Entwurf, Simulation und Implementierung ereignisdiskreter Steuerungen mit $PDEVS_{RCP}$ Version 2.0 (WIP)

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Agenda

1. Motivation
2. Rapid Control Prototyping Approach
3. PDEVS & $PDEVS_{RCP}$ Formalism
4. Open Problems of $PDEVS_{RCP}$
5. $PDEVS_{RCP}$ 2.0 Formalism
6. Application Example
7. Summary and Outlook

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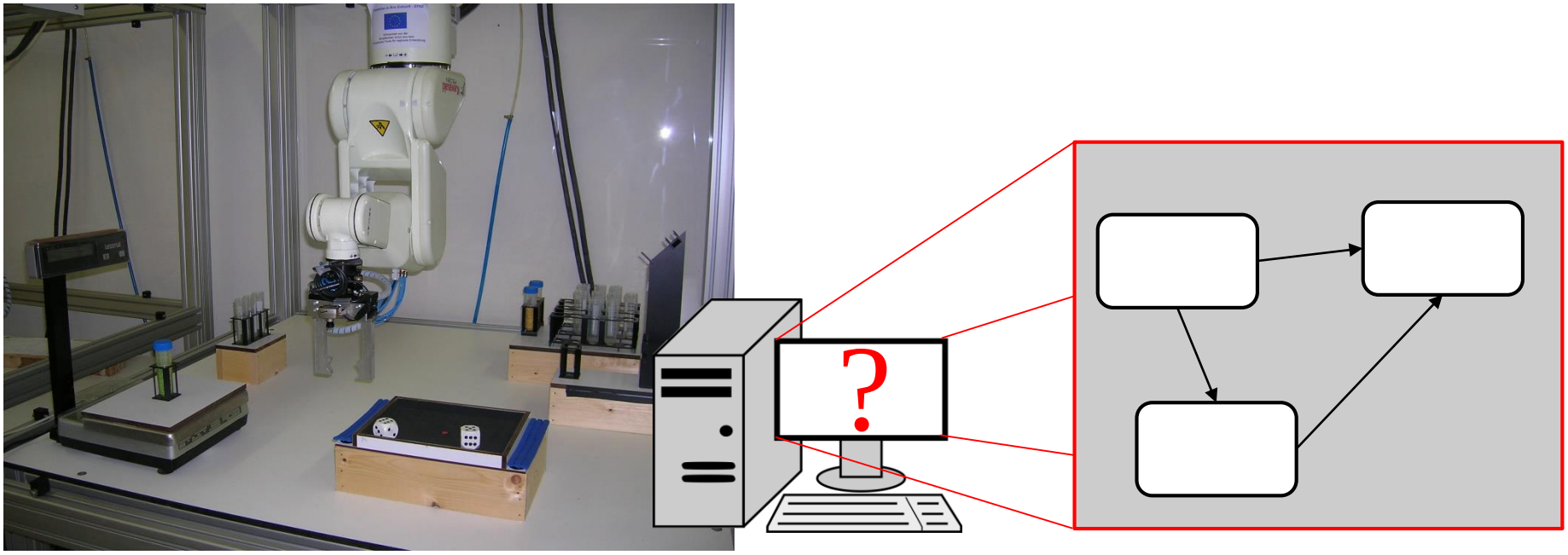
- **Nowadays control development is complex**
  testing, maintenance, extension, …
- **Ad-hoc implementations are often not possible**

➔ Design methodology:

Rapid Control Prototyping (RCP) approach by Abel (RWTH)



