Using simulation to support the design of distributed embedded control systems:
A case study

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Overall Aims

- To investigate the practicalities of using simulation to design distributed embedded control systems.
- To understand the effort involved in creating the simulation.

Objective of the current study

- Does the simulation work?
- To verify the extent to which the simulator is accurate

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Overview

- Motivation
- Background
- Case study
- Design options
- Results (simulation and HIL)
- Future work & conclusion

3

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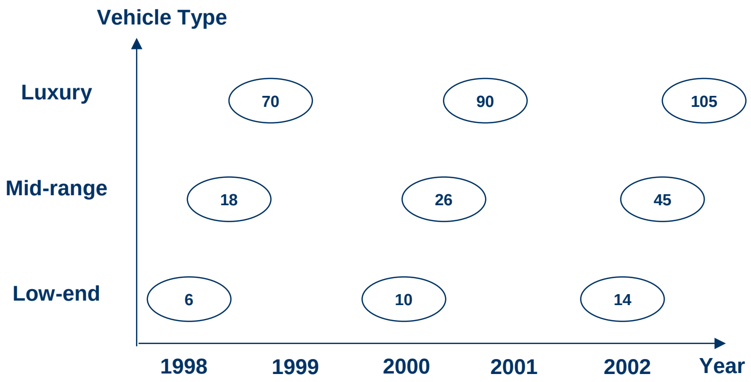
Motivation



Microcontroller implementation growth in the automobile (*Bannatyne, 2003*)

4

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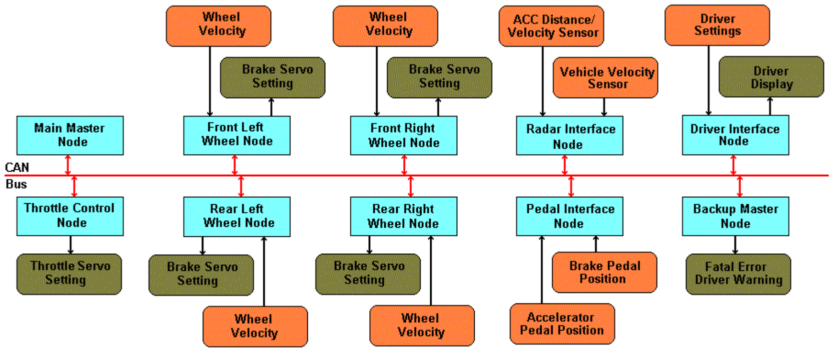
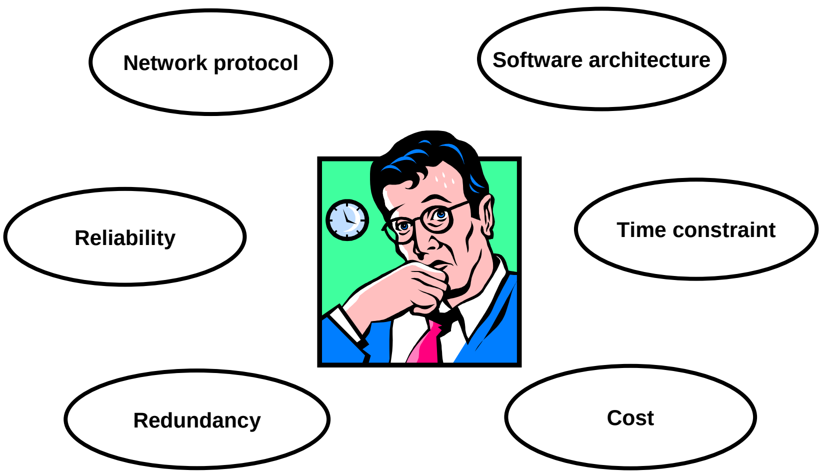


An adaptive cruise-control system (*Short et al., 2004*)



