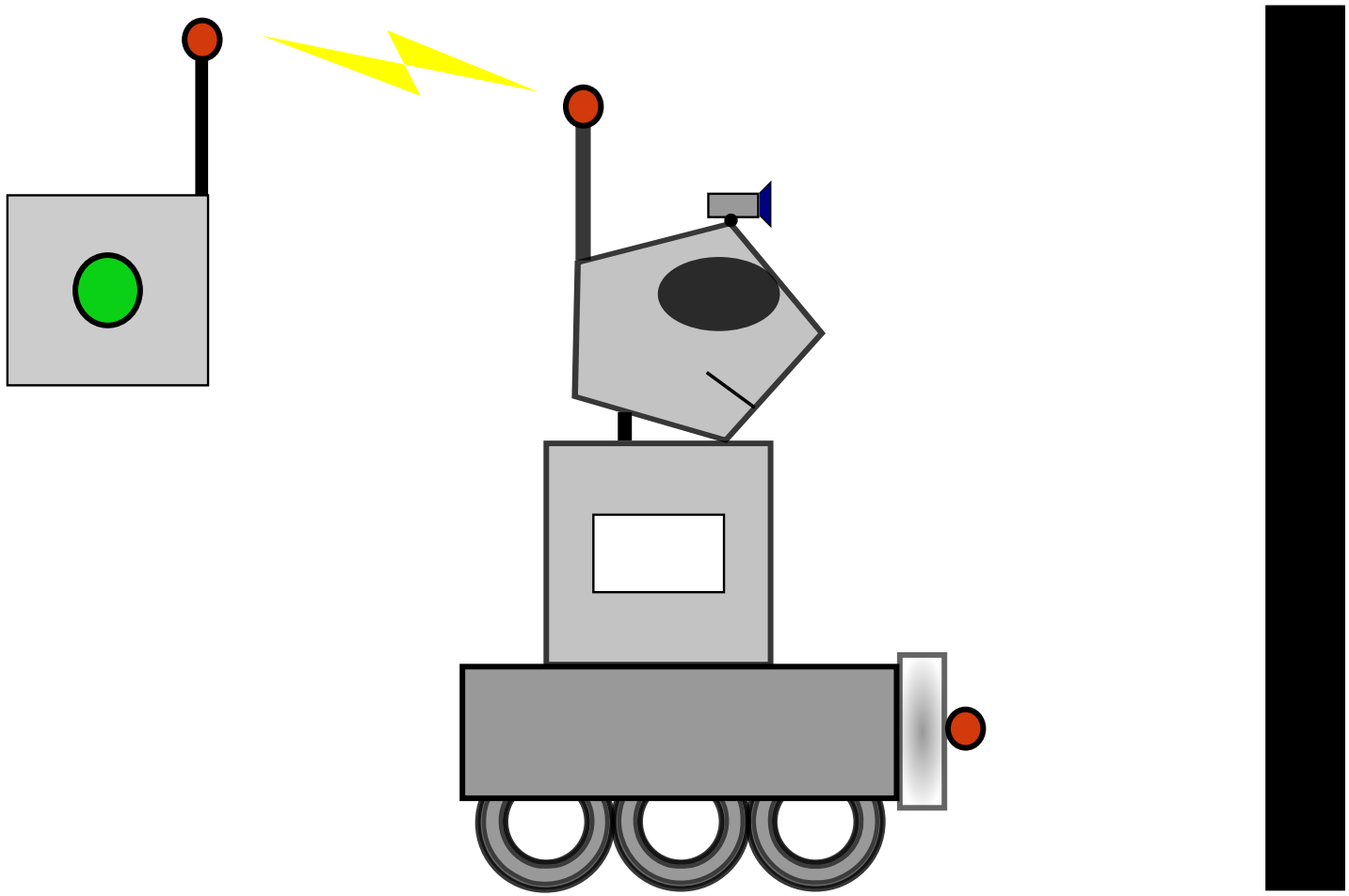
Towards Interactive Timing Analysis for Designing Reactive Systems

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

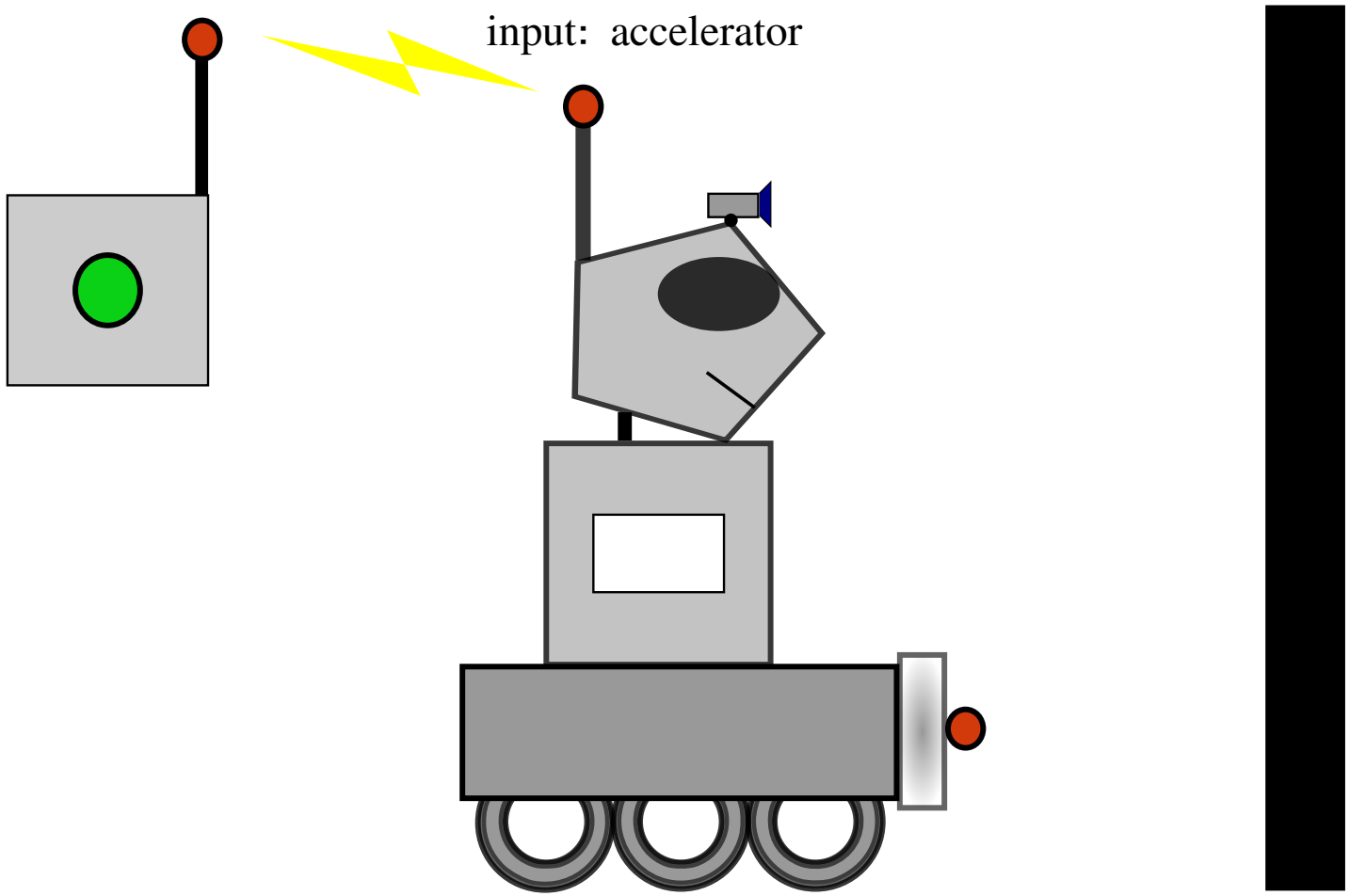
Department of Computer Science
Christian-Albrechts-University Kiel