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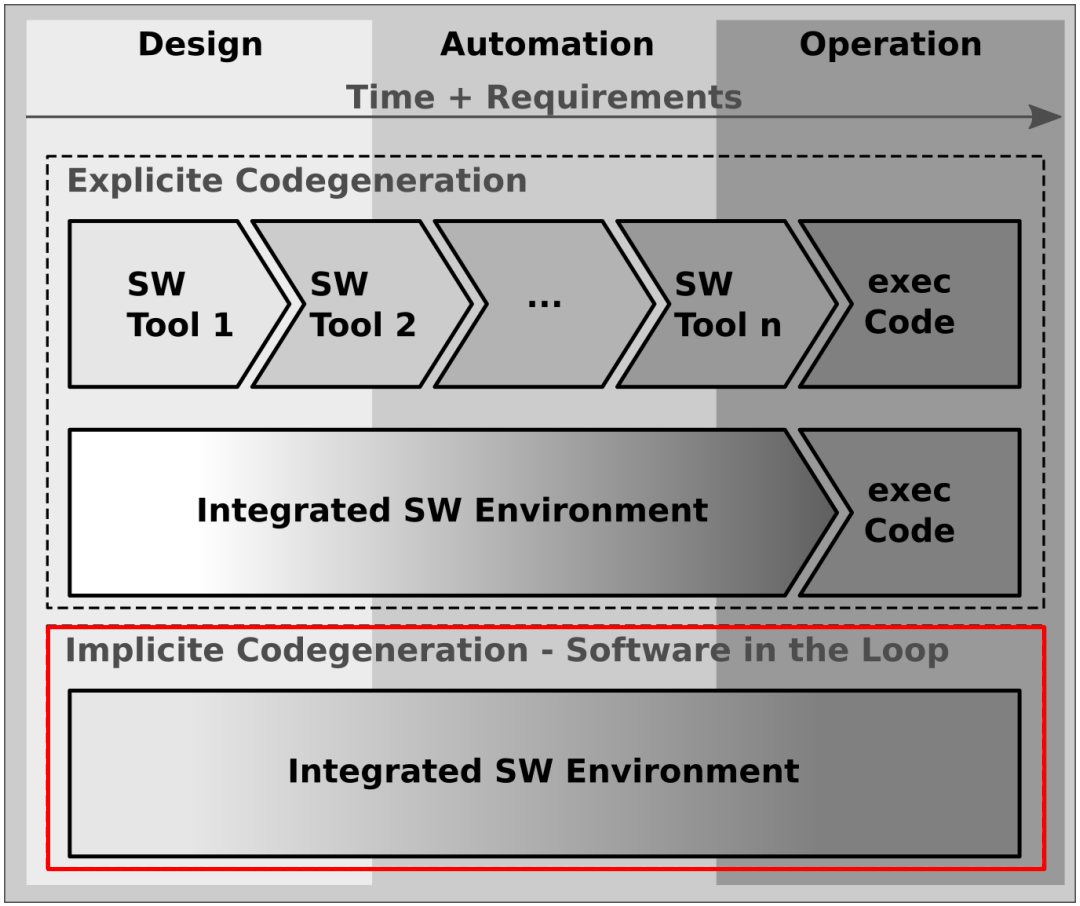
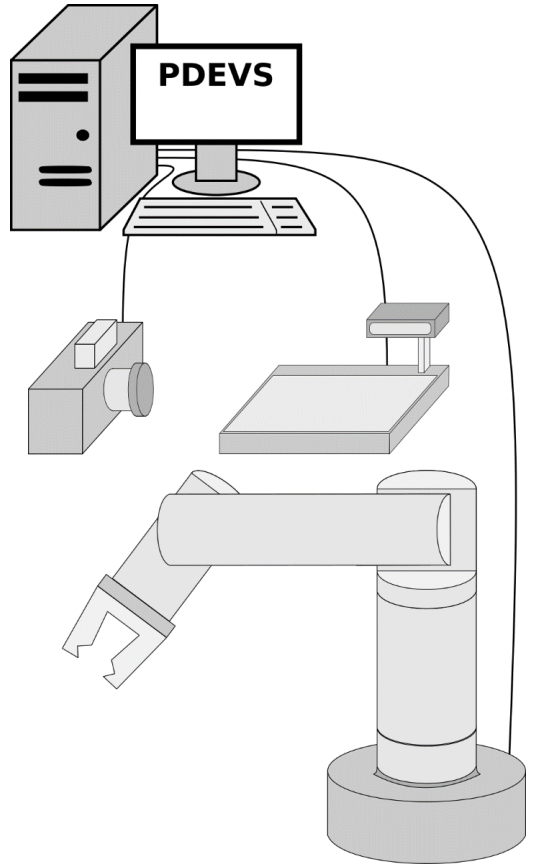
Rapid Control Prototyping Approach

- Model based approach
- Continuous control development
- Avoidance of re-implementations



event based M&S approach !

usage of PDEVS for real time control ?