Solution: Use a simulator

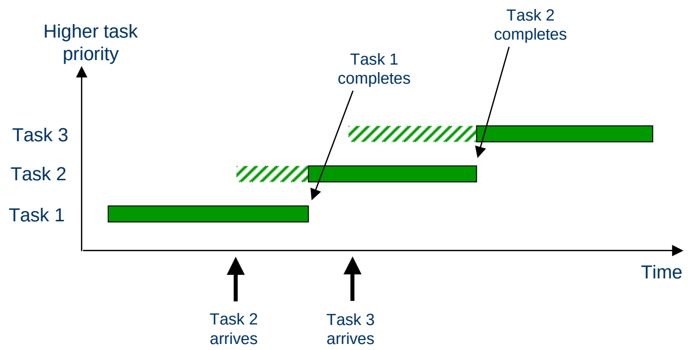
- TrueTime - Designed by Lund Institute of Technology. *(Cervin et al., 2003)*
- Facilitates the simulation of distributed real-time control systems.
- Why TrueTime?
  - Capable of simulating the plant as well as a wide range of software architectures and network protocols.
  - TrueTime is a Matlab/Simulink based tool.
  - Open source.

Software architectures

- Time-triggered systems
  - Tasks are executed periodically
- Event-triggered systems
  - Aperiodic tasks are executed in response to external events

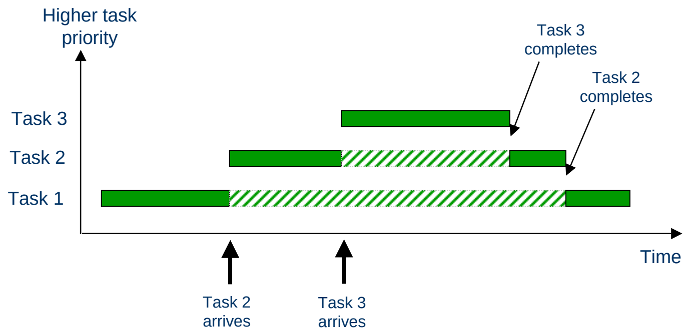
Nature of tasks: co-operative

- Co-operative task scheduling
  - Tasks will run to completion

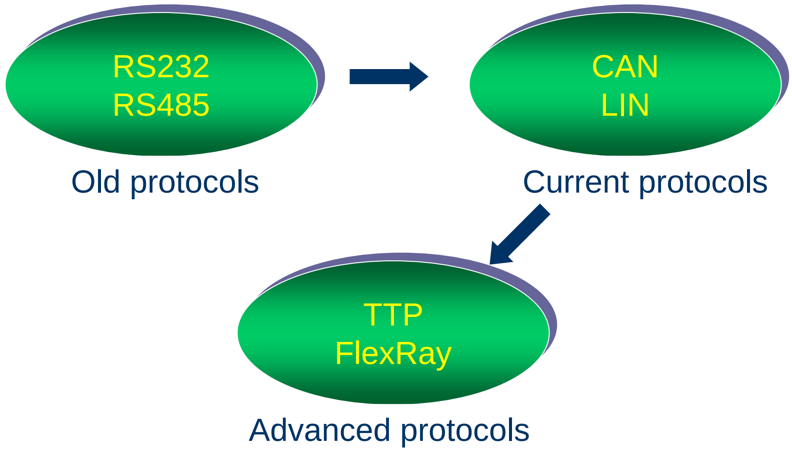


Nature of tasks: pre-emptive

- Pre-emptive task scheduling
  - Tasks can pre-empt each other



Network protocol



11

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Aims of current study

- Does the simulation work?
- To verify the extent to which the simulator is accurate

12

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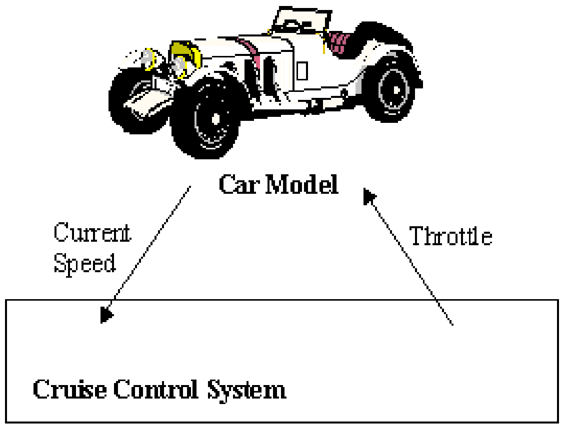
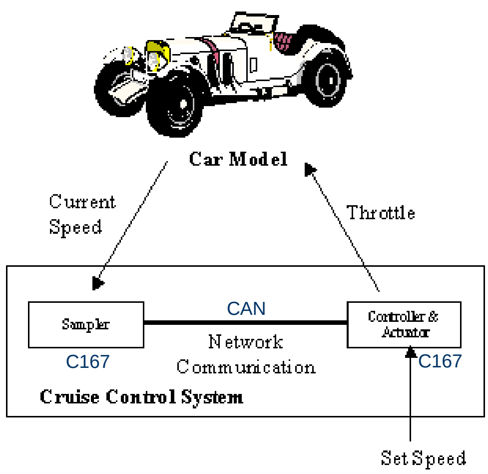
Case study: CCS



