2006 IEEE Workshop on Open Problems and Challenges in Automotive Control

Opening Remarks

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History: Electronic Powertrain Controls

- Open Loop, SISO feature level (e.g. Spark, Fuel) control
- Coordinated control across features, some interaction between systems (e.g. Engine & ABS)
- Pervasive control, “variable everything”. Extensive control across networks to achieve vehicle functions
- Control and communication between vehicles (peer to peer) and their environment
Traditional Control Systems Development

- SISO systems
- Steady state map based tables and functions
- Open loop control
- Manual tuning of open and closed loop gains
- Extensive validation of requirements, attribute performance, and software late in the development process
- Discovery of system interactions late in the development process
Changes in Our Business

- By 2010 20-30% of the cost will be in Electrical/ Electronics and Software cost is expected to rise from 4% in 2002 to 13% by 2010 (Source: AT Kearney, Mercer Management Reports)

- Reliance on controls to provide customer critical functions (drive by wire, collision avoidance, roll stability control)

- Co-development between suppliers and OEM’s (trending to have software objects from multiple source in a single ECU)

- Interaction between functions, subsystems, and vehicle level systems (including networks)

- Controls and their associated tuning (calibration) are becoming the bottleneck in introduction of new technology
What does this Mean to the Controls Community?

• Control Design:
  – Increased use of closed loop control based on observers, adaptation and model predictive control
  – Self tuning, adaptive control techniques that reduce manual calibration time and guarantee optimal performance over the life of the vehicle
  – Controller design and validation processes that prove robustness against noise and failure modes (for both linear and non-linear systems)
  – Replacement of standalone diagnostics with diagnostics that are a by-product of control
  – Fault detection and mitigation strategies that are fault tolerant but do not become a major source of complexity in their own right

• Tools and Techniques:
  – New techniques that help bridge the gap between written functional requirements and the end design
  – New techniques to analyse behaviour in subsystems and systems that exhibit state and continuous behaviour (hybrid systems)
What does this Mean to the Controls Community?

- **System Optimisation:**
  - *High degrees of freedom where optimum control is required*
  - *Greater focus on dynamics rather than steady state*
  - *Advanced DOE techniques for mapping and dynamic mapping in lieu of steady state mapping*

- **Computer Platform:**
  - *Microprocessors capable of advanced signal processing, dynamic optimisations and neural networks*

![PCM range of capability trends](image-url)
What does this Mean to the Controls Community?

- **System Interactions:**
  - Control over networks
  - *Interactions between previously separate subsystems and between OEM’s and suppliers create coupled modes and emergent properties which must be “discovered” and managed*
  - Increased complexity creates new modes that have to be assessed and managed with respect to safety, reliability and availability

- **Standards?**
  - *Operating Systems & Communication Protocols*
  - *Architectures (Software and Functional)*
  - *Modeling Standards and Architectures*
  - *Development Processes*
  - *Tool Interfaces*
Complexity Considerations

• Has consequences for design, release, manufacture and service

• The management of the complexity will inevitably rely heavily on software for design, analysis, and implementation

• Standardised software with common interfaces is predicated on standardised hardware and hardware functions that OEM’s and suppliers view as their competitive advantage.

• The “Plug and Play” PC analogy is often used but we need to use this analogy with caution

• The increased complexity is often invisible
Invisible Complexity

- The number of functions supported by controls and software are invisible externally:
  - The functions associated with meeting On Board Diagnostic regulations are approximately 30% of the P/T Control Software yet the visible part of the function is simply to turn the check engine light on/off!
  - In a recent study 70% of the software associated with a variable cam timing feature was found to be associated with Diagnostics and Failure Mode Management

- Typical control “feature” (idle speed, fuel control, … )
  - Much more than just the control law
  - Multiple versions address program-to-program variability
  - Average feature has:
    - 1-2 execution contexts
    - 20 inputs
    - 14 outputs

- About 60 features per application with more than 2000 connections among features
Specific Needs

- Tighter specifications of interface parameters and requirements for the interface parameters so that the behaviour (including accuracy & transient dynamics) of the signal is understood under all operating conditions.

- Model Based Systems Engineering:
  - Analysis, Design and DV firmly in the early phases of development.
  - Automated test vector generation
  - Controller design
  - HIL and SIL development
  - Control across networks

- Ability to extract different views of the system from a common underlying set of models and data. E.g.: Timing, Architecture and Interfaces, Control, Data flow, etc.

- Well defined software architectures proven for control (noting an inherent conflict between cohesion and coupling for control and control software).
The advanced control techniques currently being deployed are not common in the existing automotive controls skills base:

- Procedures to successfully achieve the attribute performance are essential without requiring the user to be an expert in the controller design.
- A new maintenance paradigm for control algorithms must be developed – the business risk of having an advanced controller design dependent on one individual is too high.

Existing staff will need continuing education to manage the new systems and universities will need to provide graduates with deep understanding of practical control application using the latest control techniques.
Summary

• Daunting challenges exist if we are able to successfully execute this pervasive controls environment when we also have to:
  – Manage decreasing product development schedules
  – Provide guaranteed reliability, robustness and safety. We need to recognise that we have a growing reliability and robustness issue that must be addressed

• Industry also needs to change its operating paradigm from designing control systems for hardware to designing hardware that is controllable

• The future is bright for anyone interested in automotive controls; fuel economy, emission reduction, safety, driving dynamics all demand control systems engineers!