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

industrial systems and control

Automatic Calibration and Testing for Controllers

The focus is on the development of "automatic" calibration and testing methods for control systems.

Calibration is a time consuming and expensive task requiring experts to use their knowledge about a system to modify the basic control solution and to fine-tune the system during the commissioning stage. The development of automatic calibration techniques can involve recasting the calibration process as an optimization problem. Different solutions of the problem can be assessed until an effective satisfactory optimal solution is found. The solution will provide the value of calibration parameters.

Testing: control system calibration involves the definition of a set of tuning parameters ideally chosen to achieve the required performance. Controller testing is an essential part of this activity. It is needed for effective validation of the closed-loop system in different scenarios so that it is possible to guarantee performance and determine worst-case control situations.

Calibration by Artificial Intelligence

The main limitation of classical calibration methods is their need to represent the calibration problem in a framework constrained by different assumptions (e.g. time-invariant plants or process repeatability). The advantage is the consolidated theory given by the simplified calibration problem framework. One approach for overcoming the limitations of the classical methods is to use them in conjunction with advanced statistical methods (e.g. Bayesian or Monte Carlo approaches) – this is especially applicable to controllers of limited complexity.

In the last few years, Artificial Intelligence (AI) methods and in particular metaheuristic optimizers have been considered for complex control systems calibration. These methods consider the use of pure metaheuristic (global optimization) techniques for solving the nonlinear problem of control system calibration. As an example, the Particle Swarm Optimization (PSO) approach can be used to consider the worst-case control problem (robust tuning set-up with respect to prescribed performance) and is applicable to any existing MPC problem formulation (and is extendable to any controller).

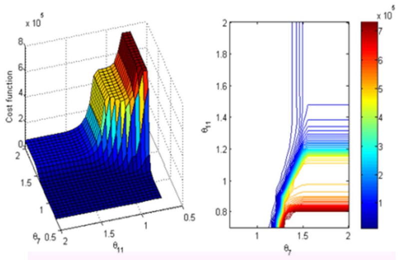
Pure metaheuristic techniques have been proposed in conjunction with alternative AI methods. Fuzzy logic-based combined algorithms have been used for industrial controller calibration. These techniques combine the fuzzy approach with meta-heuristic methods (e.g. genetic algorithms or SPO). Multi-objective fuzzy decision-making can handle qualitative statements of what the "best" control might be and is able to use multiple inputs to determine tuning parameters that best match the desired performance [4]. Furthermore, a few methods have been recently proposed for exploiting metaheuristic and modern data-driven AI algorithms. These innovative solutions are based on advanced Machine Learning (ML) and Reinforced Learning (RL) approaches.

In the next few years, this should provide a solid approach that would be able to overcome the limitations of classical solutions and pure metaheuristic approaches. The advantage of pure and combined metaheuristic algorithms is related to their flexibility to solve a wide set of different optimization problems. The disadvantage is that they are not necessarily tailored to the controller-tuning framework. Thus, they may result in slower convergence properties or lower performance than may be possible, which becomes particularly problematic as the controller complexity increases.

Industrial Systems and Control Ltd.

ISC Ltd. works across industrial sectors and has gained wide experience in a range of applications. It is this peripheral vision which is valuable for automotive companies, which have a complete understanding of current advances in the automotive industry. ISC Ltd. has particular expertise and experience on the following areas and methodologies:

- Physical system modelling and simulation, including training simulators.
- Developing tailored optimal or predictive control solutions for real-world applications.
- Production of bespoke estimation and filtering algorithms for nonlinear control.
- Use of stochastic or robust controls for different industries like wind energy and marine.
- Design of Machine Learning algorithms for industrial and embedded domains.
- Training courses mostly for the automotive industry based in the US.



