UMEÅ UNIVERSITET

Towards Semi-Automation of Forestry Cranes

Automated Trajectory Planning and Active Vibration Damping

Szabolcs Fodor

Akademisk avhandling

som med vederbörligt tillstånd av Rektor vid Umeå universitet för avläggande av teknologie doktorsexamen framläggs till offentligt försvar i N420, Naturvetarhuset, Umeå Universitet,
fredagen den 27 oktober, kl. 13:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Professor Torben Ole Andersen, Institutionen för Energiteknik, Hydrauliska och Mekatroniska System, Aalborg universitetet, Aalborg, Denmark.

Institutionen för Tillämpad Fysik och Elektronik

Organization
Umeå University
Applied Physics and Electronics

Document type
Doctoral thesis

Date of publication
06 October 2017

Author
Szabolcs Fodor

Title
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Abstract
Forests represent one of the biggest terrestrial ecosystems of Earth, that can produce important raw renewable materials such as wood with the help of sun, air and water. To efficiently extract these raw materials, the tree harvesting process is highly mechanized in developed countries, meaning that advanced forestry machines are continuously used to fell, to process and to transport the logs and biomass obtained from the forests. However, working with these machines is demanding both mentally and physically, which are known factors to negatively affect operator productivity. Mental fatigue is mostly due to the manual operation of the on-board knuckleboom crane, which requires advanced cognitive work with two joystick levers, while the most serious physical strains arise from cabin vibrations. These vibrations are generated from knuckleboom crane vibrations as a result of aggressive manual operation.

To enhance operator workload, well-being, and to increase productivity of the logging process, semi-automation functions are suggested, which are supervised automatic executions of specific work elements. Some of the related issues are addressed in the current thesis. Therefore, the content is divided into: (1) the design and development of a semi-automation function focused only on the base joint actuator (slewing actuator) of a knuckleboom crane, and (2) active vibration damping solutions to treat crane structure vibrations induced by the main lift cylinder (inner boom actuator). The considered reference machine is a downsized knuckleboom crane of a forwarder machine, which is used to pick up log assortments from a harvesting site.

The proposed semi-automation function presented in the first part could be beneficial for operators to use during log loading/unloading scenarios. It consists from a closed-loop position control architecture, to which smooth reference slewing trajectories are provided by a trajectory planner that is automated via operator commands. The used trajectory generation algorithms are taken from conventional robotics and adapted to semi-automation context with proposed modifications that can be customizable by operators.

Further, the proposed active vibration damping solutions are aimed to reduce vibrations of the knuckleboom crane excited by the inner boom actuator due to aggressive manual commands. First, a popular input shaping control technique combined with a practical switching logic was investigated to deal with the excited payload oscillations. This technique proved to be useful with a fixed crane pose, however it did not provide much robustness in terms of different link configurations. To tackle this problem an $H2$-optimal controller is developed, which is active in the pressure feedback-loop and its solely purpose is to damp the same payload oscillations. During the design process, operator commands are treated and explained from input disturbance viewpoint.

All of the hypothesis throughout this thesis were verified with extensive experimental studies using the reference machine.

Keywords
Forestry, forwarder cranes, semi-automation, slewing actuator, automated trajectory planning, oscillations, inner boom actuator, active vibration damping, frequency estimation, input shaping control technique, $H2$-optimal control

Language	ISBN	ISSN	Number of pages
English	978-91-7601-776-0	1654-5419:9	85 + 5 papers