SOFTWARE DEVELOPMENT FOR EMBEDDED SYSTEMS

Trends and Challenges in Developing Software for Embedded Systems
Motivation

This survey addresses software development in the field of embedded systems. Our goal is to determine which demands are being placed on the hardware and software in such systems. We are also interested in identifying the major issues associated with software development while understanding to what extent tools are utilized to solve these problems.

We define embedded systems as computer systems that are integrated in other products as opposed to operating in a stand-alone environment. They can be found in mobile end-user devices, automotive systems, production/manufacturing lines and power networks among other areas.
Key Facts

**Audience:** Embedded system software developers (industries: automotive, automation, telecommunications, avionics)

**Focus:** New challenges in the field of embedded systems

**Interviews**
Timeframe: November 2012 – January 2013
Participants: 7

**Online Questionnaire**
Timeframe: February 26 – April 30, 2013
Participants: 51
Interviews

To prepare for the online questionnaire, we conducted 7 interviews with software experts who work in various industries: automotive, automation, telecommunications.

All participants stated that tool support and tool interoperability require improvement. In particular, developers want better debugging tools for identifying and rectifying program flaws and errors.
Participants and Fields of Application
What industry are you active in?

Majority of the survey participants work in the automation and automotive industries.

Other industries include medical engineering, home automation etc.
In what field of application are you primarily active?

Majority of the participants are involved in **system software**, **system architectures** or **control systems** development.

Multiple choices are possible.
What does your industry or field of application place high value on when developing software?

Strong emphasis is placed on performance, deterministic behavior, and real-time capability.

(Data-) Security plays a lesser role.

Results are averaged
(0) = no value
(5) = high value
If your software has response-time constraints, what is the target range?

Timing constraints between 10µs and 10ms are the most common.

Multiple choices are possible

2/3 of all answers
Multicore
What are the key drivers behind the deployment of multicore processors in your fields of application?

Multicore processors are already being frequently deployed.

They are primarily used to support CPU-intensive algorithms.

Costs and throughput are also reasons for deployment.

Multiple choices are possible.
How will multicore systems be utilized in your fields of application in five years?

Outlook:

- Multicore processors will enjoy broad utilization.
- The number of CPU-cores will continue to increase.
- Multicore processors will tend to be used with heterogeneous architectures (integration with FPGAs or DSPs).

Multiple choices are possible.
Software Development
Which tasks are the most time-consuming in your project environment?

Debugging and testing are considered the most time-consuming tasks, followed closely by software specification and implementation.

Results are averaged
(0) = not done
(5) = very costly
What are the major challenges you face in developing software for embedded systems?

Major challenges:
- Debugging time-critical software
- Capability to reproduce errors
- Insufficient requirements specifications

In contrast to the qualified interviews, tool support and exchange formats are not key issues.

Multiple choices are possible
Tools
Which of the following tasks require tools?

The most time-consuming tasks have the greatest need for tools.

Despite higher demands on processor performance, tools for optimization are rarely needed.

Multiple choices are possible
What types of tools do you use?

Commercial tools are used especially during the early phases (V-model) of software development.

In later phases, developers also use open source software, freeware, and in-house solutions.

The frequent use of company-specific testing suites is included in in-house testing tools.
If you rely on in-house tools, what was the driver behind their development?

Major reasons for developing in-house tools are *unsuitable tools* and *missing features*.

*High procurement costs* are often mentioned as a reason.

Multiple choices are possible.
What the users say

Tool support for requirements validation - with simulation for instance - needs to be improved. Tool support for designing software architectures also needs improvement to enable the semi-formal notation of functional (state machines, algorithms) and non-functional (quality of service) requirements. Ideally, the tools should be integrated into the development process.
What the users say

A programming language that supports parallel programming structures is required. Existing approaches for C, ADA, or OpenCL are inadequate. There should be better support for parallel concepts such as SIMD-operations. Since many software developers still have a sequential mindset, training and education need to be expanded.
What the users say

Test environment needs to be expanded. Modern development processes require capabilities such as unit testing on the target hardware. Tools should be interoperable, open source and have consistent user interfaces. Many tools appear to have been merely thrown together at the last minute and end up hindering productivity instead of facilitating it.
CONCLUSION

1. The main incentives for the deployment of multicore processors are throughput and increased algorithm complexity. This leads to problems in the development of parallel software.

