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A tree climbing machine: Treebot – design and implementation

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ABSTRACT

This paper is based on a tree climbing machine Treebot that has high capability on an irregular tree environment and surpasses the state of the art tree climbing machines. Treebot's body is a novel continuum maneuver structure that has high degrees of freedom and superior extension ability. Treebot also equips with a pair of omni- directional tree grippers that enable Treebot to adhere on a wide variety of trees with a wide range of gripping curvature. By combining these two novel designs, Treebot is able to reach many places on trees including branches. Treebot can maneuver on a complex tree environment, but only five actuators are used in the mechanism. As a result, Treebot can keep in compact size and lightweight. Although Treebot weighs only 600 grams, it has payload capability of 1.75 kg which is nearly three times of its own weight. On top of that, the special design of the gripper permits zero energy consumption in static gripping. Numerous experiments have been conducted on real trees. Experimental results reveal that Treebot has excellent climbing performance on a wide variety of trees.

INTRODUCTION

Climbing machines have become a hot research topic in recent decades Most research in this area focuses on climbing manmade structures, such as vertical walls, glass windows, and structural frames. Little research has been conducted specifically on climbing natural structures such as trees. The nature of trees and manmade structures is very different. For example, trees have an irregular shape and their surface is not smooth. Some types of trees have soft bark that peels off easily. Hence, most of the methods applied in the development of wall-climbing machines are not applicable for tree climbing machines. Preventing trees from failing is important to protect human life and property in urban areas. Most trees in urban areas require regular maintenance. To reach the upper parts of a tree to perform such maintenance, workers need to climb the tree. However, tree climbing is dangerous, and thus the development of a tree-climbing machine could assist or replace tree climbers in their work.It is a climbing machine designed to replace human workers in removing branches from trees. The machine climbs by encircling the entire tree trunk. The size of the machine is thus proportional to the circumference of the trunk. Woody avoids branches by turning its body and opening the gripper, but it requires an almost straight tree trunk. Kawasakialso developed a climbing machine for tree pruning. uses a gripping mechanism inspired by lumberjacks, and uses a wheel-based driving system for vertical climbing. It encircles the entire tree trunk for fastening on a tree. It cannot avoid branches as the fastening mechanism cannot be opened. Aracil proposed a climbing machine, CPR, that uses a Gough-Stewart platform to maneuver. It consists of two rings that are joined by six **linear actuators** through universal and spherical

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joints at each end. Same as the gripping mechanism cannot open and hence it can onlyclimb on tree without existing of branch. However, it has greater maneuverability than the aforementioned two machines, and can climb a branchless tree trunk with a certain range of bending is a wall-climbing machine that imitates the movement of an insect in using six legs to maneuver. This machine has also been demonstrated to be able to climb trees. As the gripping mechanism only occupies a portion of the surface to be climbed, the size of the machine is independent of the climbing target. As a result, it is relatively small. However, it did not claim whether it can perform other motions such as transition from a trunk to a branch.It also has the another type of climbing machine designed to climb straight poles at high speed. It can be seen that these machines are limited to climbing straight tree trunks, and cannot climb trees that are curved or have branches. As branches and curvature are present in almost all trees, the application of these machines is strongly restricted.

As a result, this paper proposes a novel tree climbing machine named Treebot (as shown in Fig. 1) that has high maneuverability on tree. Treebot equips with a pair of omni- directional tree grippers that able to grip on tree surface in a wide range of gripping curvature. It enables Treebot to grip tightly on large tree trunks and small branches. The applied continuum maneuver mechanism has large workspace and high degrees of freedom (DOF). It allows Treebot to perform various actions, such as moving between trunk and branches. Treebot is compact and lightweight, only five actuators are used. The special gripping mechanism allows zero energy consumption in static gripping. With the appropriate equip- ment, Treebot could assist workers to perform arboricultural tasks such as inspection and maintenance. It could also be used as a mobile surveillance system to observe the living behavior of tree living animals.

