Tree Pruning/Inspection Robot Climbing Mechanism Design, Kinematics Study and Intelligent Control

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Abstract

Forestry plays an important role in New Zealand's economy as its third largest export earner. To achieve New Zealand Wood Council's export target of $12 billion by 2022 in forest and improve the current situation that is the reduction of wood harvesting area, the unit value and volume of lumber must be increased.

Pruning is essential and critical for obtaining high-quality timber during plantation growing. Powerful tools and robotic systems have great potential for sustainable forest management. Up to now, only a few tree-pruning robotic systems are available on the market. Unlike normal robotic manipulators or mobile robots, tree pruning robot has its unique requirements and features. The challenges include climbing pattern control, anti-free falling, and jamming on the tree trunk etc. Through the research on the available pole and tree climbing robots, this thesis presents a novel mechanism of tree climbing robotic system that could serve as a climbing platform for applications in the forest industry like tree pruning, inspection etc. that requires the installation of powerful or heavy tools. The unique features of this robotic system include the passive and active anti-falling mechanisms that prevent the robot falling to the ground under either static or dynamic situations, the capability to vertically or spirally climb up a tree trunk and the flexibility to suit different sizes of tree trunk. Furthermore, for the convenience of tree pruning and the fulfilment of robot anti-jamming feature, the robot platform while the robot climbs up should move up without tilting. An intelligent platform balance control system with real-time sensing integration was developed to overcome the climbing tilting problem. The thesis also presents the detail kinematic and dynamic study, simulation, testing and analysis.

A physical testing model of this proposed robotic system was built and tested on a cylindrical rod. The mass of the prototype model is 6.8 Kg and can take 2.1 Kg load moving at the speed of 42 mm/s. The trunk diameter that the robot can climb up ranges from 120 to 160 mm. The experiment results have good matches with the simulations and analysis.

This research established a basis for developing wheel-driven tree or pole climbing robots. The design and simulation method, robotic leg mechanism and the control methodologies could be easily applied for other wheeled tree/pole climbing robots. This research has produced 6 publications, two ASME journal papers and 4 IEEE international conference papers that are available on IEEE Xplore. The published content ranges from robotic mechanism design, signal processing, platform balance control, and robot climbing behavior optimization. This research also brought interesting topics for further research such as the integration with artificial intelligent module and mobile robot for remote tree/forest inspection after pruning or for pest control.

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