Educational Case Studies with an Open Source Embedded Real-Time Java Processor

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Educational Platform: JOP

- History: Met Martin as he finished his Ph.D. He is now with DTU

- A Java processor developed on a FPGA (ie. using VHDL) by Martin Schoeberl

- Analyzable with respect to real-time properties

- Tools exist for creating worst case execution time analysis of Java code

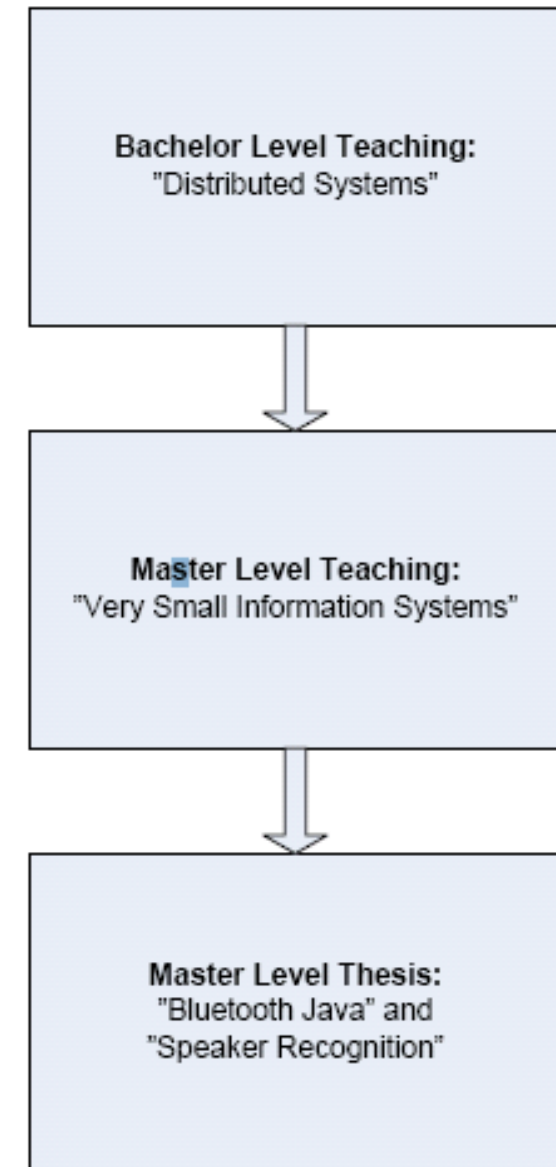- It is GNU GPL

- www.jopdesign.com and Yahoo group

JOP in Industry

- JOP was used for a distributed application for a railway

- Masts were equipped with a JOP board which lifted and lowered the electrical cords in a synchronized fashion

- Is was also used for single path railway control

JOP at a Non-technical University

- 20 boards at Dept. of Informatics, Copenhagen Business School

- Used for bachelor, master, and thesis level classes

- Soldering at a business school is interesting

Bachelor Level Teaching: "Distributed Systems"

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Master Level Teaching: "Very Small Information Systems"

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Master Level Thesis: "Bluetooth Java" and "Speaker Recognition"

Copenhagen Business School
HANDELSHØJSKOLEN

Bachelor Class

- Distributed Systems, 40 students
- Lab exercises with UDP
- Done to give students a broader understanding of the fact that embedded systems exist *even at a business school*

Master Level Class

- Distributed Data Mining
- Give the students the chance to implement something intelligent in Java
- Feel the restrictions that apply to embedded systems: fixed point math and limited stack size
- Happy for red LED...

Master Level Class

- Very Small Information Systems
- 450 Hours
- Martin Schoeberl, Rasmus Pedersen, and censor with EE background
- Intelligent humidity, activity heat control, barcode analyzer, speaker verification, stock data analysis
- Lesson: Need EE person

Master Level Theses

- Bluetooth connected to JOP via serial line, and communicating via OBEX

- Word recognition
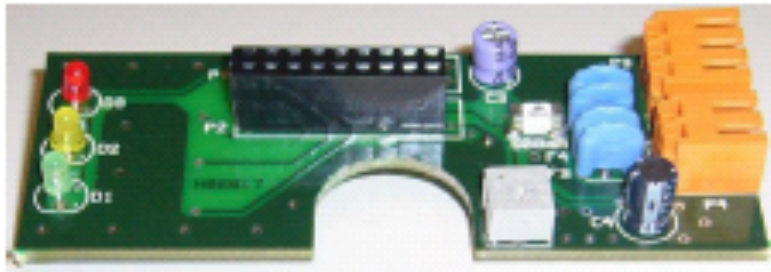
- JOP is well-documented and stable, which makes this possible, and it is in <u>Java</u>

At a Technical University

- Martin Schoeberl used JOP for several project at the Technical University of Vienna
- Interesting point: The interaction between students last longer than one semester
- Many projects…

Specialized Course

- *Java Virtual Machine in Hardware*
- Students learn the inner workings of the hardware/software tradeoffs
- They see the whole way from processor design to system design (Java virtual machine), up to application programming

Example projects from Specialized Course

- Long bytecodes
- Integer division (moving critical parts into HW)
- Comparison of a JIT capable JVM on a different architecture with JOP + scientific paper
- Alternative implementation of priority cealing emulation
- Implementation of Scoped Memory (Safety Critical Java)
- Robot control with Xbee communication for control
- Further examples are: `tableswitch/lookupswitch`, WCET with UPPAAL, JOP UI in VHDL, NFS over UDP
- Learning: Students picked a place in the design stack or covered several layers of HW/SW design in their projects

Bachelor Projects

- Lego robot controller PCB
- Joptimizer: A tool to optimize bytecodes (normally a JIT task)
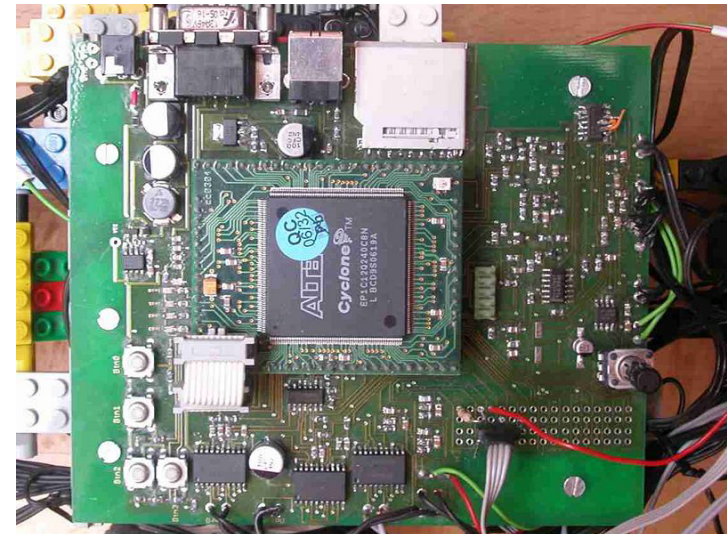
Master and Ph.D. Level Projects

- picoJava ported FPGA (also served as preparation for Ph.D. Work)

- Extenstion of worst case execution time analysis tool (the student continued this work from a master level class)

- Current work: Hardware transactional memory for chip-multiprocessor

- EU funded Ph.D. work chip-multiprocessor

Discussion/Conclusion

- JOP is well-suited for university teaching because it is more than an embedded system

- Network capabilities makes it possible to cover more classes

- Real-time properties are motivating (good stories can be told)

- Limitation/possibility: The limited stack is somthing that has to be mastered

- It is motivating for lectures/researchers engaged in similar research because there are many papers on JOP and it is an active community that supports it