2. Debugging and testing are the most time-consuming tasks. The biggest challenges are reproducing failures and debugging time-critical and parallel software. This is supported by the high demand for debugging and testing tools.
CONCLUSION

3. Data security currently plays only a secondary role. Research programs like “Industrie 4.0” and the trend towards cyber physical systems will likely increase the importance of security in the future.

4. The key drivers behind the development of in-house tools are missing functionality and high procurement costs. This is interesting to note since in-house development is usually more expensive than buying an equivalent tool.
Multicore R&D Activities at Fraunhofer ESK

Tools for analyzing multicore software

- [http://www.esk.fraunhofer.de/de/projekte/Tracing.html](http://www.esk.fraunhofer.de/de/projekte/Tracing.html)
- [http://www.esk.fraunhofer.de/de/projekte/OProfileBM.html](http://www.esk.fraunhofer.de/de/projekte/OProfileBM.html)
- MUCOS: [http://www.esk.fraunhofer.de/de/projekte/MUCOS.html](http://www.esk.fraunhofer.de/de/projekte/MUCOS.html)
- WEMUCS: [www.multicore-tools.de](http://www.multicore-tools.de)

Embedded systems testing

- TIP: [http://www.esk.fraunhofer.de/de/projekte/TIP.html](http://www.esk.fraunhofer.de/de/projekte/TIP.html)

Tools for early validation of time-critical functions

- ERNEST: [http://www.esk.fraunhofer.de/de/projekte/ERNEST.html](http://www.esk.fraunhofer.de/de/projekte/ERNEST.html)
Detailed Results by Industry
What does your industry or field of application place high value on when developing software?

Results are averaged
(0) = no value
(5) = high value
If your software has response-time constraints, what is the target range?

Multiple choices are possible

- < 1µs
- 1µs - 10µs
- 10µs - 100µs
- 100µs - 1ms
- 1ms - 10ms
- 10ms - 100ms
- 100ms - 1s
- > 1s
- No constraints

% of participants

Automotive (10 Participants)
Automation (18 Participants)
Telecommunications (5 Participants)
Avionics (4 Participants)

Multiple choices are possible
What are the key drivers behind the deployment of multicore processors in your fields of application?

Multiple choices are possible

% of participants

- Cost
- Energy efficiency
- Throughput
- CPU-intensive algorithms
- Redundancy
- No multicore

Automotive (10 Participants)
Automation (18 Participants)
Telecommunications (5 Participants)
Avionics (4 Participants)

Multiple choices are possible
How will multicore systems be utilized in your fields of application in five years?

Multiple choices are possible

- No multicore
- Not for safety-critical applications
- Will be deployed
- More cores
- Homogeneous MC-processors
- Heterogeneous MC-processors

- Automotive (10 Participants)
- Automation (18 Participants)
- Telecommunications (5 Participants)
- Avionics (4 Participants)

Multiple choices are possible
Which tasks are the most time-consuming in your project environment?

Results are averaged
(0) = not done
(5) = very costly
What are the major challenges you face in developing software for embedded systems?

Multiple choices are possible

- Insufficient requirements
- Lack of appropriate means...
- Lack of exchange formats
- Allocation to processor cores
- Multi-core know-how
- Debugging time-critical...
- Debugging multi-core systems
- Capability to reproduce errors
- Tool support
- Poor performance

% of participants

Automotive (10 Participants)
Automation (18 Participants)
Telecommunications (5 Participants)
Avionics (4 Participants)
Which of the following tasks require tools?

Multiple choices are possible

- Specifications (60% of participants)
- Architecture (80% of participants)
- Modeling (60% of participants)
- Implementation (60% of participants)
- Debugging (80% of participants)
- Analysis (100% of participants)
- Testing (80% of participants)
- Optimization (60% of participants)
- System integration (40% of participants)
- Quality assurance (40% of participants)

- Automotive (10 Participants)
- Automation (18 Participants)
- Telecommunications (5 Participants)
- Avionics (4 Participants)
What types of tools do you use?

Multiple choices are possible.
If you rely on in-house tools, what was the driver behind their development?

- Formats not supported
- Standard not supported
- Tool out of date
- Functions not available
- Procurement costs too high
- No suitable tool available
- Other reasons

Multiple choices are possible

Automotive (10 Participants)
Automation (18 Participants)
Telecommunications (5 Participants)
Avionics (4 Participants)