13

Implementation

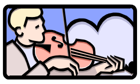


14

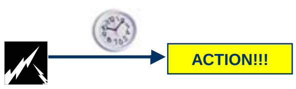
Design options

	Sampler Node	Communication	CA Node
T-T-T	Time	Time	Time
T-E-T	Time	Event	Time
E-T-E	Event	Time	Event
E-E-E	Event	Event	Event

- What do we want to know from the system?
  - Performance



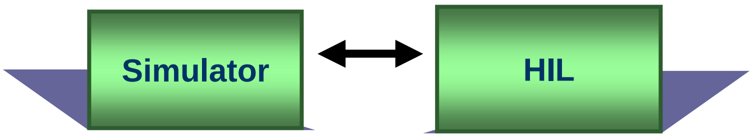
  - Event response time



  - Control delay

Results

- To compare the results of the simulator with the HIL.



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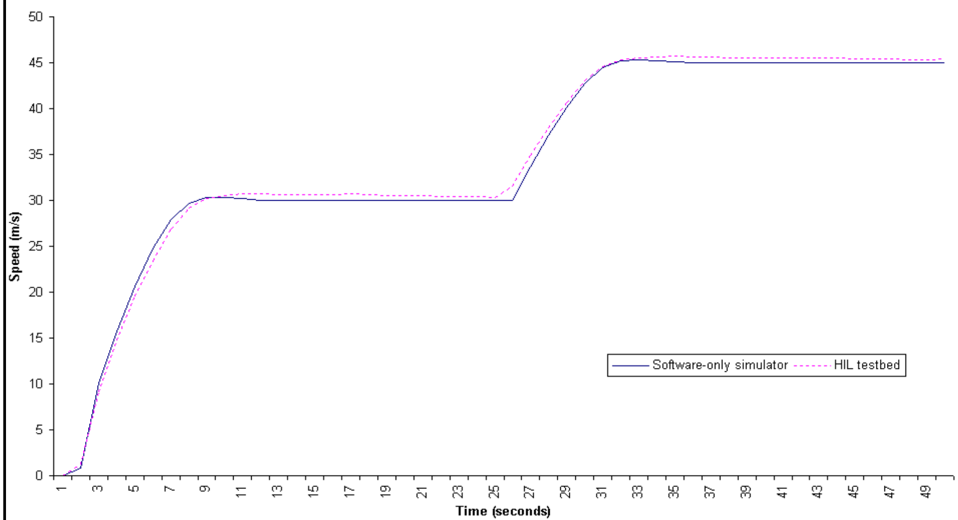
Control performance



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Event response time

	Minimum (µs)		Maximum (µs)	
System	HIL	Simulation	HIL	Simulation
T-T-T	1384	1384	2383	2384
T-E-T	419	1000	2343	2000
E-T-E	392	391	1390	1384
E-E-E	384	384	674	496