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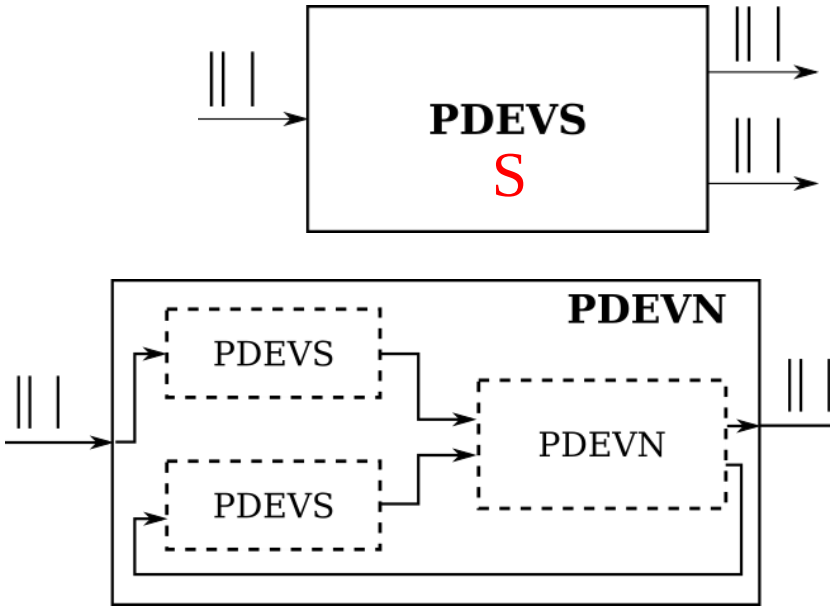
Parallel Discrete EVent System Specification

PDEVS (Chow 1996) is an extension of DEVS (Zeigler 1976)

- Event-oriented modeling approach based on modular hierarchical model specification
- PDEVS - two system types:

atomic PDEVS
dynamic behavior

coupled PDEVS (PDEVN)
composition of *atomic* or *coupled* PDEVS



PDEVS & $PDEVS_{RCP}$

$$PDEVS = \{X, Y, S, \delta_{int}, \delta_{ext}, \delta_{con}, \lambda, ta\}$$

$$PDEVS_{RCP} = \{X, Y, S, \delta_{int}, \delta_{ext}, \delta_{con}, \lambda, ta, A\} \quad \text{(RG CEA)}$$

$$X = X_{model} \cup X_{clock}$$

$$X_{model} = \{(p, v) | p \in IPorts, v \in X_p\}$$

$$\boldsymbol{X_{clock}} = \{(\text{"}\boldsymbol{clock}\text{"}, \boldsymbol{v}) | \boldsymbol{v} \in \mathbb{R}^+\}$$

$A = \{a_1, a_2, \ldots, a_n\}$ set of executable activities

$$a_n = (a_i, [ti_{min}, ti_{max}])$$

$\lambda : S \rightarrow Y \times A$ combined output and activity function

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Open problems:

(i) Specification of **activities**

(ii) Specification of the **Real Time Clock** (RTC)

(iii) How are activities specified within atomic PDEVS$_{RCP}$ components ?

(iv) Dynamic is limited ($ta(s) \in \{0, \infty\}$)

$$PDEVS_{RCP} = \{X, Y, S, \delta_{int}, \delta_{ext}, \delta_{con}, \lambda, ta, A\}$$?

$$X_{clock} = \{("clock", v) | v \in \mathbb{R}^+\}$$

atomic RTC
PDEVS$_{RCP}$? → WCT

Dynamic PDEVS components with

- $ta(s) \in \{0, \infty\}$ ✓
- $ta(s) \in \mathbb{R}^+$ X → $ta(s) \in \{0, \infty\}$ → **re-implementation**