6. April 2014 / RePP'14 Workshop

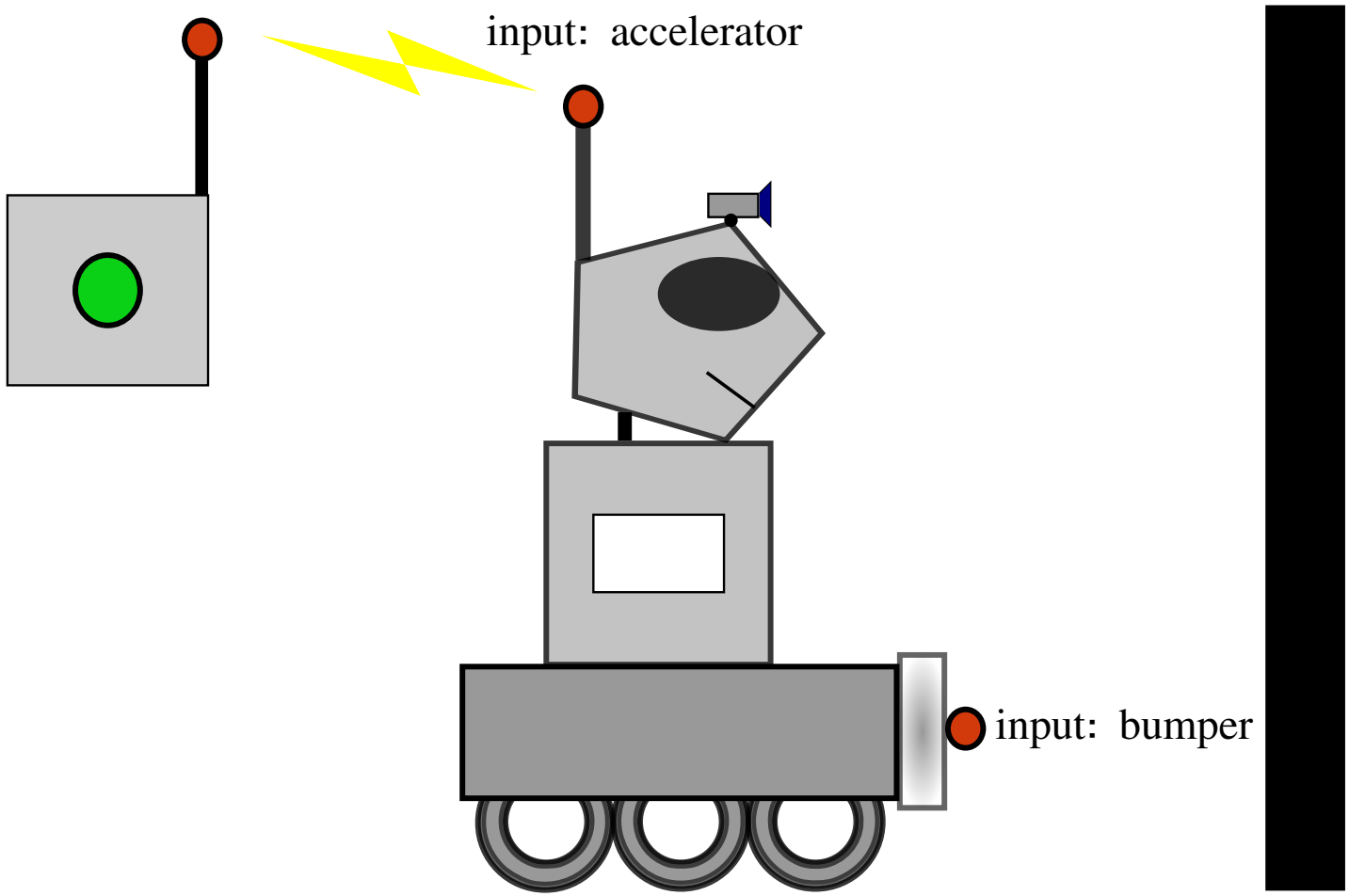
Reactive Systems



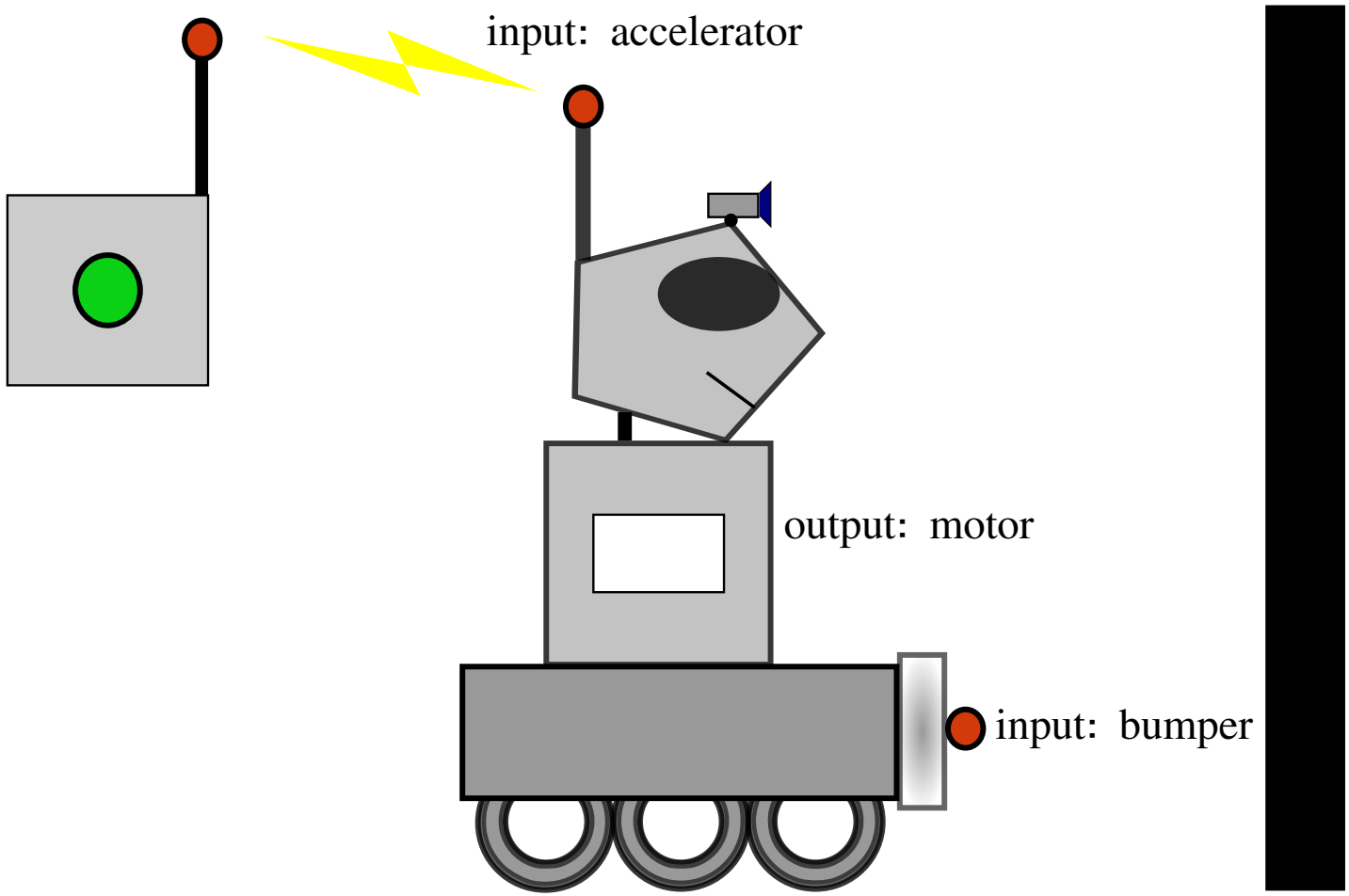
Reactive Systems



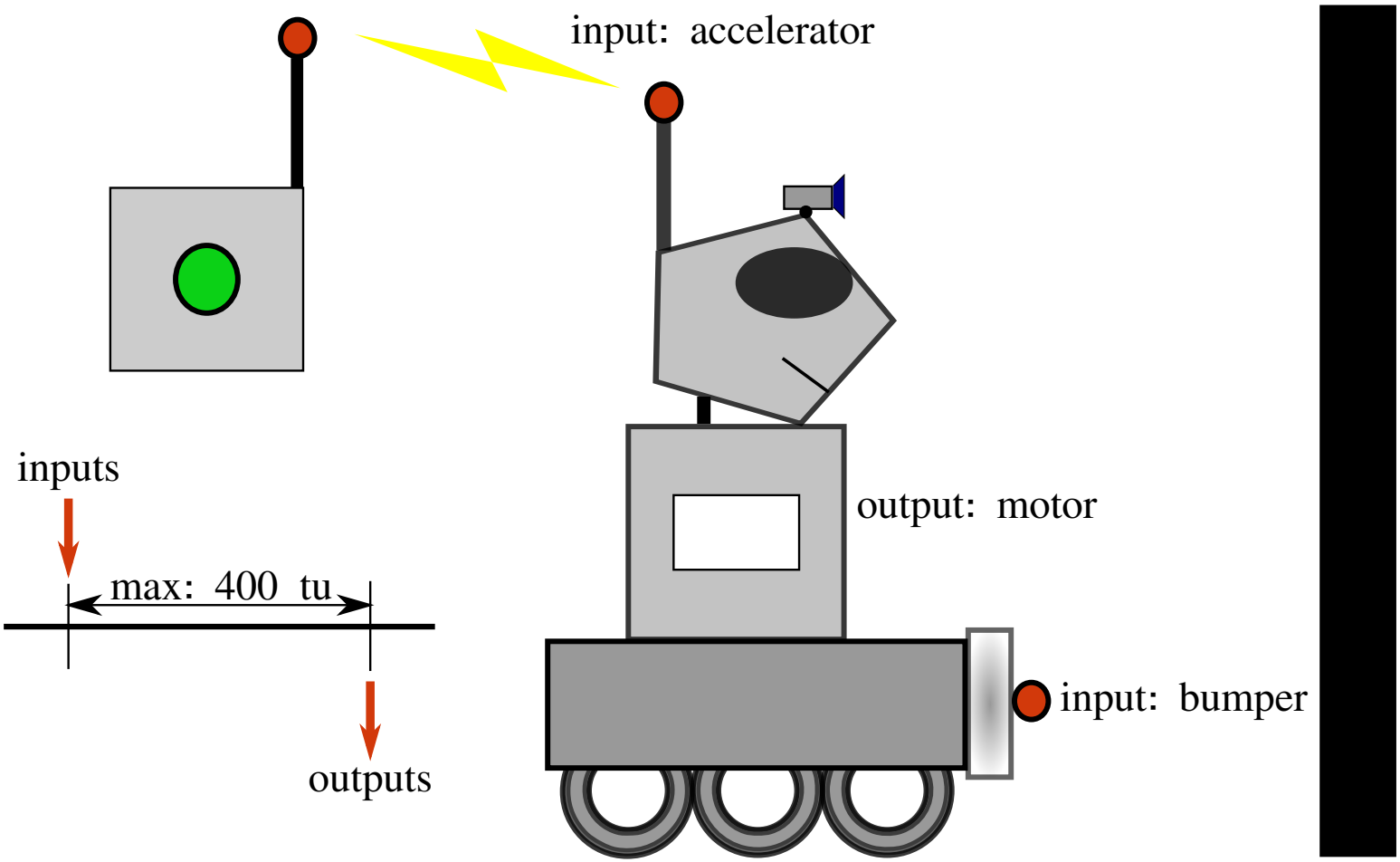
Reactive Systems



Reactive Systems

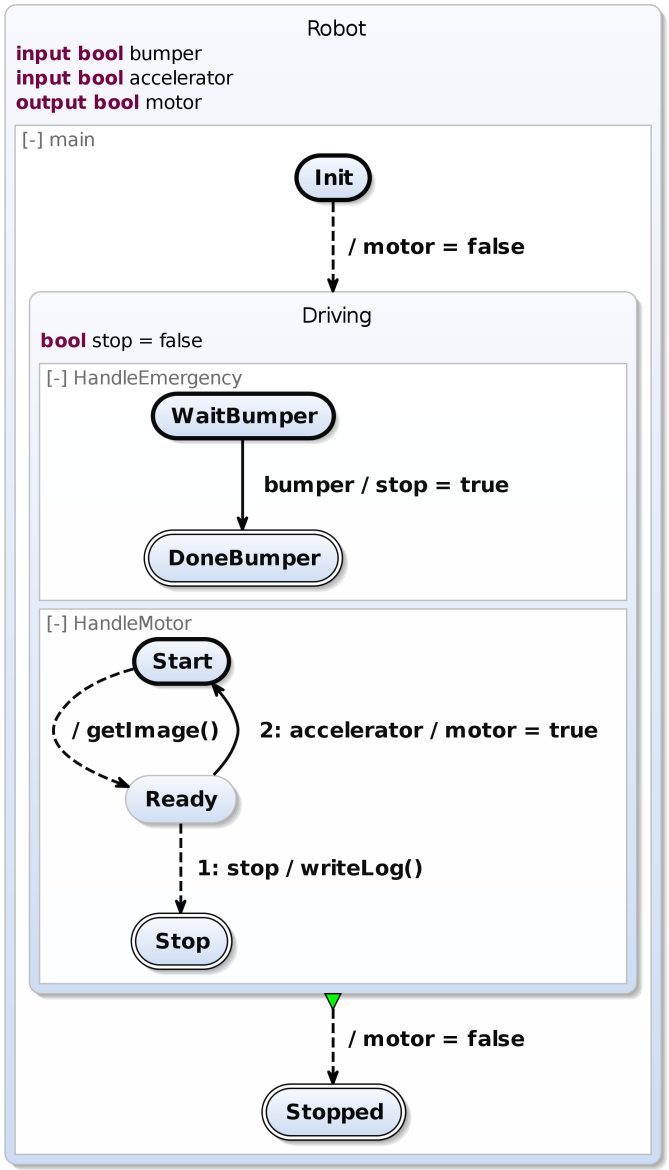


Reactive Systems

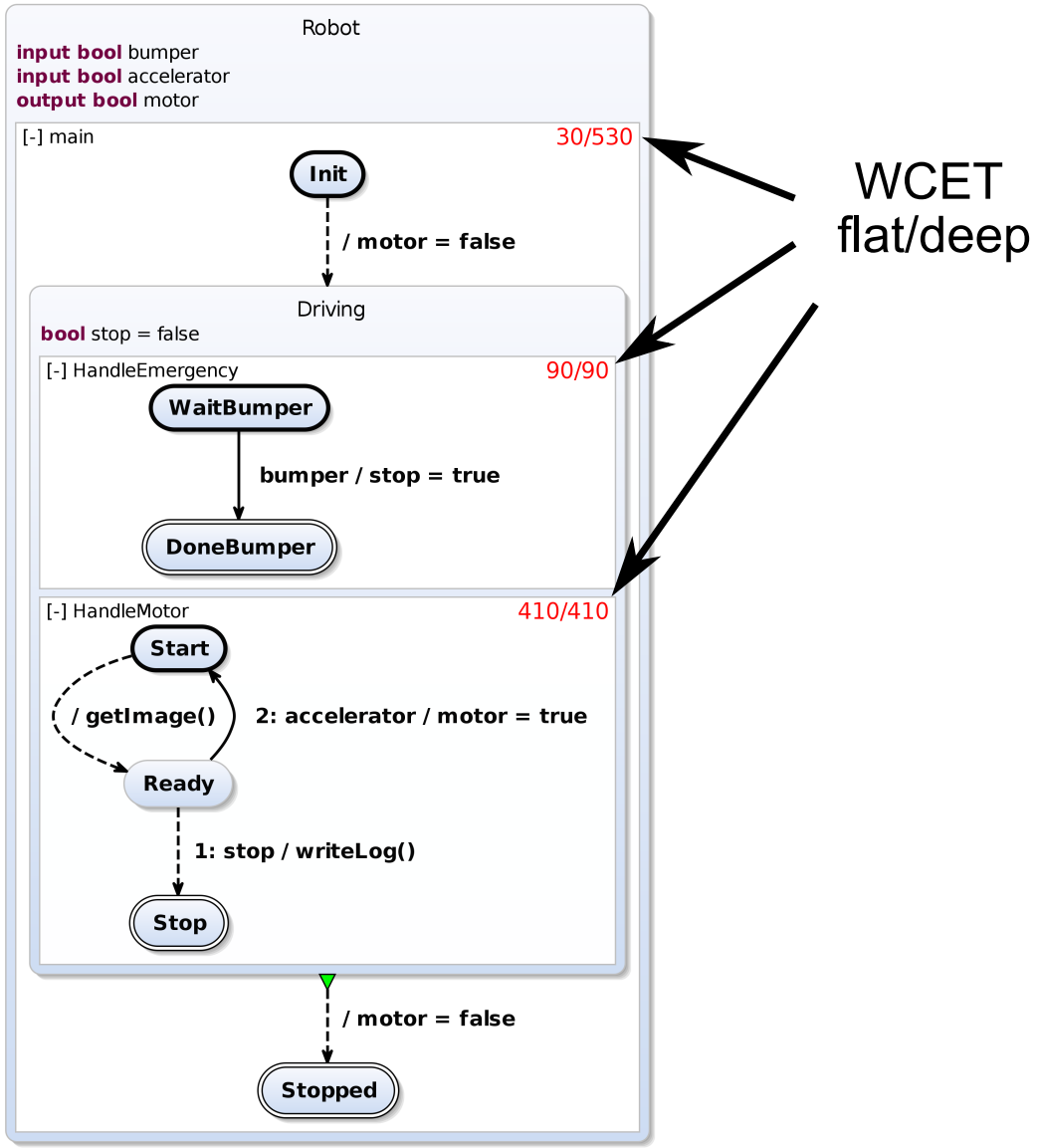


Modeling Reactive Systems

