systems engineering

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Multiscale analysis of re-entrant production lines:

An equation free approach

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Overview

- Random phase model
- Coarse projective Integration
- Further research

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For reference:

Thermalized kinetic and fluid models for re-entrant supply chains.

D. Armbruster, C. Ringhofer, *SIAM Multiscale Modeling & Simulation*, vol. 3 nr. 4, pp. 782-800 (2005)

Supply chain model

Consider chain of M suppliers S1,...,SM

$$\text{(a) } e_n^m = a_n^m + \tau_n^m, \text{ (b) } d\mathcal{P}\{\tau_n^m = r\} = \mathcal{T}_m(r, a_n^m)dr, \text{ (c) } a_n^{m+1} = e_n^m \quad (1)$$

a_n^m : time lot n arrives at supplier S_m

e_n^m: time lot n exits supplier S_m

τ_n^m: troughput time of lot n at supplier S_m

Usually:

$$\mathcal{T}_m(r, a_n^m) = \mathcal{T}_m(r, W_m(a_n^m))$$

Random phase model

$$\text{(a)}\ \phi(t+\Delta t) = \phi(t) + \frac{\Delta t}{\tau(t)},$$

$$\tau(t+\Delta t) = \kappa(t)\eta(t) + (1-\kappa(t))\tau(t),\ \ t \geq a_n,$$

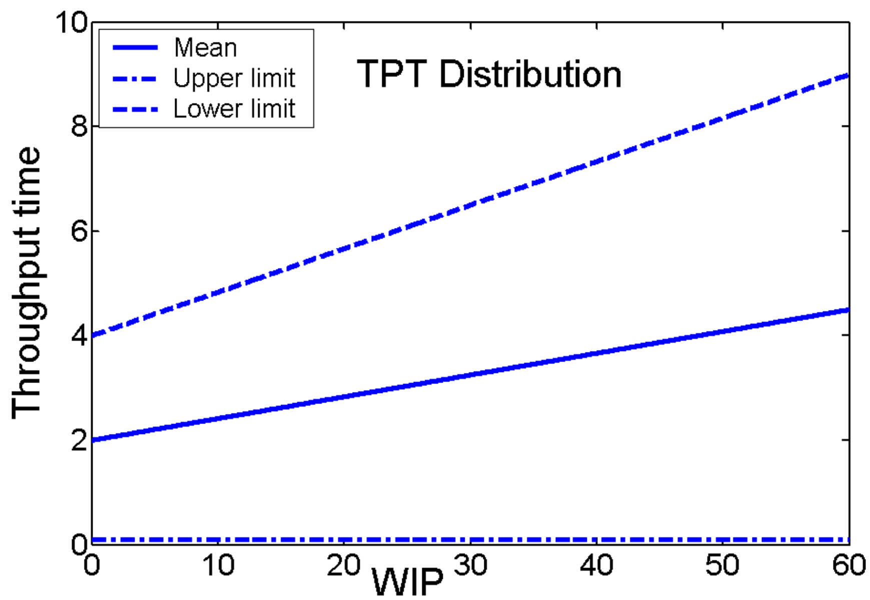
$$\text{(b)}\ \mathcal{P}\{\kappa(t)=1\} = \omega\Delta t,\ \mathcal{P}\{\kappa(t)=0\} = 1-\omega\Delta t,$$