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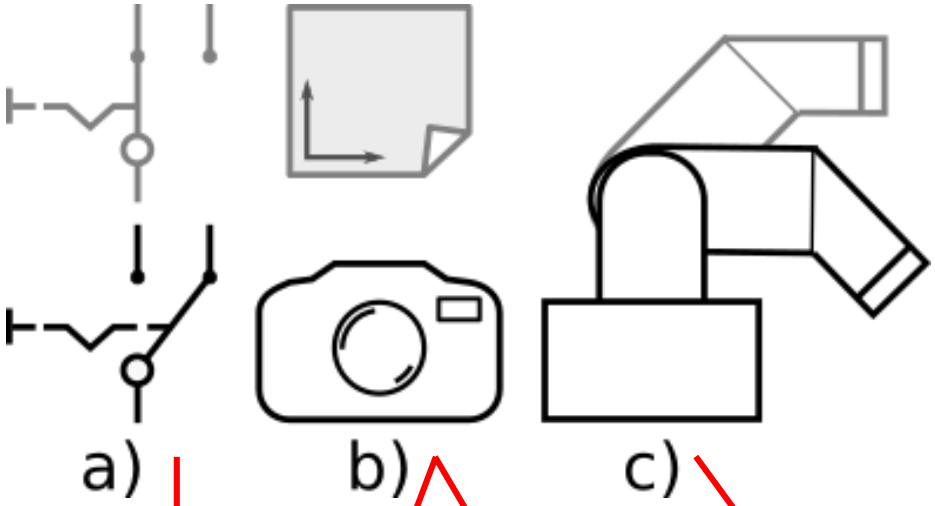
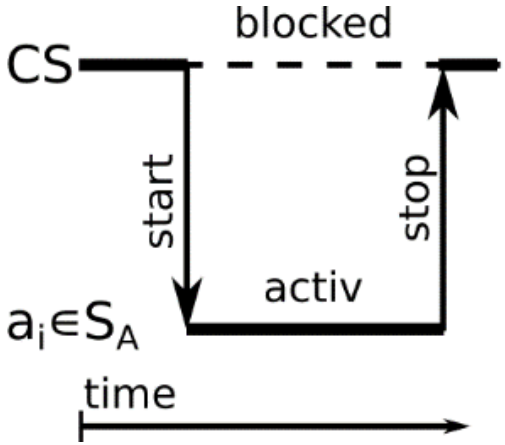
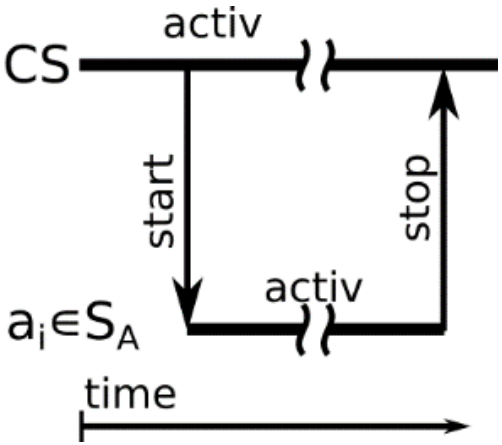
activities



synchronous



asynchronous



PDEVS$_{RCP}$ 2.0 Formalism

activity

$\boldsymbol{a_i = (M, X, S, Y, f_{ext}, f_{int}, f_{out})}$

$\boldsymbol{M}$	Set of activity methods
$\boldsymbol{X}$	Set of input values
$\boldsymbol{S}$	Set of states
$\mathbf{Y}$	Set of output values
$\boldsymbol{f_{ext}}$	$f_{ext}: S \times X \rightarrow S$
$\boldsymbol{f_{int}}$	$f_{int}: M \times S \rightarrow S$
$\boldsymbol{f_{out}}$	$f_{out}: S \rightarrow \mathrm{Y}$

$\boldsymbol{getWCT = (\mathrm{M}, X, S, Y, f_{ext}, f_{int}, f_{out})}$

$M = \{readSystemClock\}$

$X = \emptyset \Rightarrow f_{ext}$ not defined

$S = \{t_{Value}\}$ with $s_0 = 0$

$Y = \{t_{wct}\}$

$f_{int}(readSystemClock, t_{Value})$

$t_{Value} := readSystemClock$

$f_{out}(t_{Value})$

$t_{WCT} := t_{Value}$

$\boldsymbol{\mathrm{PDEVS}_{\mathrm{RCP}}\ 2.0 = (X, Y, S_{RCP}, \delta_{int}\delta_{ext}, \delta_{con}, \lambda_{RCP}, ta)}$

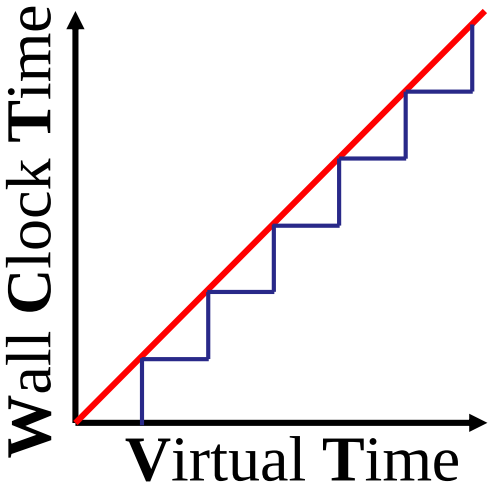
$S_{RCP} = S \cup S_A$

$S_A = \{a_1, \ldots, \boldsymbol{a_i}, \ldots, a_n\}$ //set of activities

$\lambda_{RCP}: S_{RCP} \rightarrow Y \times S_A$ // combined output and activity function