The paper is organized as follow. Section II describes the mechanical design and mechanism of Treebot. In Section III, the motion of Treebot is described. The prototype of Treebot is introduced in Section IV while the experimental results are summarized in Section V. Finally, conclusion is given in Section VI.

Fig. 1. The tree climbing machine – Treebot

MECHANICAL DESIGN OF TREEBOT

The overall design of Treebot is shown in Fig. 2. The structure of Treebot is mainly composed of two parts: an omni-directional tree gripper and a continuum manipulator. Two grippers are connected to the ends of the continuum manipulator respectively. The grippers can adhere on a tree surface tightly while the continuum manipulator acts as maneuver mechanism to move another end of the gripper to a target position.

Omni-directional Tree Gripper

There are many innovative approaches to provide adhesive force such as vacuum elastomeric adhesive electroadhesive] and fibrillar adhesive These methods work well on urban settings such as vertical walls and glass windows that are smooth and flat. However, they are not applicable on tree surface, as the nature of trees is totally different from urban settings. Claw climbing method is widely used in tree living animals such as squirrels and birds. Through the observation of the tree living animals, the claw gripping is reliable on a tree surface. As a result, the claw gripping method is adopted to provide adhesive force. The design of the proposed gripper is aimed at providing adhesive force on a wide range of gripping curvature such that the gripper is able to adhere on tree trunks and branches. The gripper is designed to be omni-directional along its principal axis so that no additional orientation actuator and control is needed about its principle axis and hence keeps Treebot in lightweight and simple.The gripper is composed of four claws equally separated by 90 degrees.

The claws adopt two bar linkages mechanism to generate optimal direction of acting force. Fig. 3 shows the gripping mechanism. All claws in a gripper are actuated by a linear motor. A pushing plate is mounted at the end of the linear motor. When the linear motor extends, the plate pushes all the phalanges 1 and hence makes the phalanges upward. The spring on joint A is further compressed and the spring on joint B is released at the same time. This motion pulls spines off from gripping substrate. When the linear motor contract, the compressed springs on joints generate a force to push claws back to the gripping substrate and at the same time the spring on joint B will further be compressed. Since the gripping force is generated by the preloaded springs only, the static gripping with zero energy consumption can be achieved. The constant force spring (a flat spiral spring) is adopted to ensure that the force is independent to the claw traveling angle. In addition, since the moving mechanism of each claw is independent, it allows the claws to travel in different angle. This ensures that all of the claws penetrate into the gripping substrate, even if it has an irregular shape,to generate the maximum force.

Continuum Manipulator

There are many types of continuum manipulators, such as wire and pneumatic-driven .Most of them are able to bend in any direction and some are even able to extend to a certain extent. Most current research uses the continuum structure in machine arms, but few researchers have realized that it can also be applied to maneuvering. The continuum mechanism is a compliant structure, as it does not contain fixed joints. Its inherent passive compliance is particular benefit for maneuvering in an arboreal environment, as it can often eliminates the need for complex force sensing and feedback control. For climbing purposes, the manipulator must be compact and lightweight. There are many types of continuum manipulator, but none of them fulfills all of these requirements. Existing continuum manipulators need to connect to large external boxes that contain wire, drivers, motors, or air pumps. Al- though some pure wire-driven continuum manipulators have the potential to be more compact and lightweight, the manipulators are not extendable. Extendibility is important, as Walker shows that the inclusion of extension ability for continuum manipulators extends the workspace considerably.

Due to these limitations, a novel design of continuum manipulator to maneuver with both bendable and extendable functionalities is proposed. The proposed continuum manip- ulator is a self-contained module that actuators are integrated and hence no external control box is required. It makes the proposed continuum manipulator compact and lightweight. In addition, the special driving mechanism allows superior extension ability that the existing designs cannot achieve.