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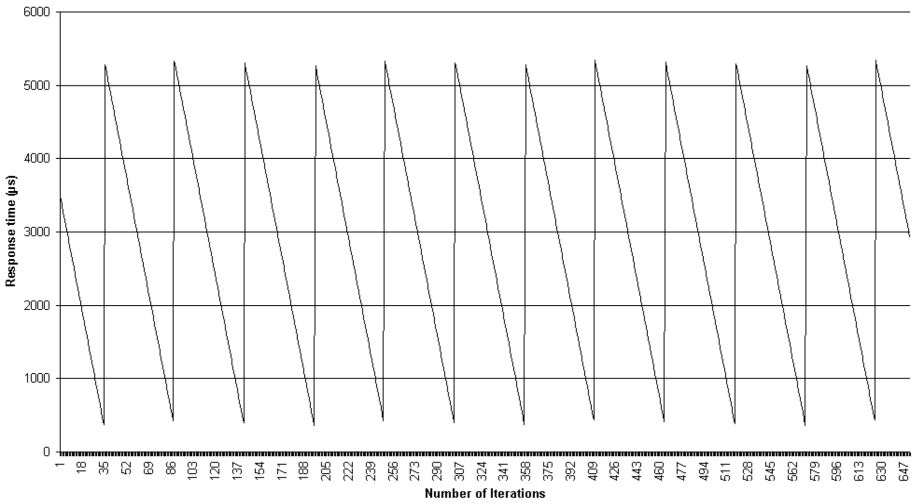
Clock drift



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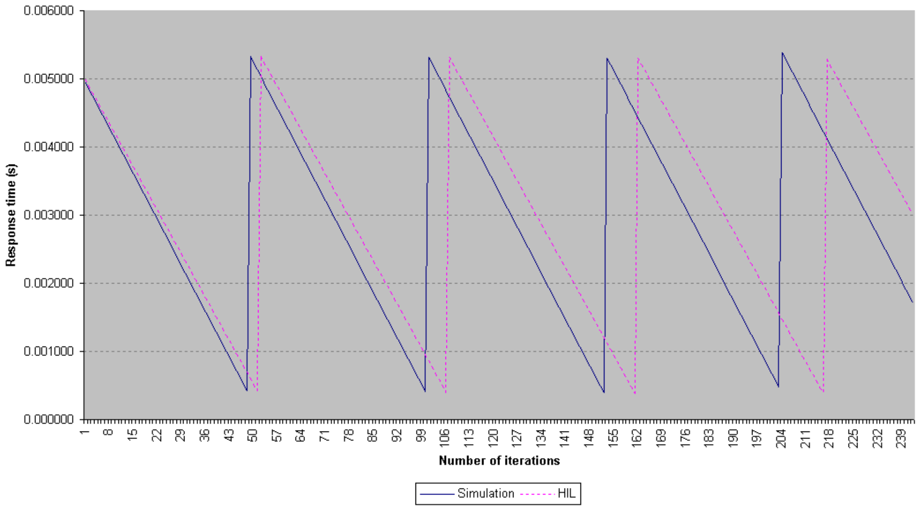
Control delay (x-T-x systems)

	Control Delay	
T-T-T System	**HIL**	**Simulation**
Minimum (µs)	1388	1373
Maximum (µs)	1398	1373
Average (µs)	1393	1373
Std Dev	2.329284	0.00
E-T-E System		
Minimum (µs)	1390	1381
Maximum (µs)	1400	1381
Average (µs)	1395	1381
Std Dev	2.256839	0.00

Results with clock drift incorporated into the simulator



	Minimum (µs)		Maximum (µs)	
System	HIL	Simulation	HIL	Simulation
T-E-T	419	384	2343	2375
E-E-E	384	384	674	756

Control delay (x-E-x)

	Control Delay	
T-E-T System	**HIL**	**Simulation**
Minimum (µs)	702	806
Maximum (µs)	50685	50056
Average (µs)	25561	24960
Std Dev	14711	14781
E-E-E System		
Minimum (µs)	448	640
Maximum (µs)	50415	50290
Average (µs)	22246	21425
Std Dev	16467	13787

Future work

- To begin to understand the typical effort that will be involved to develop a system (from simulation to the implementation phase).

Conclusion

- Simulation is an effective way of predicting the behaviour of distributed embedded systems.

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References

- Bannatyne R., (2003), “Microcontrollers For Automobiles”, Transportation Systems Group, Motorola Inc., Micro Control Journal.
- Cervin A., Henriksson D., Lincoln B., Eker J., Årzén K., (2003), How Does control Timing Affect Performance? – Analysis And Simulation Of Timing Using Jitterbug And TrueTime, IEEE Control Systems Journal (Vol. 23).
- Short M., Pont M. J. and Huang Q., (2004), 10-Node Distributed ACC System: Co-Operative Implementation, Technical Report ESL 04-05, Embedded Systems Laboratory, University Of Leicester.

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