Real Time Clock (RTC)

atomic RTC
PDEVS$_{RCP}$ 2.0



$\boldsymbol{RTC} = (\boldsymbol{X}, \boldsymbol{Y}, \boldsymbol{S_{RCP}}, \boldsymbol{\delta_{int}}\boldsymbol{\delta_{ext}}, \boldsymbol{\delta_{con}}, \boldsymbol{\lambda_{RCP}}, \boldsymbol{ta})$
$X = \emptyset, Y = \emptyset \Rightarrow \ \delta_{ext}, \delta_{con}$ not defined
$S_{RCP} = S \cup S_A; S = \{\sigma, t_{Last}, t_{WCT}\}; S_A = \{\boldsymbol{getWCT}\}$
$s_{RCP,0} = (0,0,0, getWCT)$
$ta(\sigma, t_{Last}, t_{WCT}, getWCT) := \ \sigma$
$\lambda_{RCP}(\sigma, t_{Last}, t_{WCT}, getWCT)$
$\quad \boldsymbol{getWCT.f_{int}(getWCT.M, getWCT.S)}$
$\delta_{int}(\sigma, t_{Last}, t_{WCT}, getWCT)$
$\quad \boldsymbol{t_{WCT} := getWCT.f_{out}(getWCT.S)}$
$\quad if\ t_{WCT} - \ t_{Last} < 0.1$
$\quad$ yes: $\sigma := 0$ **//VT advance = 0**
$\quad$ no: $\sigma := 0.1; t_{Last} := t_{WCT}$ **//VT advance = 0.1**

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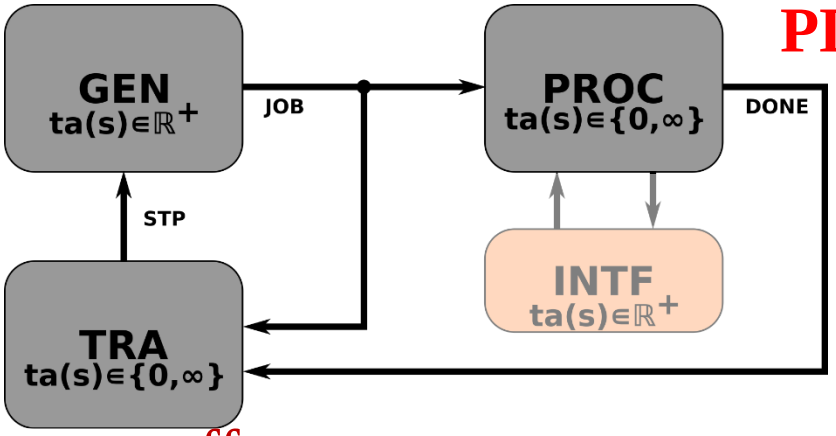
Application Example