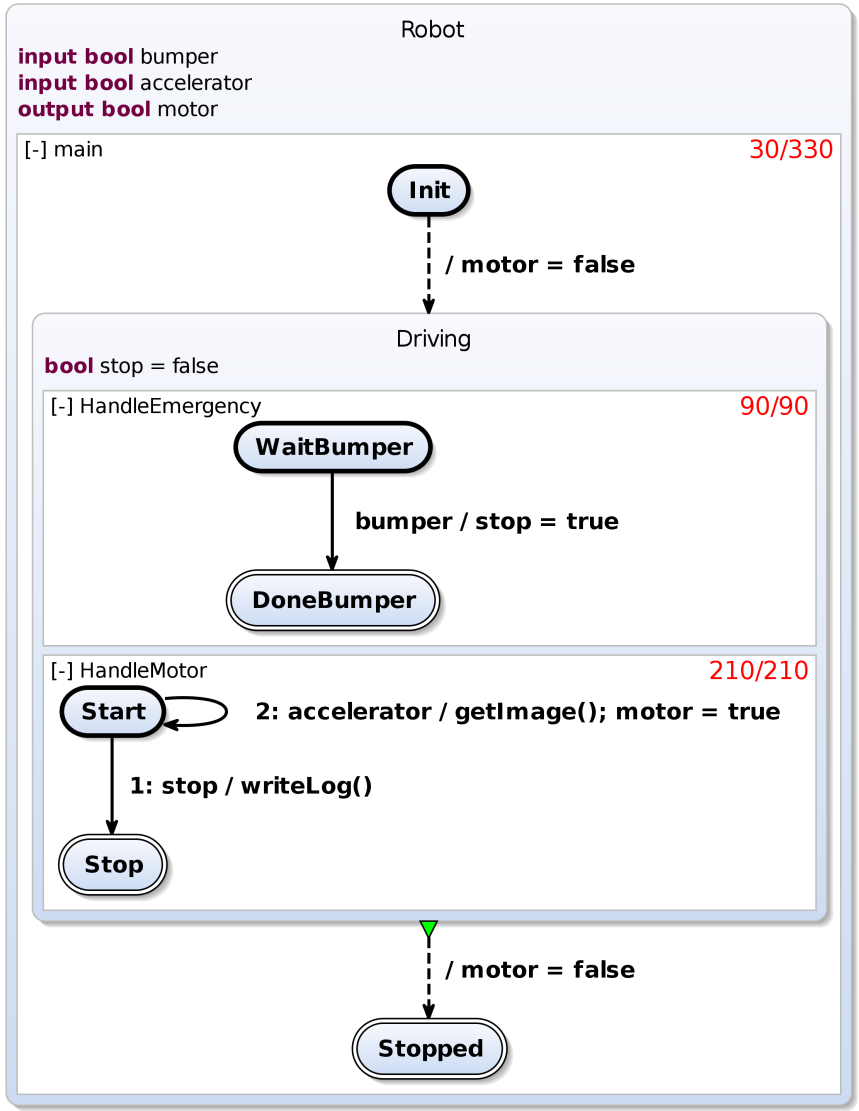
SCCharts:
v. Hanxleden et. al., SCCharts: Sequentially Constructive Statecharts for safety-critical applications, PLDI'14



Timing Information



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

Issues

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

Issues

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

