Component-based approach for embedded systems

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Component-based approach

- Building systems from (existing) components
  - Providing support for the development of systems as assemblies of components
  - Supporting the development of components as reusable units
  - Facilitating the maintenance and evolution of systems by customizing and replacing their components
Implications

- Component development is separated from system development process
  - Less programming efforts to build systems
  - System verification and validation more difficult and more important
  - Different requirements management

Describing a Component

- To be able to describe a component completely the component should consist of the following elements:
  - A set of interfaces provided to, or required from the environment.
  - An executable code, which can be coupled to the code of other components via interfaces.
- How to specify a component?
CBSE process issues

• Different types of approaches
  – Using components as well defined design units
  – Product-line approach
    • Building many variants and versions of a product based on the same architecture and varying components. Components are developed in-house
  – COTS (Commercial off the shelf) components
    • Building systems from existing components

Example: The architecture of a car control system

- ECU – Electronic Control Unit
How much is CBSE attractive for different domains?

- Advantages from a business point of view:
  - Shorter time-to-market, lower development and maintenance costs
- Advantages from technical and engineering point of view
  - Increased understandability of (complex) systems
  - Increased the usability, interoperability, flexibility, adaptability, dependability…
- Advantages from strategic point of view of a society
  - Increasing software market, generation of new companies
- CB-approach has been successful in many application domains:
  - Web- and internet-based applications
  - Desktop and office applications, Graphical tools, GUI-based applications
  - In certain segments of telecommunication, consumer electronics…
Do existing component technologies meet the requirements of embedded systems?

- Widely-used component models (Microsoft COM/DCOM and .NET, Sun EJB,J2SEE, OMG Corba CM,…)
  - Focus on functionality, flexibility, run-time adaptability, simpler development and maintenance
  - Do not consider non-functional requirements
    - Timing properties (performance), resource consumptions
    - Reliability, availability, quality of services…

**Important questions for component-based development feasibility:**
- Which are the primary requirements in different domains?
- Can component-based development provide solutions that meet these requirements?

Specific requirements of embedded systems

- Real-time requirements
- Resource consumption
  - CPU, Memory, Power, Physical space
- Dependability
  - Safety, reliability, availability
- Life-cycle properties (long life systems)
  - Maintainability, expandability
  - Portability
- Increasing interoperability
Basic concepts for Component-based Embedded Systems

• Main concern
  – Predictability of different properties (on account of flexibility)

• Difference between small and large embedded systems

Component models for small embedded systems vs. General-purpose component models

**General-purpose components**
- Run-time composition (late binding)
- Set of interfaces, "bugs" of services
- Contractual-based interfaces
- Not resource-usage aware
- Coarse-grained
- Portability - Binary independence (Black-box reuse)

**Small Embedded Systems**
- Composition time separated from run-time
- Optimization at configuration time (direct references, unneeded functionality removed)
- Explicit context dependencies
  - Run-time environment (CPU, RTOS, resource constraints)
- Fine-grained
- Reuse & portability
  - white, glass, or grey box components
  - source code portability

There is a need for component models dedicated to (small) embedded systems
Examples of component models for embedded systems

- **SaveCCM**
  - Experimental (research) component model
  - Simple enough to be analyzable and predictable
- **Koala – Philips**
  - Consumer electronics
  - Treats software components as hardware components
- **PECOS – ABB**
  - Small fieldbus devices
  - Managing power consumption and real-time properties

Component-based approach for **LARGE** embedded systems

- the resource constraints are not the primary concerns.
- The complexity and interoperability important
- Minimizing the development costs

- *For this reason general-purpose component technologies are of more interest than in a case for small systems.*
Widely-used component models and embedded systems

• Direct use of component models
  – CORBA (telecommunication)
  – COM/DCOM, .NET – process industry
• Improved component-models (with added functionalities)
  – OPC (OLE process control Foundation)
• Restricted (use of) component-models to achieve predictability
  – Using only specification (IDL), no multiple interface, etc.

OPC (OLE for Process Control)

• industry standard for communication between components in field devices, automation equipment and business applications (generic driver)
• data model
• set of interfaces for COM
  – server interfaces
  – callback interfaces
• managed by OPC Foundation (www.opcfoundation.org)
Example - Adoption of a general-purpose component model

**ABB Controller - Componentization of a system**

- **Requirements**
  - Improve the development process
    - Distributed development
    - Shorter time-to-market
  - Redefined architecture
- **Conditions:**
  - Keep the main requirements (real-time) unchanged
- **Solution**
  - Componentize the software architecture
  - Use of a subset of a component model
Use of the Component Object Model (COM)

- COM is a public specification (by Microsoft) which emphasizes separation of interfaces and implementation
- A well-defined subset of the COM specification has been adopted
- COM compliant interfaces can be used on platforms without COM run-time support

- On platforms with COM run-time support:
  - Protocol handlers implemented as COM classes

- On platforms without COM run-time support:
  - Protocol handlers implemented as C++ classes, which are statically linked with the framework

Conclusion: What are the needs within Embedded Systems?

- Need for component models and frameworks for embedded systems.
  - the run-time platform must provide certain services, which however must use only limited resources.
- Obtaining extra-functional properties of components in particular timing and performance properties.
- Component certification
- Platform and vendor independence
- Component noninterference applications, (in terms of memory protection, resource usage, etc).
- Tool support: The adoption of component technology depends on the development of tool support.
References

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3. (Modeling of vehicular embedded control systems)
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6. Safety-critical and dependability aspects
7. Real-time systems
8. Verification and testing methods
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References

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    • http://www.sei.cmu.edu/pacc/CBSE8/
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    • http://research.microsoft.com/~cszypers/events/wcop2004
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