input puffer

robot

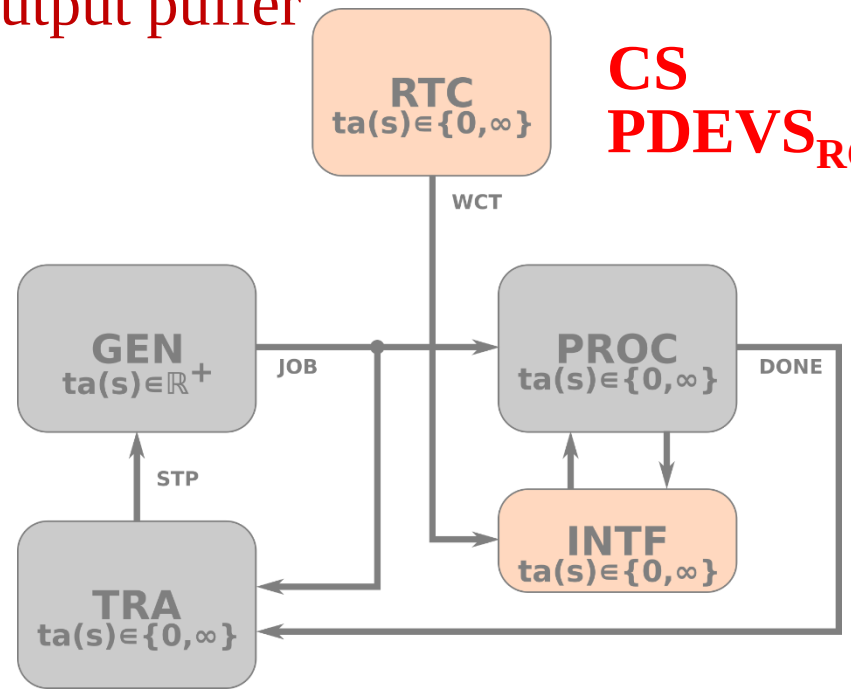
SM
PDEVS

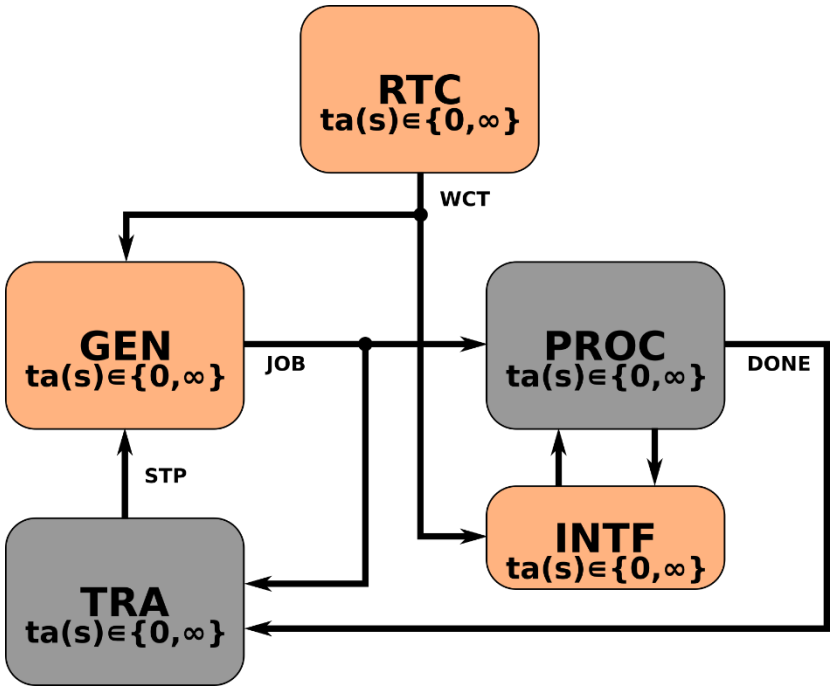


output puffer

GEN	Generator
PROC	Processor
TRA	Transducer
INTF	Interface
RTC	Real Time Clock
SM	Simulation Model
CS	Control Software

