Scalable Six-Legged Ambulating Robot for Inaccessible Environments

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1 Motivation

Robotics can play a key role when dealing with environments that are inaccessible or hazardous for humans including ship hulls, bridge installations, oil rigs, and first reponse scenarios. Due to irregular terrain, wheeled vehicles are ineffective at traversing the necessary terrain. Legged systems are a salient solution. However, legged systems require special considerations regarding workspace and stability.This paper presents the design considerations and development of a scalable six-legged ambulating robotWith enhanced workspace capability to enable larger stable workspaces under different configrations, space constraints, and terrain.

2 State of the art

Multiple robotic solutions have been developed to handle maintenance and repair within highly constrained environments including hull blasting [1], bridge inspection [2], pipe inspection [3], tank inspection [4], and sewer inspection [5]. However, these systems are still rather limited when handling highly irregular terrain and are generally incapable of providing the necessary degrees-of-freedom for repair work.

3 Own Approach

The proposed research aims at developing a scalable mobile micro-machine, based on hexapod robots to remove humans from inaccessible and hazardous environments. An example scenario is shown in Fig. 1. To make the robot able to change its size to adjust itself to get into different environments with different sizes. Adding extendibility to the hexapod widens the workspace for machining purposes, provides the hexapod with the ability to walk with different steps and thereby different speeds, and allows for dynamic adjustment for walking, manipulation, and energy usage.

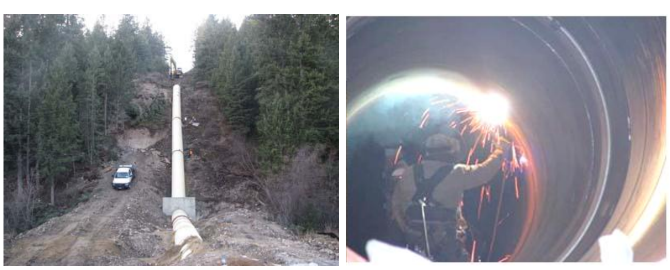

Figure 1. Using hexapod robots instead of human in difficult to acces, confined, and hazardous environments [6]

4 Current Results

A scalable hexapod walking robot based on the proposed approach was designed and prototyped as shown in Fig. 2. Each leg in SHWR is provided with 5-DOF using three pivot joints as hip, knee, ankle joints, and two prismatic joints. The prismatic joints give the leg the ability of changing the overall leg length. This will enable the robot to be able to change its size to adjust for the environment. This mechanism of the legs provides 6-DOF to the platform for manipulation purposes. Therefore, the SHWR has 36-DOF totally including 6-DOF for the platform and 30-DOF for six legs, 5-DOF per leg.

Figure 2. Scalable six-legged ambulating robot

5 Best Possible Outcome

By continuing this research, we expect to have a scalable robot usable for a wide range of inaccessible environments.

References

[1] A. Iborra, B. Alvarez, F. Ortiz, F. Mar´ın, C. Fern´andez, and J. Fern´andez-Mero˜no, “Service robot for hull-blasting,” in The 27th Annual Conference of the IEEE Industrial Electronics Society, IECON’01, vol. 3, 2001, pp. 2178–2183.
[2] J. Oh, A. Lee, S. Oh, Y. Choi, B. Yi, and H. Yang, “Design and control of bridge inspection robot system,” in International Conference on Mechatronics and Automation, 2007, pp. 3634–3639.
[3] C. Choi, B. Park, and S. Jung, “The design and analysis of a feeder pipe inspection robot with an automatic pipe tracking system,” IEEE/ASME Transactions on Mechatronics, vol. 15, no. 5, pp. 736–745, 2010.
[4] H. Schempf, B. Chemel, and N. Everett, “Neptune: above-ground storage tank inspection robot system,” IEEE Robotics and Automation Magazine, vol. 2, no. 2, pp. 9–15, 1995.
[5] A. Nassiraei, Y. Kawamura, A. Ahrary, Y. Mikuriya, and K. Ishii, “Concept and design of a fully autonomous sewer pipe inspection mobile robot,” in IEEE International Conference on Robotics and Automation, 2007, pp. 136–143.
[6] http://www.bitterrootirrigationdistrict.net/media-gallery/

Foot Force-Based Reactive Stability Control of Multi-Legged Robots

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1 Motivation

It is essential for any multi-legged walking robot to be able to maintain its stability under unpredicted external stimuli such as when walking over irregular terrain or slope or when some external force and moment are exerted. The possibility of losing the stability will increase when using legged robots for unknown environments with uneven terrain. In such cases, the robot should be able to compensate loss of the stability. For controlling the robot under such conditions, stability analysis and control is a key component.