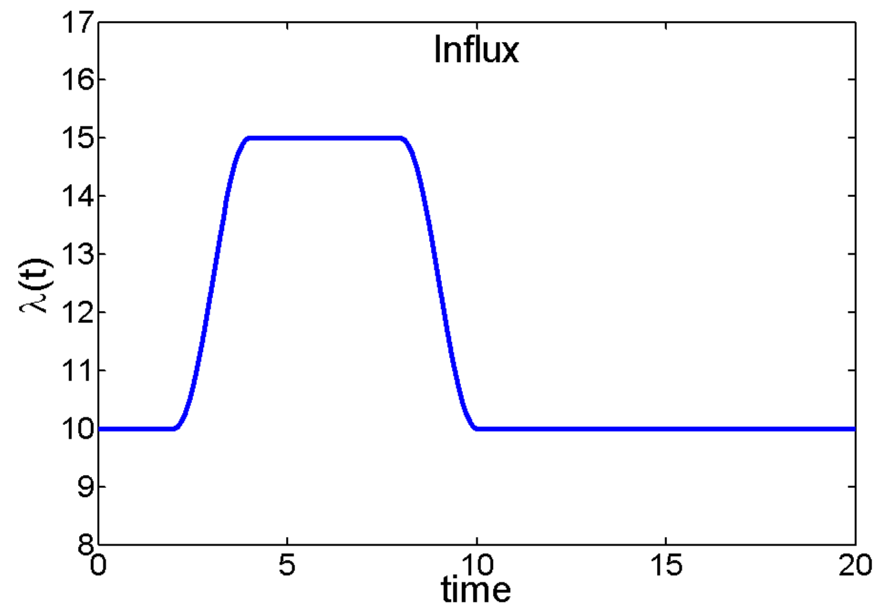
$$d\mathcal{P}\{\eta(t) \leq r\} = \mathcal{T}(r,t)dr,$$

$$\text{(c)}\phi(a_n) = 0,\ \ d\mathcal{P}\{\tau(a_n) \leq r\} = \mathcal{T}(r,a_n)dr$$

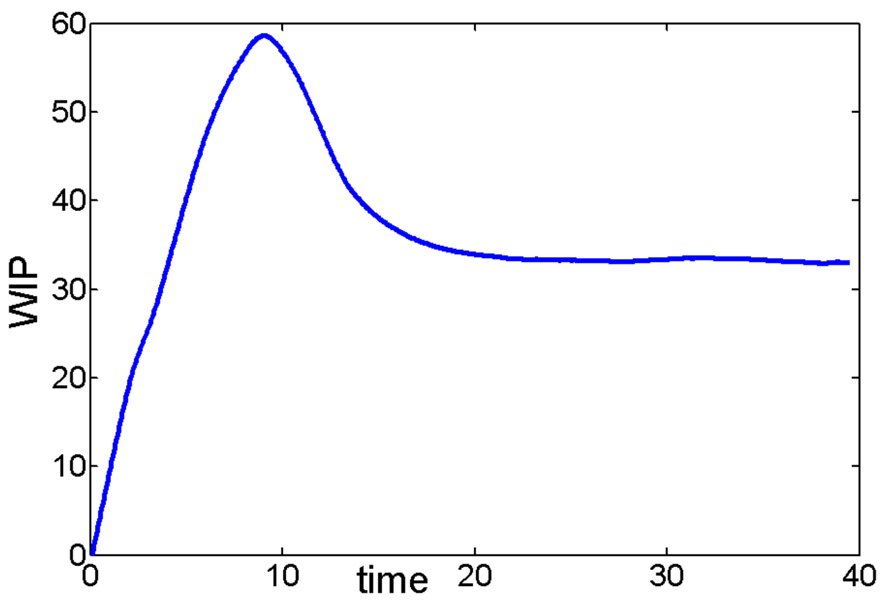
choose $\omega(r,t) = \frac{\lambda(t)}{rT_{-1}},\ T_{-1} = \int r^{-1}\mathcal{T}(r,t)dr$

