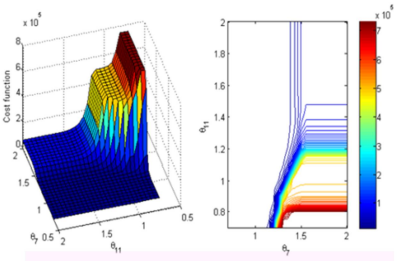
- modelling and simulation
- control design
- system troubleshooting
- technology transfer and training
- energy efficiency investigation
- software tools

industrial systems and control

The Role of Artificial Intelligence in Control



Artificial Intelligence (AI) is the term initially proposed for indicating the set of techniques to develop machines operating like humans, featuring the ability to think and learn by themselves. AI is the field that describes machine learning to respond to certain sets of behaviour and learn like humans. Since AI was first introduced to the market, is has been the reason for a quick change in technology and business.

There is an increasing size of data and information provided by different types of connected object. There is also the ability to automatically manage a wide dataset and exploiting correlations. Pure data-driven AI techniques, focus the interest of the overall society on the Machine Learning (ML) techniques. ML is the name used for indicating the set of AI solution able to automatically learn from data, neglecting any a-priori knowledge about the physical meaning of the system being analysed.

AI, and modern data-driven ML techniques are changing the structure, organization and technology over much of the industrial and technical world, influencing specialist fields, such as the control theory and control system design and development sector.

AI Algorithms, Models and Applications

Modern AI, and the widely used ML solutions are based on models and techniques designed according to different scientific findings, such as math, biology, and statistics. A variety of paradigms have been developed for a huge set of different applications and then generalized, giving a set of models and techniques easy-to-customize to any control problem. Meta-heuristic algorithms, Neural Networks, Fuzzy systems and Support Vector Machines are widely used in for developing the more recent and advanced AI-based solutions, according to modern Deep Learning and Reinforced Learning paradigms.

Due to the flexibility of the techniques giving the modern ML framework, ad-hoc AI solutions can overcome some limits of modern control theory, improving the performance of control algorithms in different fields, such as Robotics, Process Automation, Decision Management and Adaptive Manufacturing.

AI in Control: Off-line Solutions

Off-line solutions group the set of ML-based applications to exploit the potential of AI for simplifying design issues while developing a control system. Typical solutions consider AI-based automatic calibration systems, data-generators for Rapid Prototyping (RP) test and algorithms for estimation of unmeasurable signals/parameters. AI algorithms can be designed for defining the optimal set of calibration parameters able to control a complex system over all the set of operating conditions. This approach considers the development of a ML solution based on supervised and reinforced learning paradigms, to reduce the time-expensive calibration procedures based on expert operators and standard model-based control methods.

Measurements provided by the real system to be controlled can also be used for developing AI-based algorithms able to emulate the behaviour of the real process. This avoids the development of a physically based model. By exploiting the universal approximation capabilities of NNs and SVMs, algorithms evaluate the effectiveness of a control system in simulation, by considering software able to replicate nonlinear behaviour of the real system, including the set of relationships not considered a priori by a model based on physical equations. Further, according to the unsupervised learning paradigm, ML methods study the dynamics of a system evaluating the time-varying nonlinear dynamics of uncertain parameters affecting the behaviour of the process and the related control performance.

Our Expertise

- **In-depth understanding of control technologies**
- **Extensive experience in diverse industrial applications**
- **High-fidelity modelling of system behaviour**
- **Expert analysis of complex problems**
- **Proven project management and research skills**

Our Core Competencies

- **Dynamic modelling & simulation**
- **Control strategy design and implementation**
- **Optimization**
- **Algorithm development**
- **Benefits analysis and technology review**
- **Research & Development**
- **Troubleshooting**
- **Training**

Our Philosophy

- **Approaching problems with an open mind**
- **Dedicated to identifying practical and innovative solutions without compromising performance.**
- **Imparting understanding and empowering clients to drive improvements themselves.**

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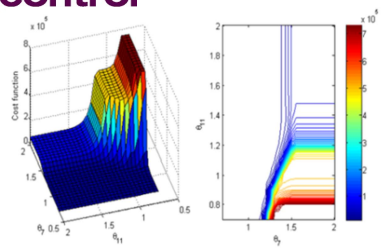
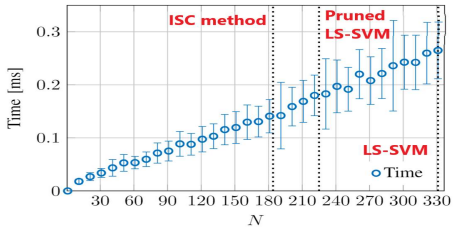