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

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

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

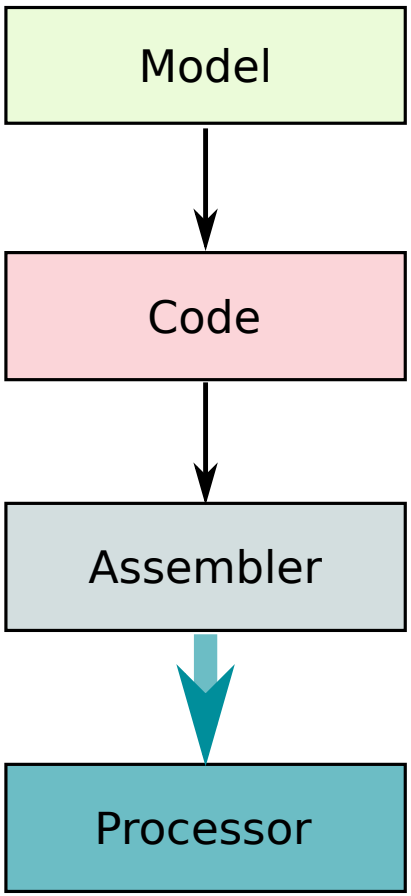
Contributions

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

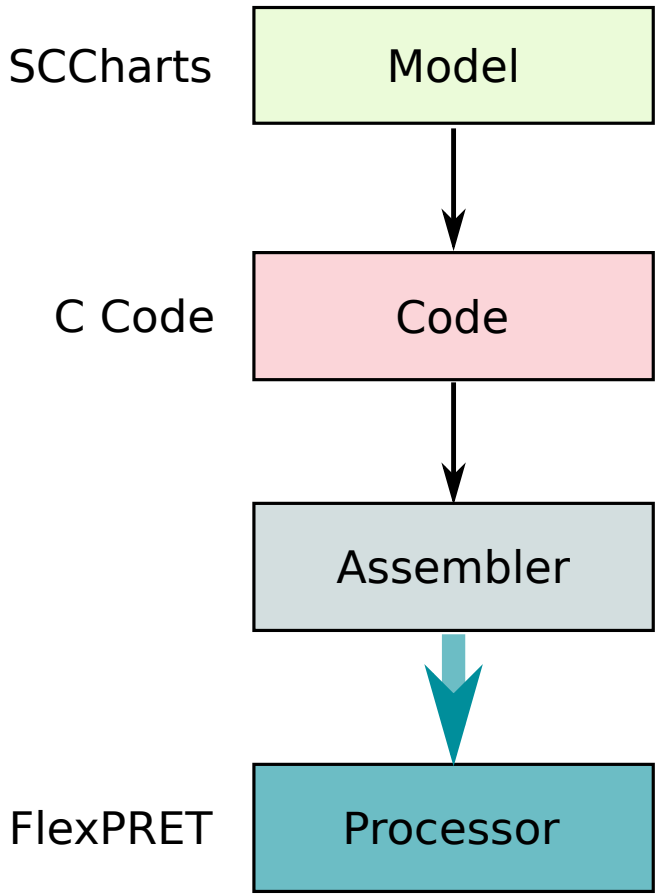
Types of Timing Information

- 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.

