

The Strategic Research Centre for the Manufacturing Industry

Learning Control

Lessons learned from the Flanders Make project "Robust and Fast Learning Control"

Thursday, 28 September 2017

12h00 **Sandwich Lunch**

13h00 **Introduction into learning control**

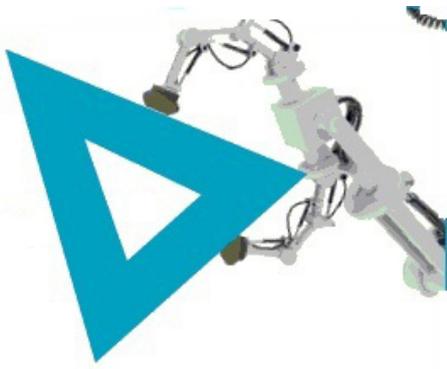
Erik Hostens, Project Manager, Flanders Make

The industry faces a growing demand from customers to increase the performance and energy efficiency of machines and vehicles. The typical response to this demand is applying more advanced controllers in systems and components. Present industrial applications typically rely on a fixed feedforward or feedback controller to steer the actuators. What makes learning control different from these techniques is that for the latter the performance does not improve over time, not even if the same operation is performed repeatedly. In contrast, learning controllers register the performance during past executions of a specific task, after which the control for the next execution of this task is adjusted so as to improve the execution. They require less detailed models of the controlled plant as model-plant mismatches, if any, can be learned (and thus resolved).

13h30 **Learning control in practice**

Torsten Knüppel, Research Engineer, Flanders Make
Armin Steinhauser, Researcher, Flanders Make/KU Leuven
Jeroen Willems, Research Engineer, Flanders Make

We are aiming for a solution that requires little expert knowledge on systems and control. To this end, we have developed a user-friendly software toolbox that takes a plant model, goal function and constraints as user inputs and automatically calculates the resulting learning control. We will show the ease and potential of this toolbox with on-line and recorded demos. We will also show how we deal with the practical challenges of learning control through the use of safe learning, shared learning and simple learning. As the learning controller changes its actions on-line, guarantees are needed with respect to safety and system limits, especially when it appears difficult to model the full system behaviour. Safe learning offers a robust solution that starts the control actions with conservative margins but gradually decreases the safety margins as the system behaviour learns subsequent trials. For calibration purposes, shared learning can be applied to simultaneously learn optimal control actions for a wide range of configurations, thereby speeding up the calibration process significantly. The learning controller performs an on-line, non-linear optimisation, the complexity of which is still out of reach for industrial embedded controllers. Simple learning is the translation of the original full optimisation problem into a simplified relation between input and output parameters and can be used in an on-line, rule-based strategy. As such, learning control is possible, even on lower-level controllers, and is also more in line with control strategies that are widely used in industrial environments.



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14h30 **Auto-navigation of autonomous vessels**
Peter Staelens, Technical Director, dotOcean

The collaboration of dotOcean with Flanders Make in this project has, among others, resulted in the development of Calypso, a fleet of autonomous, self-learning vessels connected through the cloud. A central server platform holds a virtual world, where information between distributed systems and people is shared and consistently combined, including maps of the environment, weather conditions, currents, ships' locations and courses. The autonomous vessels use this information to intelligently plan their trajectories and avoid obstacles. Calibration and tuning of standard reactive auto-navigation is very tedious, given the wide range of vessel types and environmental conditions. Learning control can learn the optimal behaviour on-line for a particular situation and also intelligently extrapolate the optimal behaviour to other situations and vessels. Currents and winds are measured on-line and shared with other vessels within the same network.

15h00 **Coffee Break**