AI in Control: On-line Solutions

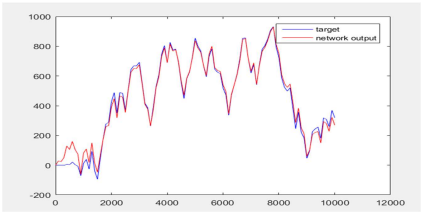
On-line solutions group the set of applications involving the use of AI algorithms for working in conjunction with controllers/observers according to standard control theory for closed loop AI-based control systems. Standard methods consider the use of ML for defining observers, estimators or pure AI-based controller. The first set includes AI algorithms designed for computing on-line the value of system state/variable or equivalent models representing a nonlinear system (e.g. Linear Parameter-Varying models). Because these algorithms are based on pure data-driven ML, AI-based observer are able to provide better results with respect to the model-based methods, including the possibility to increase on-line the base of knowledge used for training the algorithm in an efficient way. Estimator is a term used here for indicating the set of ML solutions designed for providing an effective estimation of future dynamics of a set of time-varying variables over a given horizon. The main use of this set of algorithm is to provide useful information for improving the capabilities of control systems, by adapting their calibration parameters or providing useful information for computing a predictive control law. The last set of solutions is focused on the implementation of complex control systems, possibly approximating a computationally expensive control algorithm (e.g. nonlinear predictive control) with a ML algorithm able to replicate the control action while reducing computational burden and memory storage.

ISC Expertise in AI-based Control Solutions

ISC ltd has 30 years' experience in the development of classical and advanced control system, and adaptive algorithms. Considering modern ML techniques, ISC is in the vanguard of research and development of effective solutions for improving capabilities of controllers by merging AI capabilities and features advanced control theory paradigm. Recent research activities related for merging AI and control theory capabilities involves the development of ML solutions for control and identification.

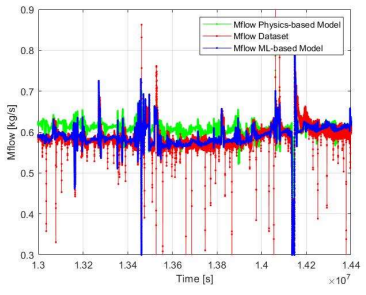


Least Square Support Vector Machine for LPV identification – Dataset selection for Reduction of on-line computational burden

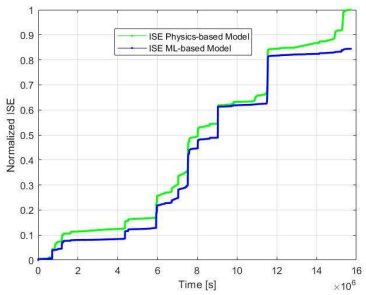


Supervised Learning NN-based Nonlinear Modelling – Ground Vehicle heading dynamics case study

One of the main aspects reducing the effectiveness of ML techniques for control purpose is related to the time required for computing the algorithm. Considering NNs and SVMs as the most widely used ML techniques, ISC activity has been focus on developing simple and effective algorithm aided for real-time computation. SVMs are learning algorithms providing a flexible framework customizable for facing different identification and control problem by the more appropriate problem formulation. Due to its structure, SVM feature a linear dependency between the size of the dataset used for training and the computational burden for executing the algorithm. By the use of advanced optimization techniques, the ISC research on LS-SVM enables the development of an innovative algorithm for reducing the computational burden, maintaining capabilities of standard SVM methods. The effectiveness of the proposed approach has been evaluated by testing the capabilities of the LS-SVM method for modelling the behaviour of a nonlinear cascade tank system in the form of an LPV model.



Digital Twin Performance Comparison - Neural Network Vs. First-order model Vs. Real Plant Data



Digital Twin Performance Comparison - Neural Network Vs. First-order model Normalized Integral Square Error

In the case of a nonlinear model with unknown dynamics, the use of NNs is considered a standard solution applying AI techniques. ISC has applied NN-based algorithms for solving different identification and estimation problems, by developing ad-hoc networks able to replicate nonlinear dynamics by a pure data-driven approach. The solutions reduced the size of the network, and related number of parameters and the gains to calibrate, reducing the training time for setting up the network.

Clients Include

- **Torotrak: variable transmission system.**
- **Visteon: applying LabVIEW to automotive power control.**
- **General Motors: SI engine control.**
- **General Motors: SCR system identification.**
- **General Motors: Control model calibration.**
- **Toyota: Diesel engine control.**
- **Cummins: Diesel engine design methods assessment.**
- **Ford: Autonomous vehicle control.**
- **FCA: Training Activity via Electronic throttle design study.**
- **NXP: Hybrid Electric powertrain control.**

Recent Automotive Training Courses

- **Ford at Dearborn annual courses between 2004-2019**
- **Cummins at Columbus, 2018**
- **Toyota at Ann Arbor 2014 & 2018**
- **Chrysler at Auburn Hills 2011-2016**
- **Freescale in Glasgow and Detroit 2008**
- **NXP in Glasgow 2018**
- **GM Detroit 2015**
- **Jaguar in Coventry and Gaydon 2006 & 2009**
- **Riccardo in Leamington and Shoreham 2006 & 2009**
- **Visteon in Detroit 2004**

"Approaching a problem with an open mind is an important aspect of the ISC philosophy, as is using the simplest, most cost-effective solution."

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