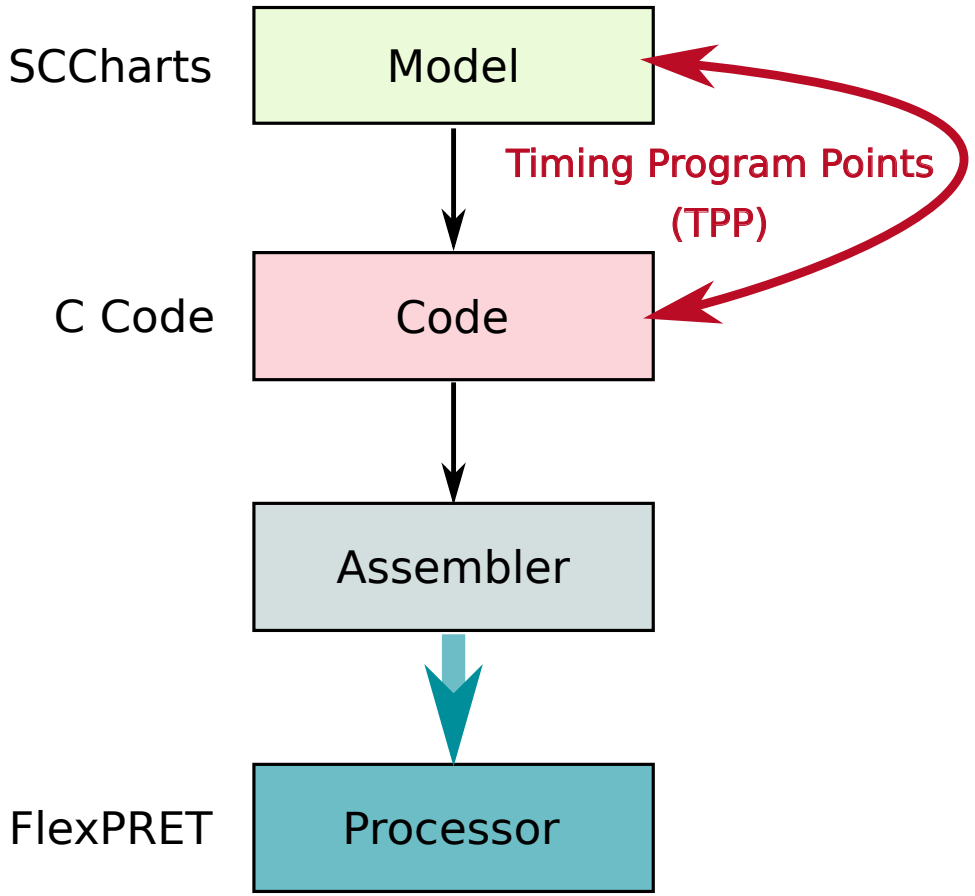
Timing Information Flow Chain I



Timing Information Flow Chain I



Timing Information Flow Chain I



Program Points

```
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_T) {
15     g9 = pre ( g8 );
16     g10 = g9 & bumper;
17     if (g10) {
18       stop = true;
19       g10_T = false;
20     };
21     g8 = g7 |
22       ( g9 & ! bumper );
23   };
24  //handleMotor
25  TPP(2);
26   g1 = g0;
27   if (g4_T) {
28     g3 = pre ( g2 );
29     g3b = g3;
30     g4 = g3b & stop;
31     if (g4) {
32       writeLog ();
33       g4_T = false;
34     };
35     g5 = g3b & ! stop;
36     g6 = g5 & accelerator;
37     if (g6) {
38       getImage();
39       motor = true;
40     };
41     g2 = g1 |
42     ( g6 |
43     ( g5 & ! accelerator ));
44   };
45  //main
46  TPP(3);
47   g11 = g0_F &
48     ! ( g4_T | g10_T );
49   if (g11) {
50     g0_F = false;
51   };
52  // implicit TPP
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}.

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

- $f \in F$: 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)