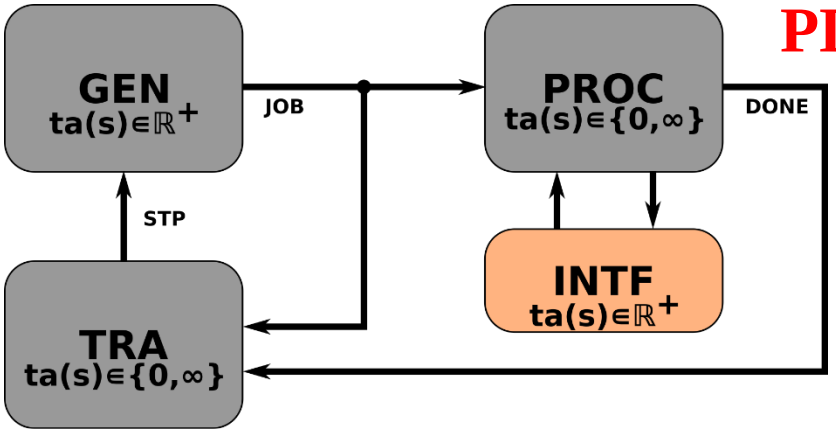
CS
PDEVS$_{RCP}$





Application Example

SM
PDEVS



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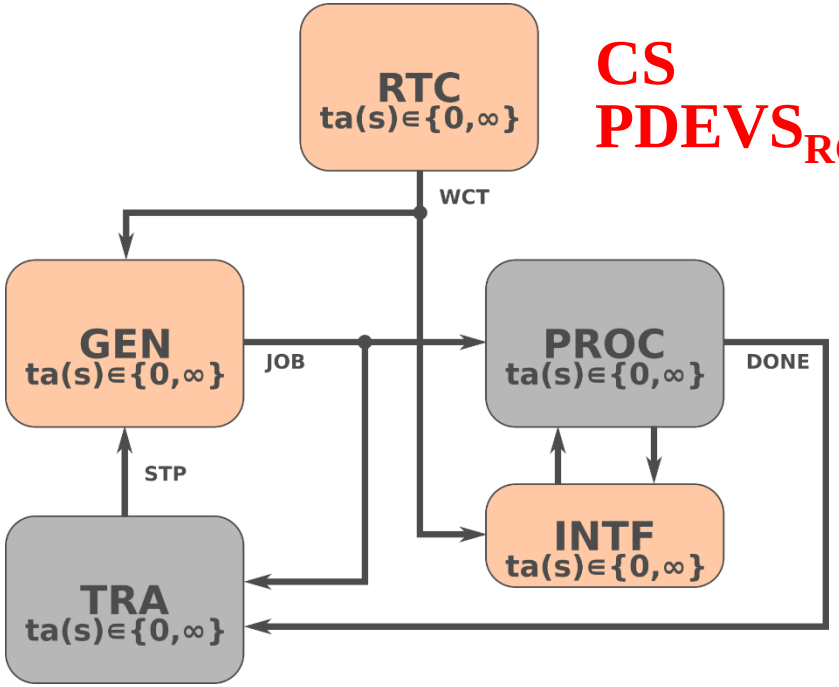
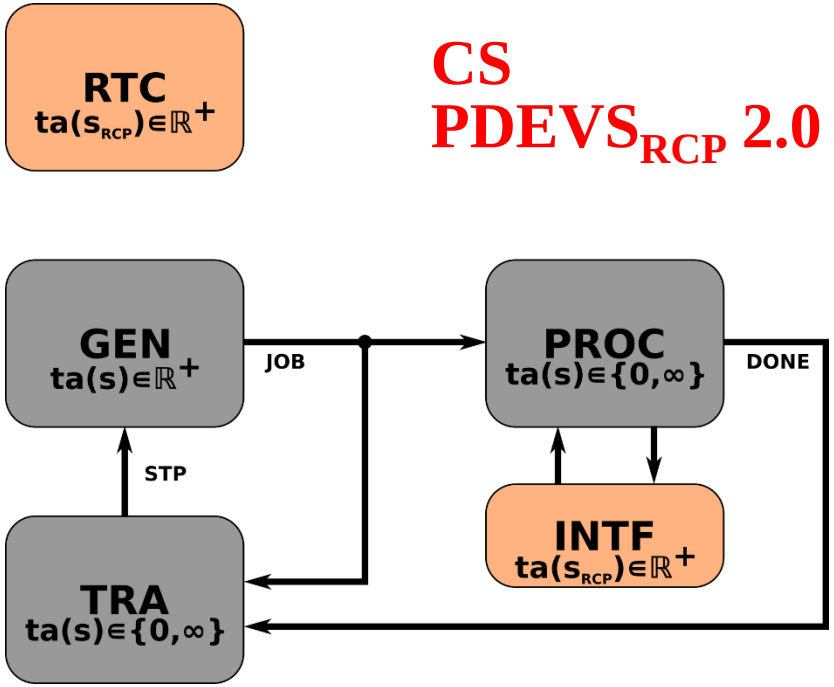
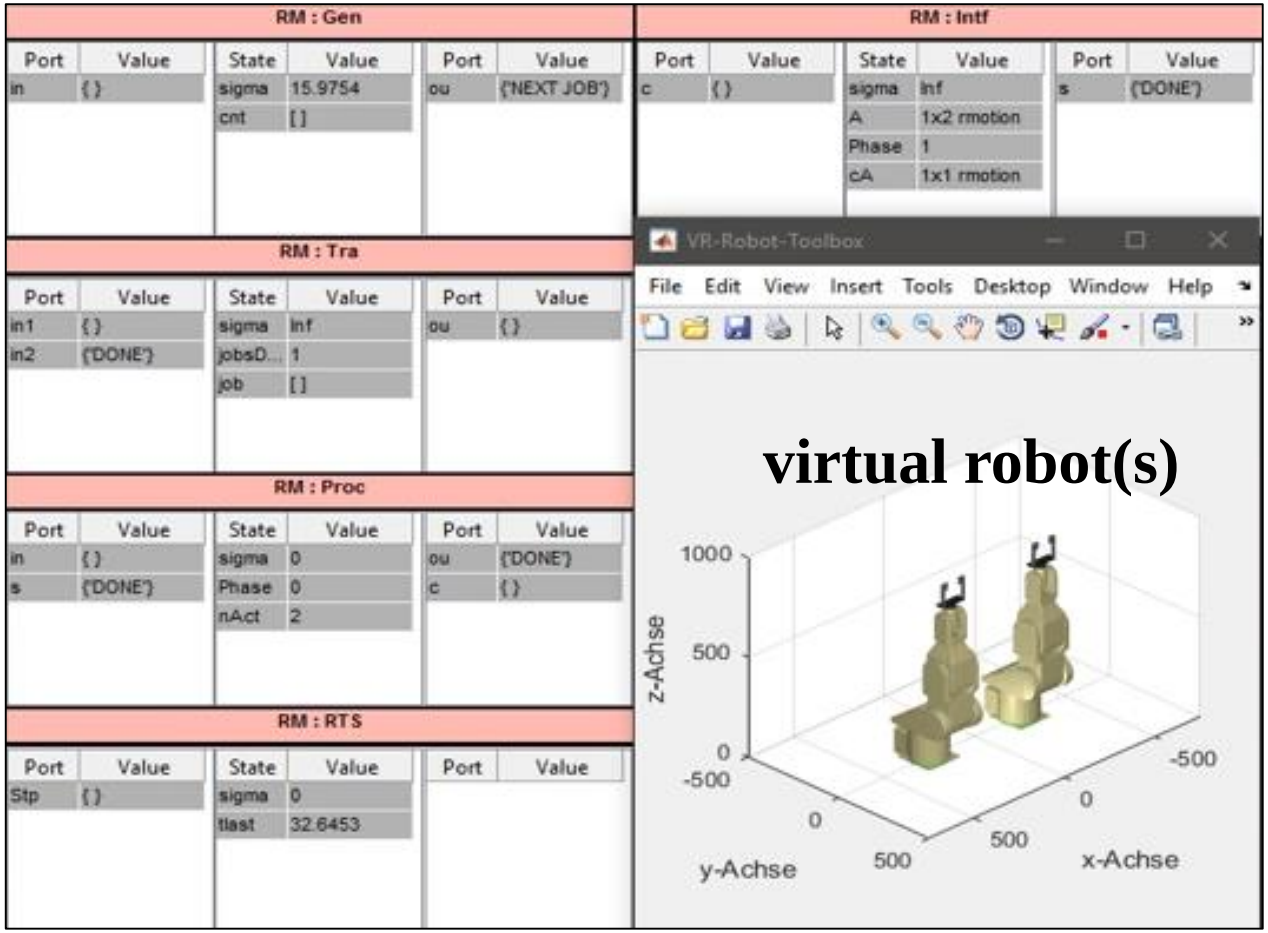
CS
PDEVS$_{RCP}$