Fig. 4 shows the CAD model of the proposed continuum manipulator. It is formed by three mechanical springs that are connected in parallel. The distance between the center of the continuum manipulator and springs are equal and the springs are equally separated by 120 degrees as shown in Fig. 7(a). One end of spring is fixed on a plate, while the other end does not have any fixed connection. The springs pass through a plate which contains three DC motors to control the length of springs between two plates indepen-dently. Through the control of the length of each spring, the continuum manipulator can perform bending and extension motions. Commonly, the number of actuators required in each section of continuum manipulator is more than the number of admissible degrees of freedom. However, in the proposed structure, only three actuators are used but it can provide 3 DOF. This structure provides maximal DOF with minimal actuators. The actuation mechanism is similar to rack and pinion mechanism which allows unlimited extension of the continuum manipulator theoretically. In practice, it is limited by the length of the springs only. The spring can be treated as a bendable rack. The spring should only be allowed to bend in any direction but not able to compress or extend so as to keep a constant gap distance for pinion to drive. On top of that, keeping the springs in constant distance through the entire manipulator is important to keep a uniform shape. As a result, several passive spacers are installed at the middle of the manipulator to constrain the distance among springs. The maximal distance between constraint plates are constrained by wires.

MOTION OF TREEBOT

Locomotion of Treebot

The locomotion of Treebot is similar to inchworms which is a kind of biped locomotion. Fig. 5 shows a complete climbing gait of the locomotion. It is composed of six climbing steps. The square colored in grey represents the closed gripper that attached on the substrate while the square colored in white represents the opened gripper that detached on the substrate. The order of motion in the figure represents the locomotion of moving forward. The locomotion of mov ing backward is just in reverse order.

Treebot is able to change a moving direction in three-dimensional space by bending the continuum manipulator. It allows Treebot to climb along a curved shape of tree or avoid obstacles such as non-passing through branches. This ability makes Treebot has high maneuverability that surpass the existing tree climbing machines.

Kinematics of the Continuum Manipulator

Jones [30] introduces a kinematic model for a general class of continuum machine. It is found that this model is also suitable to represent the properties of the proposed

Control of Treebot

In this state, Treebot is a remote control machine. The control input of the gripper is simply an on/off command to make grippers fully open or close. As for the control of the continuum manipulator, since it has three DOF, three channels of input are needed. One way is to directly input the length of each spring. However, it is not an intuitive way for human manipulation. Human being always has a perspective of the direction of motion when controlling something, i.e., the concept of left, right, front and back. As a result, to make an intuitive.

EXPERIMENTS AND RESULTS

Numerous experiments have been conducted to evaluate the performance of Treebot in different aspects, i.e.,

- 1)Climbing on different species of trees;
- 2) Transition motion;
- 3)Turning motion;
- 4) Slope climbing.

Climbing on different species of trees

The tree climbing tests have been implemented on thirteen species of trees. Treebot is commanded to perform vertical climb up motion. The species of trees, diameters and the number of total trials and successful climbing gaits are summarized in Table II. Results show that Treebot performs well on a wide variety of trees. It can be noticed that the range of successful climbing diameter of tree is wide, from 64 mm to 452 mm. However, Treebot will fail on several species of trees, i.e., Melaleuca quinquenervia, Cinnamomum camphora and Bambusa vulgaris var. Striata. The reason of fail climbing on Bambusa vulgaris var. Striata is that the tree surface is very hard that the spine on gripper is difficult to penetrate. As for the Melaleuca quinquenervia and Cinnamomum camphora, their barks can be peeled off easily. Even the gripper can grip the tree, Treebot will fall with bark. By the experimental results, it can be concluded that Treebot performs well on the trees that the surfaces are not very hard and have less exfoliation.