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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Registered in Scotland 105188

applied control technology consortium

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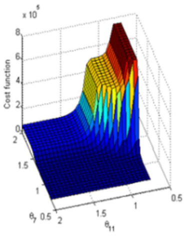
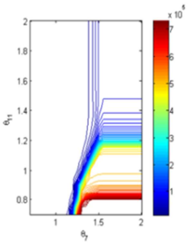
Automatic Controller Testing

Every system should be designed so that it satisfies a set of requirements. Different verification methods can be used to guarantee that the system behavior is appropriate with respect to sequencing of events, conditional reachability, invariants, and real-time constraints.

“Verification” provides a formal proof of correctness of the system for a (possibly infinite) set of parameters and inputs. Technologies such as model checking and theorem proving can be used to perform verification for software systems. Some of these tools can be applied to embedded control systems, but no mature tools exist that can be applied to detailed industrial models that capture plant behavior, such as engine dynamics. Furthermore, applying verification techniques to embedded control systems is a challenging task. These systems can often be classified as hybrid systems, which are systems that exhibit both continuous and discrete behavior. The general problem of verifying hybrid systems is known to be *undecidable*. This “undecidability” result means that it is provable that no computer algorithm can decide whether an arbitrary hybrid system satisfies any given formal specification. Different tools exist for verifying specific subclasses of hybrid systems, but each suffers from significant limitations (e.g. CE2E, UPAAL).

If proving the absolute correctness is not possible, another approach is to assume that a bug exists and then employ a technique to actively search for the incorrect behavior. This is the goal of the “falsification” framework: the system is driven to exhibit its inappropriate behavior if any exists. Several tools recently developed use simulation-guided approaches to testing based on the notion of falsification. Optimization-guided falsification is an emerging approach for testing closed-loop models by intelligently obtaining test inputs to expose undesirable model behavior. The inputs to a falsification algorithm are a closed-loop model, a set of correctness requirements, a specification of the system parameters, and a definition of the exogenous inputs to the closed-loop model. Information about the inappropriate behavior obtained from the falsification test procedure is then used for improving the system behavior (controller redesign and/or recalibration).





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 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.”

Industrial Systems and Control Ltd., Expertise

ISC Ltd. remains closely linked to the Industrial Control Centre at the University and benefits from cooperation in Ph.D. programs. However, ISC Ltd. undertakes practical application projects in addition to more sophisticated advanced control design projects. We work right the way through to prototyping and implementation and that broad exposure brings a lot of benefits to the practicality of our solutions. For example, the first serious automotive project, 30 years ago, was on the simulation for the Torotrak variable transmission system. ISC has experience in the use of Rapid Prototyping control tools such as Matlab/Simulink, dSpace, NI LabVIEW, and NI Powertrain Controls Hardware, as well as the LHP software for linking various modeling tools.

ISC was recognized by National Instruments in Austin, with two awards for an offshore wind turbine access control system. The Turbine Access System (TAS) is a lightweight, hydraulic gangway developed by Houlder Ltd and BMT that allows engineers to transfer from small service boats onto offshore wind turbines. ISC won both the Advanced Control category and the overall Application of the Year award at the Graphical System Design Achievement Awards in 2012. In the following year, ISC was presented with two NI Graphical System Design Achievement (GSDA) awards. The challenge was to create an intuitive, reliable system to deploy, position and stow 70-ton hydraulic gripper arms used in guiding steel monopiles for offshore wind farm construction. These controllers were designed and commissioned by ISC, using LabVIEW software and NI CompactRIO.

ISC as a Business

The company was established almost 30 years ago by the University of Strathclyde to encourage technology transfer in advanced control methods. It ran a training and technology transfer program under the ACTC (Applied Control Technology Consortium) that involved many of the world’s leading companies across business sectors. The training courses now offered by ISC build upon that material and experience. Many of the engineers in ISC first researched in the University but have now worked within the company for many years.

One of the advantages of ISC, relative to industrial groups in Universities, is the fact that it has permanent staff and can undertake confidential work in a professional way regarding timekeeping, schedules, and quality of deliverables. The fact that companies can return to ISC after a few years and gain access to the same engineers and software for further developments is often immensely valuable.

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