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}.

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

- $f \in F$: 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)

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}.

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

- $f \in F$: 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)

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}.

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

- $f \in F$: 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)

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}.

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

- $f \in F$: 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)

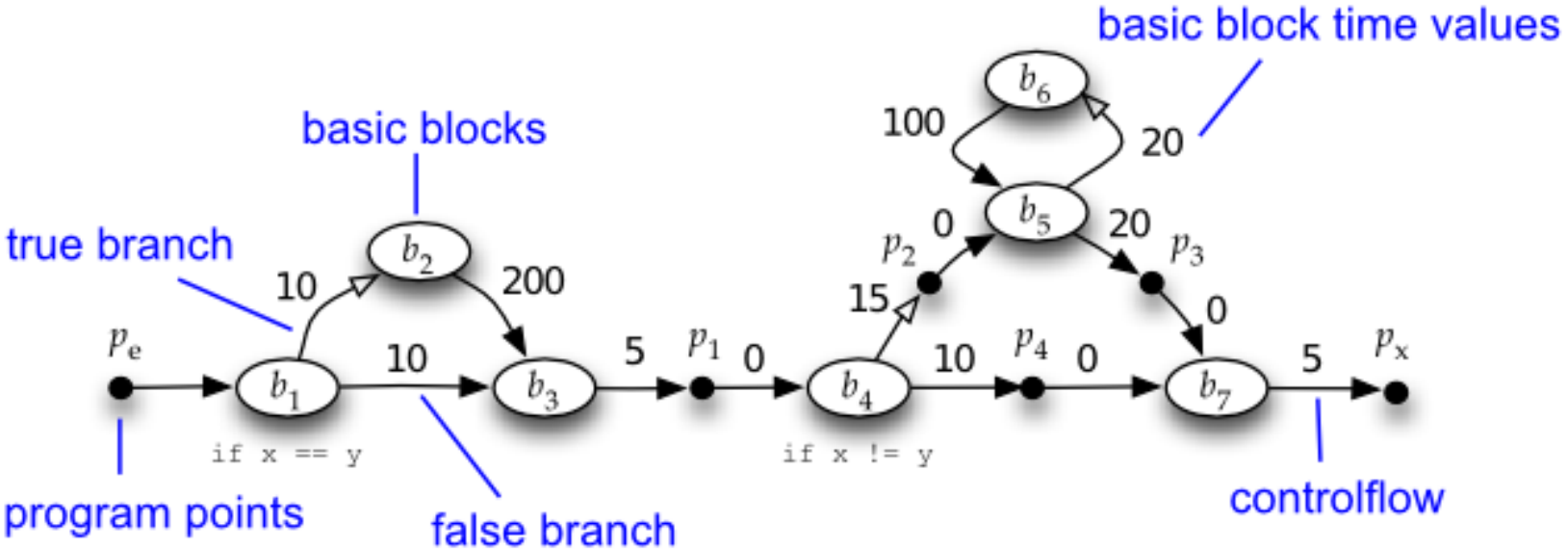
Definition (Interactive Timing Analysis)

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}.

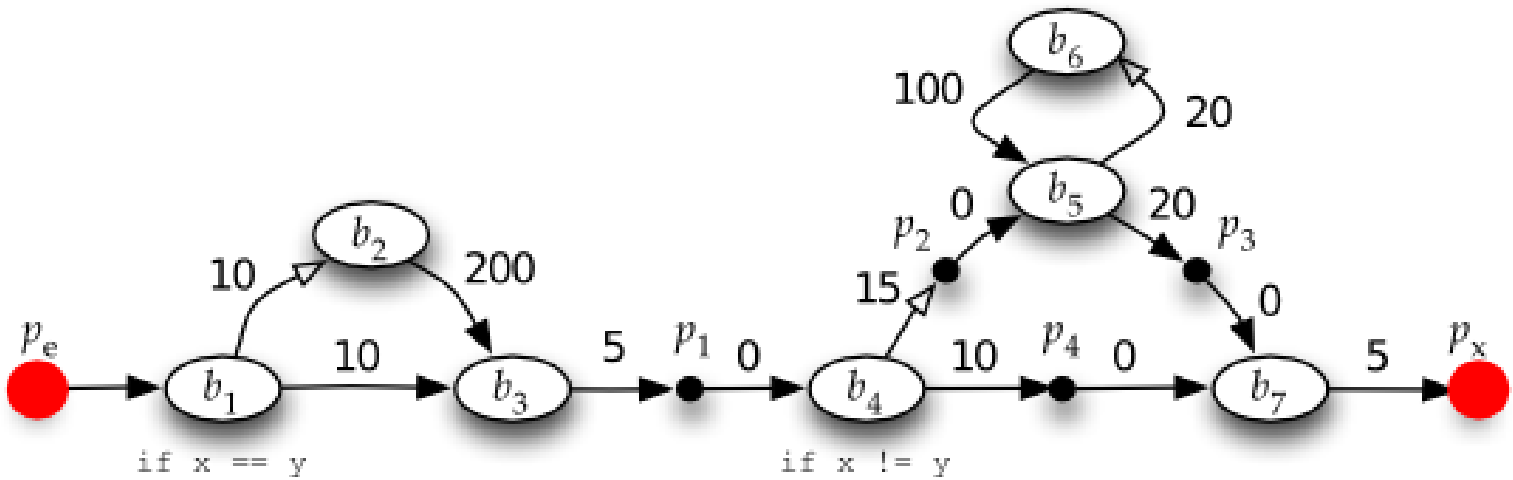
$$t_{req} = (f, a, g, e, P, R). \tag{1}$$

- $f \in F$: 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)

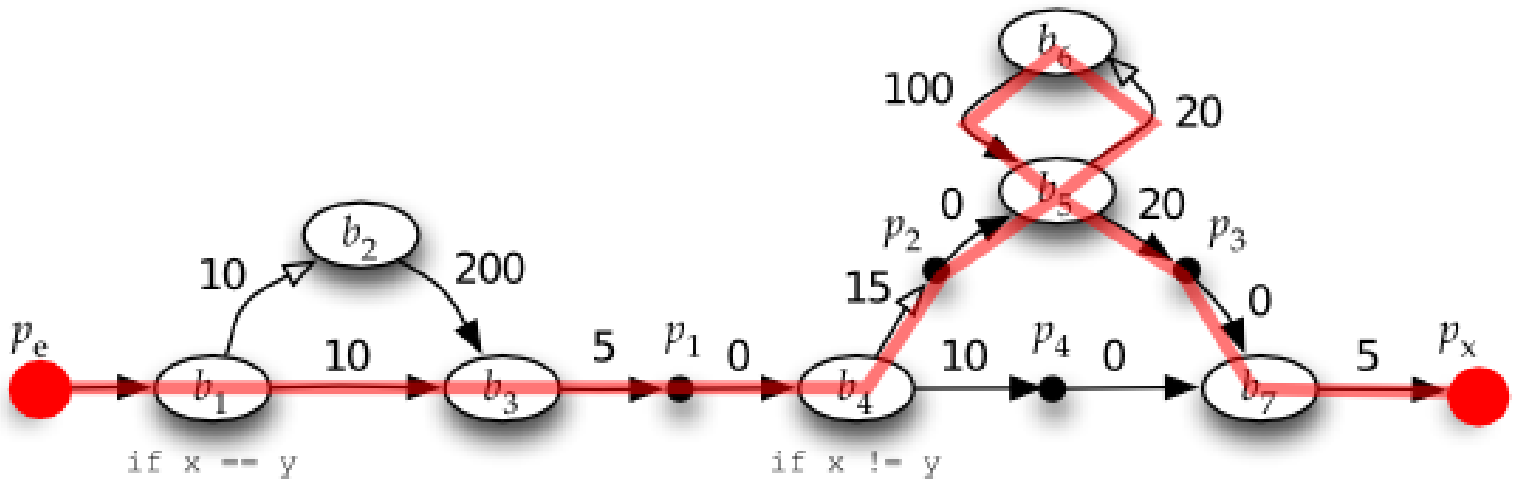
Timing Graph



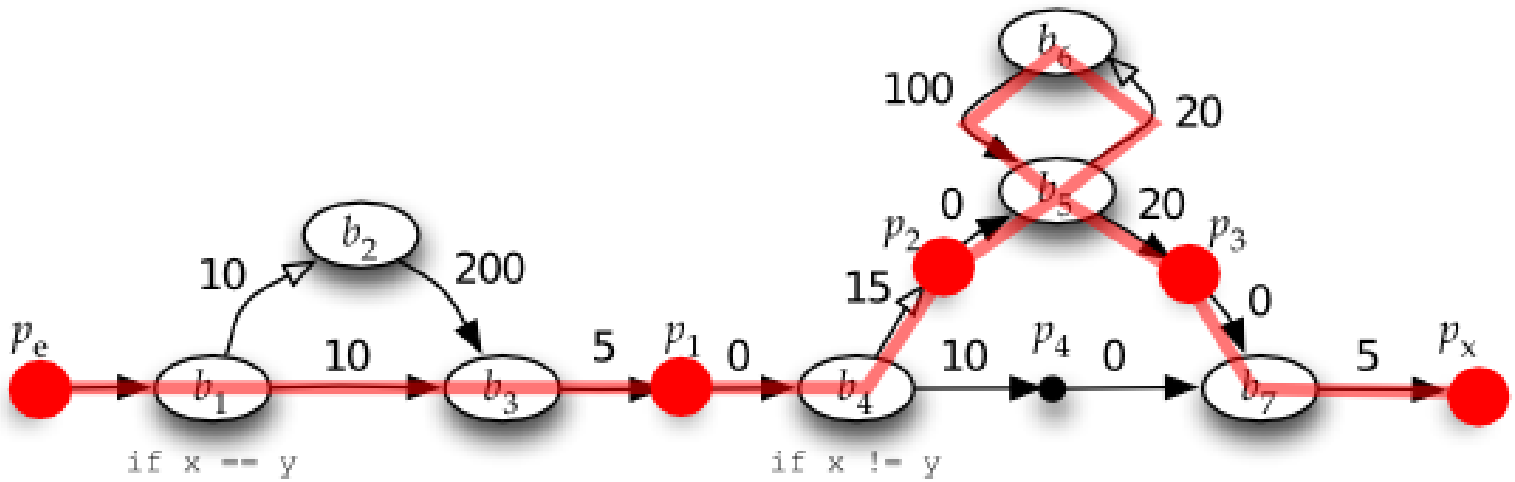
Timing Graph



