Towards Interactive Timing Analysis for Designing Reactive Systems

Insa Fuhrmann, David Broman, Steven Smyth, Reinhard von Hanxleden

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6. April 2014 / RePP’14 Workshop
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Motivation
Contributions
Classifications
Tool Chain and TPP
Formal Interface
Related Work
Conclusion and Future Work

Reactive Systems
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Reactive Systems

input: accelerator

input: bumper
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Reactive Systems

input: accelerator

output: motor

input: bumper
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Reactive Systems

input: accelerator

max: 400 tu

output: motor

input: bumper

inputs

outputs
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**SCCharts:**
v. Hanxleden et. al., SCCharts: Sequentially Constructive Statecharts for safety-critical applications, PLDI’14

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Modeling Reactive Systems

![Diagram of SCCharts](image-url)
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Timing Information

WCET flat/deep
Improved Robot Example
Issues

1. Different meanings and aggregation of timing values possible
2. Flow of timing information through abstraction layers
3. Analysis must be highly responsive
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Contributions

1. Classification of timing values
2. General timing information propagation concept (work-in-progress toolchain)
3. Formal interface between modeling and analysis tool, separate analysis for tick function and called functions
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Types of Timing Information

- **Fractional** WCET (or BCET) of a model element: Cost of its share of the overall WCET or BCET path.
- **Local** WCET (or BCET) of a model element: Cost of the most (least) expensive execution path that lies in this element.
Timing Information Flow Chain I

Model

Code

Assembler

Processor
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Timing Information Flow Chain I

SCCharts → Model

C Code → Code

Assembler

FlexPRET → Processor
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Timing Information Flow Chain I

SCCharts → Model → Timing Program Points (TPP) → C Code → Code → Assembler → FlexPRET → Processor
Program Points

```plaintext
1 tick() {
2    //main
3    // implicit TPP
4    g0 = _GO;
5    if (g0) {
6        motor = false;
7        g0._F = true;
8        g4._T = true;
9        g10._T = true;
10    };
11    //handleEmergency
12    TPP(1);
13    g7 = g0;
14    if (g10) {
15        g9 = pre (g8);
16        g10 = g9 & bumper;
17        if (g10) {
18            stop = true;
19        }
20    };
21    g8 = g7 | (g9 & ! bumper);
22    };
23    //handleMotor
24    TPP(2);
25    g1 = g0;
26    if (g4._T) {
27        g3 = pre (g2);
28        g3b = g3;
29        g4 = g3b & stop;
30        if (g4) {
31            writeLog();
32        }
33        g5 = g3b & ! stop;
34        g6 = g5 & accelerator;
35        g2 = g1 | (g6 | (g5 & ! accelerator));
36    }
37    if (g6) {
38        getImage();
39        motor = true;
40    };
41    g2 = g1 | (g6 | (g5 & ! accelerator));
42    }
43    //main
44    TPP(3);
45    g11 = g0._F & ! (g4._T | g10._T);
46    if (g11) {
47        g0._F = false;
48    };
49    // implicit TPP
50    }
51    if (g11) {
52        g0._F = false;
53    }
```
Contributions - Revisited

1. Classification of timing values
2. General timing information propagation concept (work-in-progress toolchain)
3. Formal interface between modeling and analysis tool, separate analysis for tick function and called functions
Definition (Interactive Timing Analysis)

Given a program consisting of a set of functions $F$, a set of global variables $G$, and a timing analysis request $t_{req}$, return a timing response $t_{res}$.

$$t_{req} = (f, a, g, e, P, R).$$ (1)

- $f \in F$: function to be analysed
- Assumptions: $a$ for arguments, $g$ for global variables, and $e$ for called functions
- $P$: set of timing program points in function $f$
- $R$: set of requested analyses (will be defined shortly)
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$$t_{req} = (f, a, g, e, P, R).$$ \hspace{1cm} (1)

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\[
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Timing Graph
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Analysis Request

- Each element of $R$ is a triple $(y, p_a, p_b)$
- $p_a \in P$ and $p_b \in P$ start and end TPP
- $y \in Y$: type of requested analysis value

$$Y = \{WCP, BCP, LWCET, LBCET, FWCET, FBCET\} \quad (2)$$
Timing Response

The timing response $t_{res}$ for a specific timing request $t_{req}$ is a function

$$t_{res} : R \rightarrow \mathbb{N}_{\perp \epsilon} \cup \mathcal{P}(\bar{p})$$  \hspace{1cm} (3)

i.e. the return value is a number, one of the values infinity and unknown, or an element of the set of finite paths of program points.


SCADE, aiT
Conclusion

- Classification of timing values
- Formalization of interaction of modeling tool and timing analysis
- General concept of TPP for timing information propagation
- Separation of concerns will hopefully allow for fast analysis
Future Work

- Finish implementation, Evaluation
- Experimental studies
- TPP in cycles
Thanks for your attention! Do you have questions?
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Additional Material: Timing Response II

\[
\text{t}_{\text{res}}(r) = \begin{cases} 
\mathcal{T}(\bar{v}^w_{p_1,p_2}) & \text{if } r = (\text{WCP}, p_1, p_2) \\
\mathcal{T}(\bar{v}^b_{p_1,p_2}) & \text{if } r = (\text{BCP}, p_1, p_2) \\
\mathcal{E}(\bar{v}^w_{p_1,p_2}) & \text{if } r = (\text{LWCET}, p_1, p_2) \\
\mathcal{E}(\bar{v}^b_{p_1,p_2}) & \text{if } r = (\text{LBCET}, p_1, p_2) \\
\mathcal{E}(\mathcal{F}_{p_1,p_2}(\bar{v}^w_{p_e,p_x})) & \text{if } r = (\text{FWCET}, p_1, p_2) \\
\mathcal{E}(\mathcal{F}_{p_1,p_2}(\bar{v}^b_{p_e,p_x})) & \text{if } r = (\text{FBCET}, p_1, p_2) 
\end{cases}
\]