2 State of the art

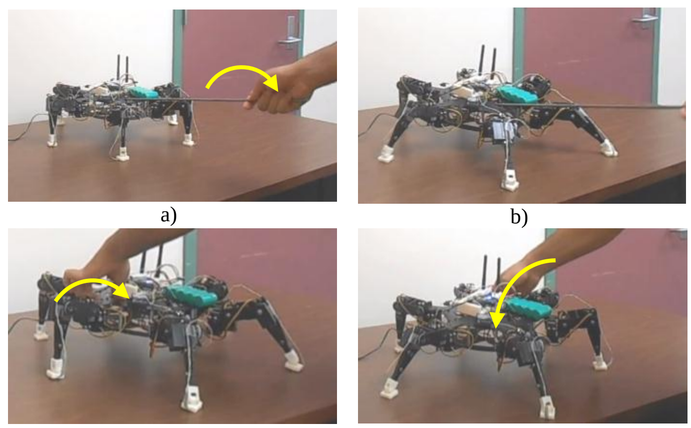
There are several widely used stability criteria in the field of multi-legged and multi-wheeled systems. These criteria can be divided into static and dynamics-based criteria, and further classified into five categories based on the stability metric: distance [1], angle[2], energy[3], moment[4], and force [5]. However, to be used for a real-time reactive stability controller over unknown terrain, their calculation and sensory information cost would be very high since they need real-time information and calculation of the geometry and inertia of the system.

3 Own Approach

In order for the robot to be able to compensate loss of the stability by a real-time reaction control system, two steps are necessary. 1) Stability Measurement and Prediction and 2) Reaction. Our previously presented Foot Force stabitli Margin (FFSM) [5] is considered for the controller in order for the robot to have a sense of stability to be able to measure the stability of the robot and predict when it is going to lose its stability. Once the robot has an understanding of stability, in case of losing stability, the robot needs to decide what to do for compensation. This decision is broken up into body CG motion and changing the foothold distribution. The later was chosen in this work to compensate for the lost stability and recover itself to the maximum possible stability level. Therefore, if the stability of the robot falls under the defined boundary for the controller based on FFSM, the footholds of the robot will change according to the foot force distribution of the robot at the moment.

4 Current Results

A Lynxmotion hexapod robot was programmed to implement the proposed approach for reactive stability control of the system. The robot was stimulated by external force (Fig 1a) and the expected reaction was observed (Fig 1b). When the stability of system was affected by the external load, the system immediately compensated by extending the legs. The system reaction to different loading scenariors are presented in Figs. 1c and 1d.



a) b) c) d)

Figure 1. Experimental implementation of reactive stability

5 Best Possible Outcome

By continuing this research, we expect to have a complete autonomus reactive stability control system for any type of uneven terrain and external stimuli.

References

[1] R.B. McGhee and A.A. Frank, "On the Stability Properties of Quadruped Creeping Gaits," *Mathematical Bioscience*,3, 331-351, 1968.
[2] E.G. Papadopoulos and D.A. Rey, "A New Measure of Tipover Stability Margin for Mobile Manipulators," *Proceedings of the IEEE International Conference on Robotics and Automation*,3111-3116, 1996.
[3] A. Ghasempoor and N. Sepehri, "A measure of Machine Stability for Moving Base Manipulators," *Proceedings of the IEEE International Conference on Robotics and Automation*, 2249-2254, 1995.
[4] D. Kang, Y. Lee, S. Lee, Y. Hong, and Z. Bien, "A Study on an Adaptive Gait for a Quadruped Walking Robot under External Forces," *Proceedings of the IEEE International Conference on Robotics and Automation*, 2777-2782, 1997.
[5] Mahdi Agheli, Stephen S. Nestinger, Foot Force Criterion for Robot Stability, *in proceedings of the 15th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines*, Johns Hopkins University, Maryland, USA, July 23-26, 2012.