Transition motion

In order to verify the maneuverability of Treebot, a tran- sition motion from a trunk to a branch has been tested. An experiment has been implemented on a Bauhinia blakeana. The diameter of the initial gripping trunk is 280 mm and the slope is about 45 degrees while the diameter of the target gripping branch is 118 mm and the slope is about 90 degrees. Part of the transition motions are shown in Fig. 9. It shows that Treebot was succeeded to leave the trunk andcompletely climbed on the branch. This transition motion takes three climbing gaits within three minutes.

Slope climbing

This experiment examined the maximal climbing slope of Treebot. It has been implemented on a Bauhinia blakeana with diameter 172 mm. The climbing angle is about 103 degrees. Part of the climbing motions can be found in It can be seen that Treebot climbed up the tree successfully. There is no over slope climbing effect appeared in the experiment.

CONCLUSION

In this paper is a trre climbing machine "Treebot" is presented that the maneuverability surpasses the state of the art tree climbing machines. It is composed of a pair of omni-directional tree grippers for holding the machine on a tree surface and a novel 3 DOF continuum manipulator for maneuvering. The locomotion and workspace of Treebot are also discussed. Numerous experiments have been conducted. Experimental results reveal that Treebot has excellent climb- ing performance on a wide range of trees. It is found that it works well on trees that surfaces are not very hard and have less exfoliation. Results also show that the Treebot has high maneuverability on tree environment.

REFERENCES

[1]. B. Aksak, M. P. Murphy, and M. Sitti, "Gecko inspired micro-fibrillar adhesives for wall climbing machines on micro/nanoscale rough sur- faces", IEEE International Conference on Machineics and Automation, Pasadena, CA, USA, 3058-3063, 2008, 19-23

[2]. H. Prahlad, R. Pelrine, S. Stanford, J. Marlow, and R. Kornbluh, "Electroadhesive Machines-Wall Climbing Machines Enabled by a Novel, Robust, and Electrically Controllable Adhesion Technology", IEEE International Conference on Machineics and Automation, Pasadena, CA, USA, 19-23, 2008.

[3]. S. Kim, M. Spenko, S. Trujillo, B. Heyneman, D. Santos and M. R. Cutkosky, "Smooth Vertical Surface Climbing With Directional Adhesion", IEEE Transactions on Machineics, 24, 1, 2008.

[4]. M. Murphy, M. Sitti, "Waalbot: An Agile Small-Scale Wall Climbing Machine Utilizing Dry Elastomer Adhesives", IEEE/ASME Transactions on Mechatronics, 12(3), 2007.

[5]. D. Xu, X. Gao, X. Wu, N. Fan, K. Li, K. Kikuchi, "Suction Ability Analyses of a Novel Wall Climbing Machine", Proceedings of the IEEE International Conference on Machineics and Biomimetics, Kunming, China, December 2006, 17-20.

[6]. W. Shen, J. Gu and Y. Shen "Permanent Magnetic System Design for the Wall-climbing Machine", Proceedings of the IEEE International Conference on Mechatronics and Automation Niagara Falls, Canada, 2005.

[7]. S. J. Segal, S. Virost and W. R. Provancher, "ROCR: Dynamic Vertical Wall Climbing with a Pendular Two-Link Mass-Shifting Machine",

[8]. IEEE International Conference on Machineics and Automation, Pasadena, CA, USA, 2008, 19-23.

[9]. Y. Kushihashi, et al., "Development of Tree Climbing and Pruning Machine, Woody-1-Simplification of Control using adjust Function of Grasping Power" (in japanese). Proceedings of JSME Conference on Machineics and Mechatronics 1A1-E08, 2006.

[10]. H. Kawasaki, et al., "Novel climbing method of pruning machine", Proceedings of the SICE Annual Conference, Tokyo, 2008, 160-163.

[11]. R. Aracil, R.J. Saltarn, and O. Reinoso, "A climbing parallel machine: a machine to climb along tubular and metallic structures", IEEE Machineics and Automation Magazine, 13(1), 2006, 16-22.