Industrial Requirements for WCET Tools

Answers to the ARTIST Questionnaire

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Respondents

- Answered by 12 participants 😞
- Functions: Developers, Engineers, Managers, CTO R&D, Director, Program Manager, Chief Scientist ☺
- Responsible for groups of size:
  - 1-5  9x
  - 6-10  1x
  - 21-100  2x
For which applications/systems do you need WCET tools in your own development?

- **Automotive** (Engine Control), guiding systems, Automotive control units
- **Avionics**, On-board SW on satellites
- **OS**, customer applications
- **Synchronous programs**
- **Embedded controllers**
- **DSP embedded systems** development
- **Evaluation of supplier systems**
Under which **Formal Rules** do you work, e.g. DO 178B?

- 5 none
- 4 DO178B,
- US DoD services, NASA
- IEC61508, ...
- ISO9000
- ECSS, usually project-tailored
- DO-248; DO-254; AC 20.115B
• Do you **use Coding Guidelines** to support WCET analysis?
  – 9 No
  – 3 Yes

• Are you **willing to adhere to Coding Guidelines** to help WCET analysis?
  – 10 Yes
  – 2 No
Need/Plan to Use

- **Processor Architectures with**
  - 8 Instruction or data cache
  - 7 Branch Prediction
  - 3 Multi-level cache hierarchy
  - 5 Superscalar out-of-order execution

- **Hardware Platforms**
  - 4 Mono and multi processor
  - 8 Mono processor
For which **Processors** would you like to have Timing tools available?

- **The usual suspects**
  - 7 PowerPC
  - 4 ARM resp. ARM7 and ARM9
  - 3 C166/7
  - Tricore, Coldfire, TMS, sharc, HC12, M16C, TX49, TS101, 68K, MIPS

- **Surprises**
  - 1 Pentium, 2 x86
  - 2 V850
For which Target Software Platforms would you like to have Timing Analysis tools available?

- 11 Real-Time OS
- 7 Hardware
- 2 Middleware
*III. Current Practice*

Do you use tools for Schedulability Analysis?

- 7 Based on **Response Time/Rate Monotonic Analysis**
- 4 Based on **Time Triggered Scheduling**
- 1 ARINC 653 (hierarchical model)
- 2 NO TOOL
Do you use tools for WCET Analysis?

- 1 For whole systems
- 1 For parts of the system
- 10 N/A
Do you use Measuring of the Execution Time to Estimate WCET?

8 Via Code Instrumentation
6 Via Debug Tools (BDM, JTAG, or other)
4 Via Logic Analyzer

Others:
- RTOS includes support
- Chip Internal counter.
- We review suppliers analysis
How much **Effort** do you spend in Timing Validation?

- 15 % of development
- 5-10 % of development
- 1 % of development
- 9 N/A
How much Development Time is spent in Measuring the Execution Time of code pieces in addition to Estimating the WCET?

- 10% of development
- 5% of development
*IV. Requirements*

What should be the Functionality of the Tools?

- 6 Very rough *first estimate*
- 6 Back annotation of results into the source code
- 7 Proposals for *cache locking*
- 9 Stack-Extent Analysis
- 7 Best Case Execution Time
- 1 Annotated Assembly listing
Other Analyses

- Execution time coupled to its probability
- Average Execution Time
- Assurance of WCET to safety/criticality level required
- Distributions/histograms; indications/estimates of WCET
- Verification of some pre-, postconditions and invariants of functions
- Analysis of code parts with disabled interrupts
- Measurement of OS and communication impact
What is the Tolerable Learning Effort for users of the tool?

- 2 2 days
- 2 3 days
- 1 5 days
- 1 5-10 days
How much Effort for Annotation of the Code is tolerable?

• 7 Bound for Loops and Recursion
• 3 Locked Cache Contents
• Others:
  – loop bounds often obvious, recursion prohibited at high criticality levels
  – as little as possible
  – as much as possible
What would be Tolerable Analysis Times on realistic code sizes, e.g. 100k instructions?

- 100 000 minutes 😊
- 10 minutes
- 1-10 minutes
- 10-120 minutes
- 60-120 minutes
Would you adopt a Processor with High Predictability with some loss in average case performance?

(Note, this may mean improved WCET!)

• 9 Yes
• 3 No
Which other Tools should a WCET tool be Integrated with to suit your development flow?

- Enea ASF/DART, some UML-tool
- Ascet SD, Matlab/Simulink
- schedulability, CM, traceability, requirements capture
- WCET and flow analysis must be integrated
Other Remarks

- One respondent is claiming that the questions asked do not fully capture all of the issues due to:
  - different embedded applications with differing needs
  - a WCET prediction should be bound to a level of assurance associated with that prediction
  - predicting WCET should be part of the entire process of developing software, from design to deployment and maintenance
Other Remarks (cont.)

- The faster the analysis time the better, but very tight predictions would be worth several days of analysis time.

- Limiting the scope of processors is reasonable, though it limits the market in which a timing analysis tool can be applied.

- Limiting the language of programs being analyzed is reasonable, though some users may complain.

- The price of a timing analysis tool is a very sensitive issue since it can affect the viability of the product.
Other Remarks (cont.)

• The tools should be automated and should require little or no user intervention.

• Timing analysis tools should be complemented with stress testing, presumably due to WCET tools not being completely reliable.

• There are many complicated architectural features that are difficult to analyze, which include DMA and bus arbitration in complex multi-DSP systems.

• Some vendors rely on suppliers to provide WCET information that can be used in certification efforts.
What is the maximum tolerable price per seat for such a tool (under the assumption that its use saves money spent in validation otherwise)?

- 1 up to 10000 $
- 7 up to 5000 $
- 1 up to 50000 $
- 3 Don't know
Conclusions

• WCET Prediction is important.
  – willingness to sacrifice performance for predictibility

• Future Issues
  – interaction with energy awareness
  – extending WCET determination to high-level design