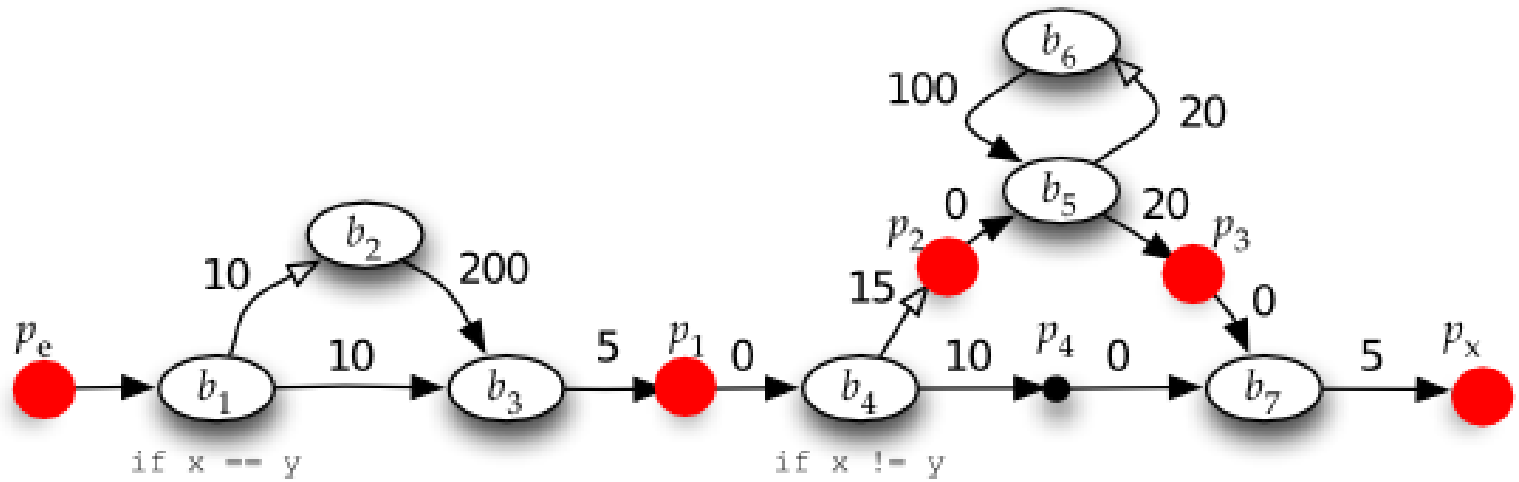
Timing Graph



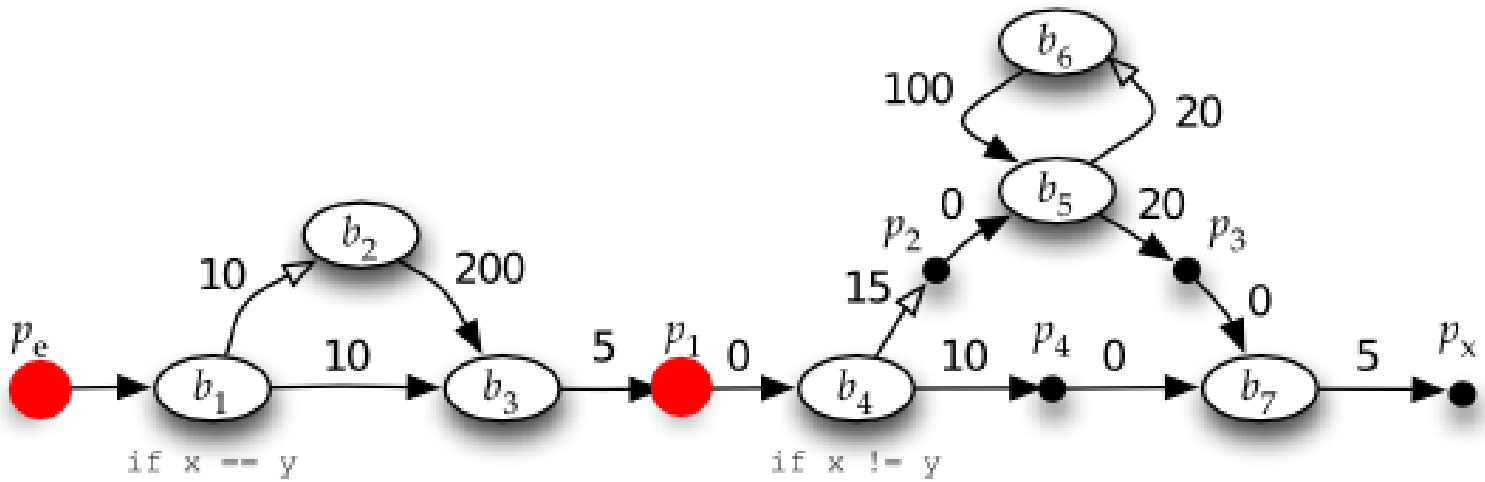
Timing Graph



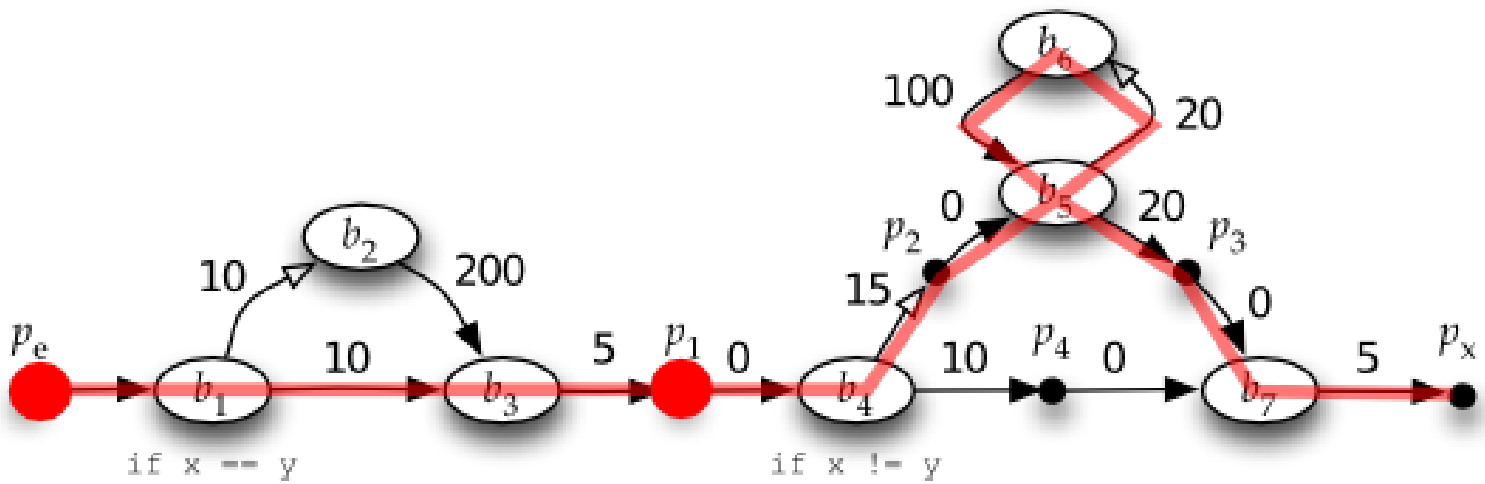
Timing Graph



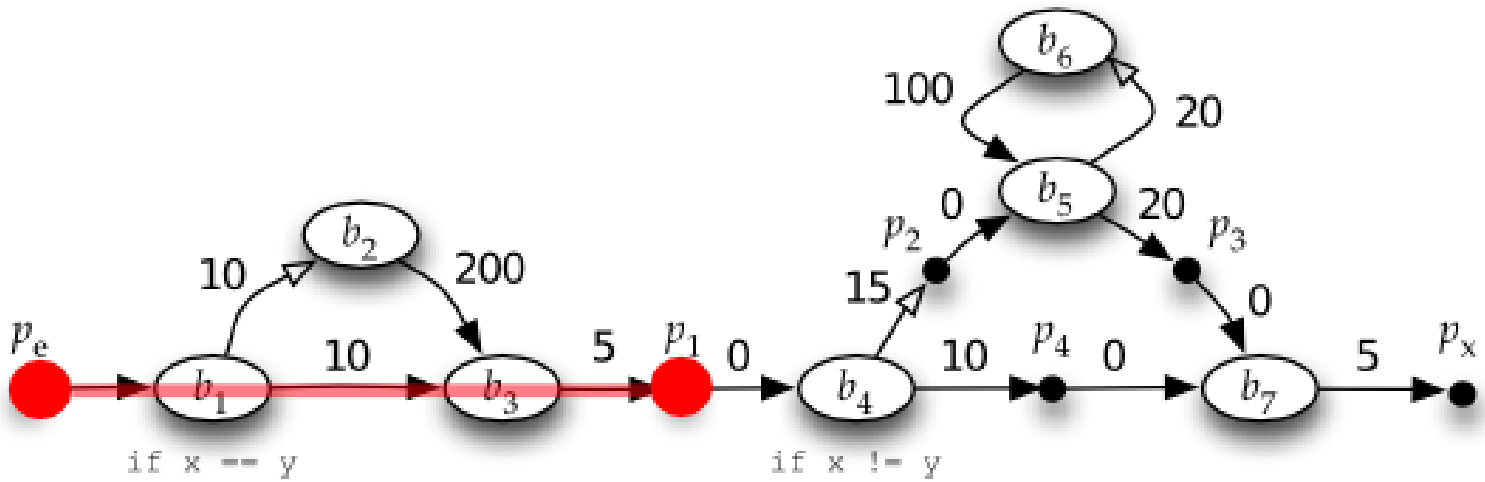
Timing Graph



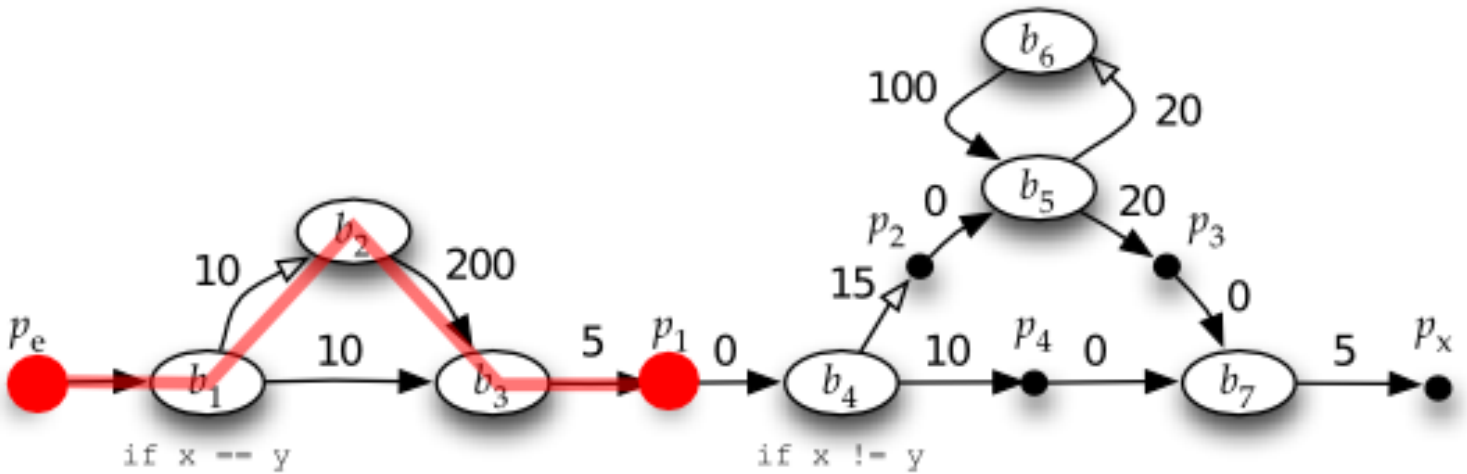
Timing Graph



Timing Graph



Timing Graph



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

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

Timing Response

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

$$t_{res} : R \rightarrow \mathbb{N}_{\perp_\epsilon} \cup \mathcal{P}(\bar{p}) \tag{3}$$

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.

Fast WCET Analysis: [12] Harmon et. al.: Fast, interactive worst-case execution time analysis with back-annotation. Industrial IEEE Transactions on Informatics 2012

Interactive C-Code analysis: [13] Ko et. al.: Supporting the specification and analysis of timing constraints. IEEE Real-Time Technology and Applications Symposium 1996

Analysis of Java Code: [14] Persson, Hedin: Interactive execution time predictions using reference attributed grammars. WAGA99: 1999

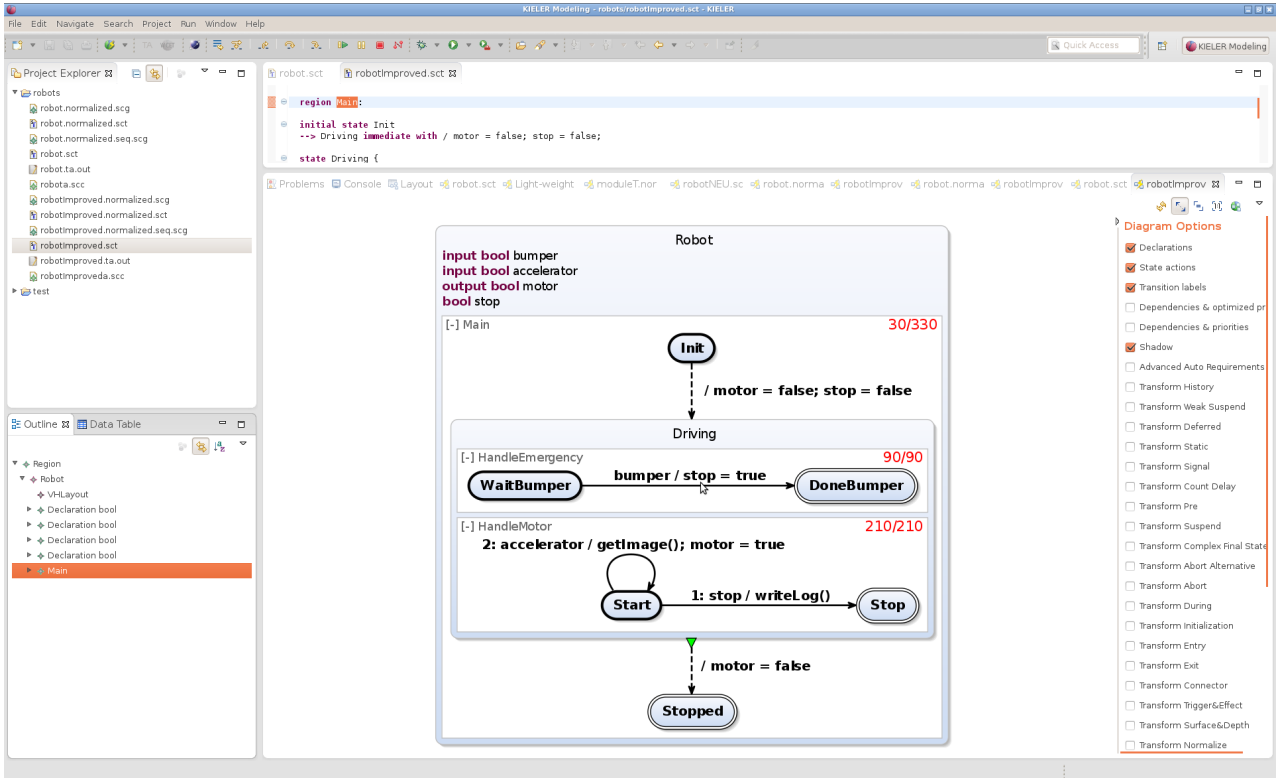
