X. Dai, 2011. “Backstepping Based Global Exponential Stabilization of a Tracked Mobile Robot with Slipping Perturbation.” Journal of Bionic Engineering., 8: 69-76.