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**INCREASING ENERGY EFFICIENCY  
OF ROBOTIZED PRODUCTION  
SYSTEMS IN AUTOMOBILE  
MANUFACTURING**

**Doctoral thesis**

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# ABSTRACT

Energy efficiency is one of the fundamental properties of sustainable manufacturing. Industrial robots are deployed in many manufacturing industries and are a key technology in implementing production on the desired scale, speed, quality and costs. This work proposes various methods for the energy efficient use of medium and high payload industrial robots and robotized production systems. This is multidisciplinary research and refers to topics in high-level production control architecture, manipulator motion planning and electrical engineering.

A new, complete robot system model is developed, applicable to various types of 6 degrees-of-freedom articulated manipulators, considering actuator drive systems and controller cabinet losses. In this thesis, methods for energy-efficient large-scale robotized production planning are proposed, such as idling strategies, strategic selection of the robot manipulator type and intelligent brake management. A cluster analysis of the robot trajectory planning algorithms and a case study of dynamic robot program optimization within a robot production cell in the automotive industry are given. The effective use of regenerative energy is evaluated and a novel power converter system for multi-robot cells is proposed to enable energy sharing between several robot actuator drive systems.

Experimental validation and a viability proof of the proposed optimization approaches are provided with respect to a detailed analysis of actual robot usage in the automotive industry. The multi-robot model is also implemented in a compact software tool. It is estimated that complementary implementation of all proposed methods increases the energy efficiency of robot manufacturing systems of ca. 30% over the state of the art.

## ANOTĀCIJA

Bez robotikas autoindustrija šodien nav iedomājama - industriālie roboti ļauj sasniegt vēlamos ražošanas apjomus, kvalitāti un ātrumu. Taču vienmēr pieaugošās elektroenerģijas cenas kā arī dažādi politikas instrumenti industrializētajās valstīs ir galvenie motivatori kļūt energoefektivitātei par vienu no ražošanas uzņēmumu galvenajiem stūrakmeņiem.

Šajā darbā izpētītas dažādas metodes industriālo robotu energoefektivitātes palielināšanai. Darbā izstrādāts robota sistēmas modelis, kas izmantots robotizētu ražošanas uzdevumu energopatēriņa analīzei un pielietojams dažādiem 6-asu manipulatoriem. Darbā piedāvātas vairākas metodes un shēmas plaša mēroga robotizētas ražošanas energoefektivitātes celšanai, kā, piemēram, manipulatora tipa izvēle, stratēģijas efektīvai mehānisko bremžu pielietošanai un ražošanas intervālu izmantošanai. Analizēta programmu loģika un kustību vadības algoritmi balstoties uz visa veida robota sistēmas zudumiem. Praktiski pierādīta metode dinamiskai kustību vadības optimizācijai demonstrēta robotizētā ražošanas šūnas modeli. Izpētīti pasīvie enerģijas uzkrājēji kā arī izstrādāta jauna tipa jaudas pārveidotāja shēma robotu rekuperatīvās enerģijas apmaiņai.

Darbs orientēts uz praktiski realizējamiem ražošanas uzlabojumiem un vairums minēto metožu ir eksperimentāli pārbaudītas. Balstoties uz robotu faktisko izmantošanu autoindustrijā, kopējo robotu energopatēriņu iespējams samazināt par 30%, pielietojot visas uzlabošanas metodes vienlaicīgi.

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