Matlab/Simulink analysis: [15] Kirner et.al.: Fully automatic worst-case execution time analysis for Matlab/Simulink models. In: Proceedings of the 14th Euromicro Conference on Real-Time Systems 2002

SCADE, aiT

Conclusion

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

Future Work

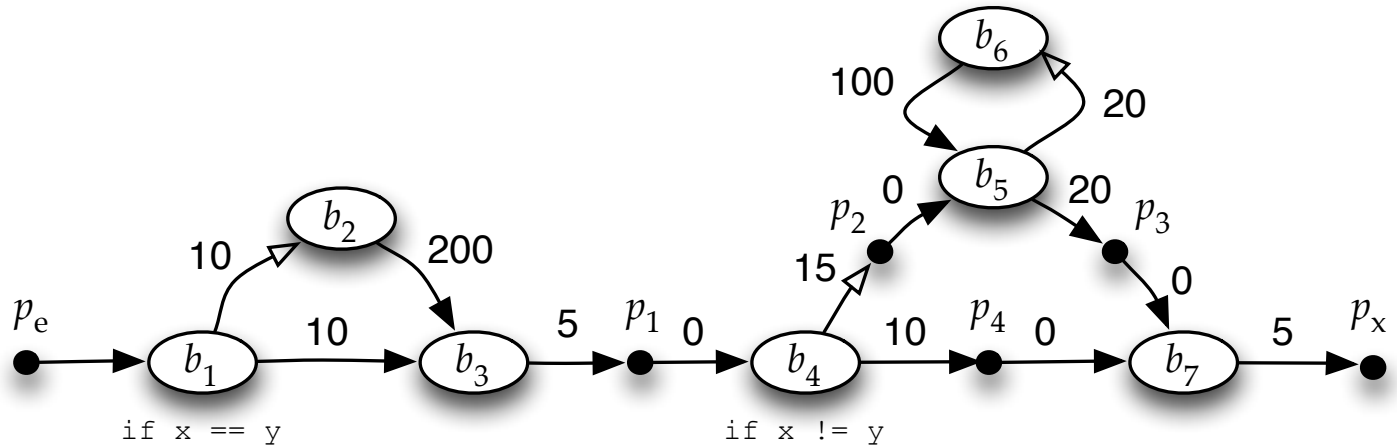


- Finish implementation, Evaluation
- Experimental studies
- TPP in cycles

End

Thanks for your attention! Do you have questions?

Additional Material: Timing Response II



$$t_{res}(r) = \begin{cases} \mathcal{T}(\bar{v}^{w}_{p_1,p_2}) & \text{if} \quad r = (\texttt{WCP}, p_1, p_2) \\ \mathcal{T}(\bar{v}^{b}_{p_1,p_2}) & \text{if} \quad r = (\texttt{BCP}, p_1, p_2) \\ \mathcal{E}(\bar{v}^{w}_{p_1,p_2}) & \text{if} \quad r = (\texttt{LWCET}, p_1, p_2) \\ \mathcal{E}(\bar{v}^{b}_{p_1,p_2}) & \text{if} \quad r = (\texttt{LBCET}, p_1, p_2) \\ \mathcal{E}(\mathcal{F}_{p_1,p_2}(\bar{v}^{w}_{p_e,p_x})) & \text{if} \quad r = (\texttt{FWCET}, p_1, p_2) \\ \mathcal{E}(\mathcal{F}_{p_1,p_2}(\bar{v}^{b}_{p_e,p_x})) & \text{if} \quad r = (\texttt{FBCET}, p_1, p_2) \end{cases} \tag{4}$$