CS
PDEVS$_{RCP}$ 2.0



CS based on PDEVS$_{RCP}$ 2.0 (MATLAB/DEVS)



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Summary and Outlook

Summary:

- **Analysis of first version of $PDEVS_{RCP}$**
- **Highlighting of open problems of $PDEVS_{RCP}$**
- **Definition and implementation of $PDEVS_{RCP}$ 2.0**
- **Comparision of both $PDEVS_{RCP}$ variants**

Outlook:

- **Classification of $PDEVS_{RCP}$ 2.0 in context of system therory**
- **Usage of the new concept for robot control development**

Thank you for your attention

[1] D. Abel, A. Bollig, Rapid Control Prototyping, Methoden und Anwendung, Springer, 2006.
[2] G. Maletzki, Rapid Control Prototyping komplexer und flexibler Robotersteuerungen auf Basis des SBC-Ansatzes. Diss., Uni. Rostock/HS Wismar, 2014.
[3] B.P. Zeigler, H. Praehofer, T.G. Kim, Theory of modeling and simulation 2nd ed., Acad. Pr, 2000.
[4] S.M. Cho, T.G. Kim, Real Time Simulation Framework for RT-DEVS Models, Trans. Soc. Comput. Simul. Int. 18 (4) (2001) 203–215.
[5] J.L. Risco-Martín, S. Mittal, J.C. Fabero, P. Malagón, J.L. Ayala, Real-time Hardware/Software Co-design Using Devs-based Transparent M&S Framework, in: Proc. of the Summer Computer Conf., 45:1-45:8.
[6] T. Schwatinski, T. Pawletta, S. Pawletta, C. Kai-ser: Simulation-based development and operation of controls on the basis of the DEVS for-malism. Proc. 7th EUROSIM Conf., Vol.2, Prag, Czech Rep., 2010, 8 pages.
[7] A.C.-H. Chow, Parallel DEVS: A Parallel, Hierarchical, Modular Modeling Formalism and Its Distributed Simulator, Trans. Soc. Comput. Simul. Int. 13 (2) (1996) 55–67.
[8] B. Freymann, T. Pawletta, S. Pawletta, Multi-Robotersteuerungen mit variablen Interaktionsprinzipien auf Basis des Simulation Based Control Frameworks und dem Dicrete Event System Specification Formalismus, Proc. ASIM STS/GMMS WS, ARGESIM Rep. No.50, 2015, 67–77.
[9] B. Freymann, T. Pawletta, T. Schwatinski, S. Pawletta, Modellbibliothek für die Interaktion von Robotern in der MATLAB/DEVS-Umgebung auf Basis des SBC-Frameworks, Proc. ASIM STS/GMMS WS, ARGESIM Rep. No.42, 2014, 199–208.

Backup

CLOSURE UNDER COUPLING