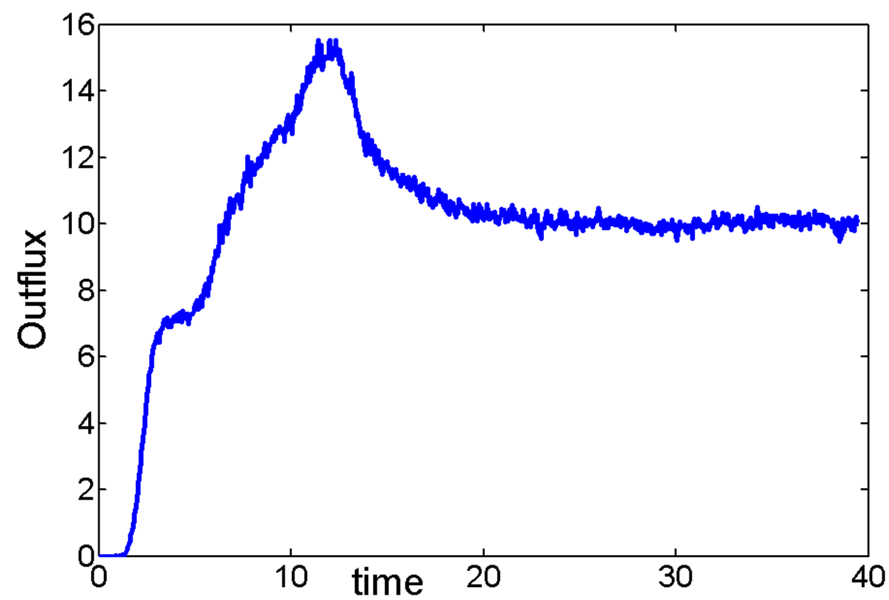
Numerical example





Numerical example





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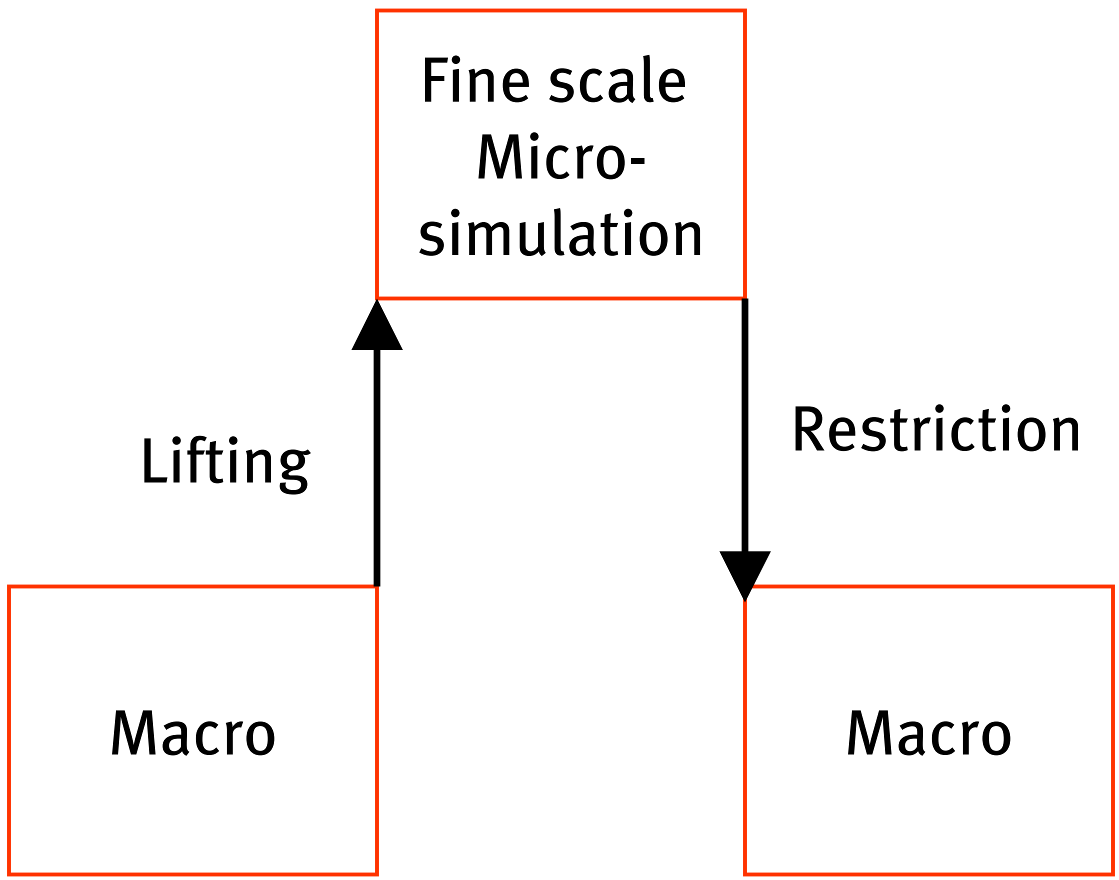
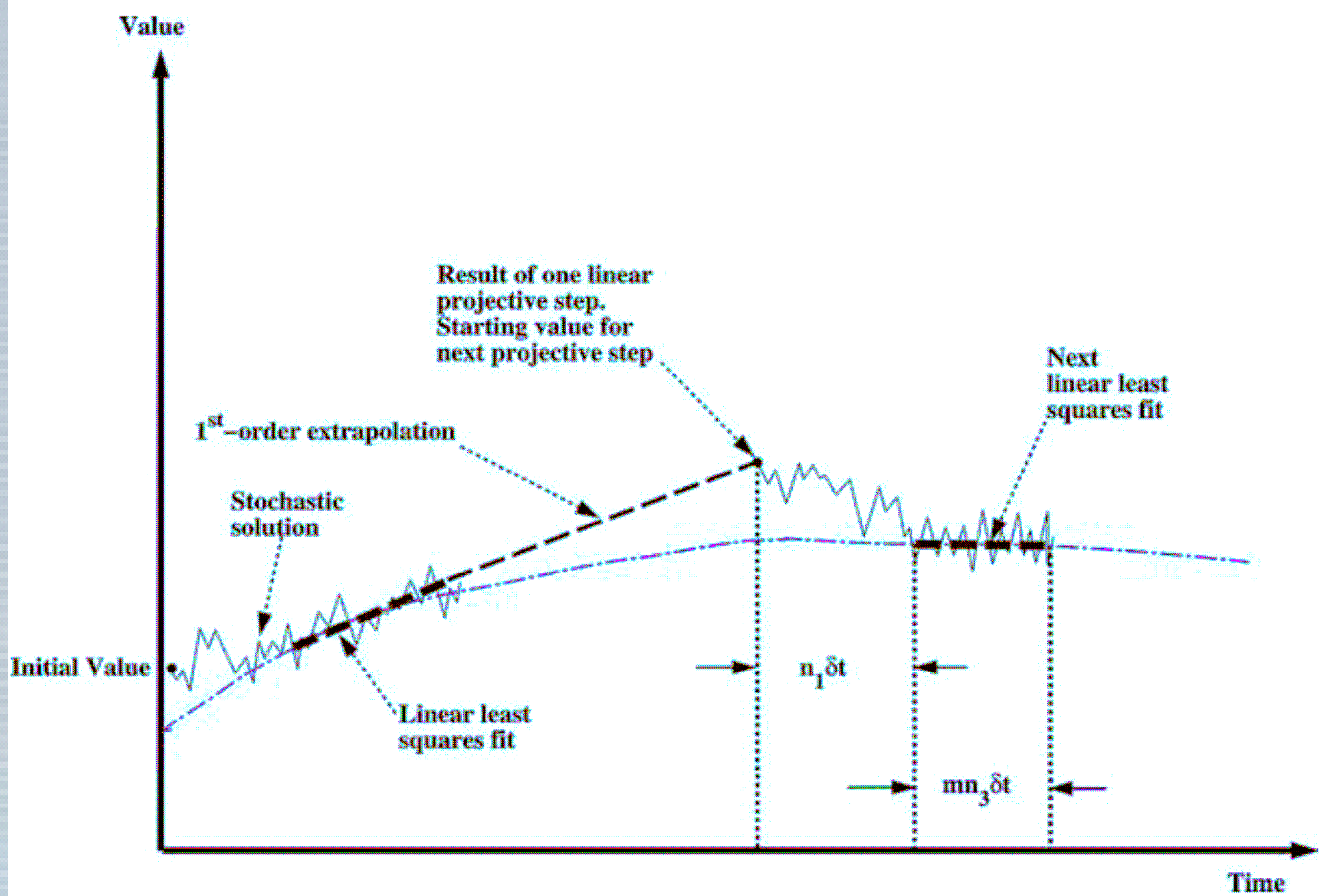
Multiscale analysis of re-entrant production lines: An equation free approach

Y. Zou, I. G. Kevrekidis, D.Armbruster, *Physica A: Statistical Mechanics and its Applications*, vol. 363-1, pp. 1-13 (2006)

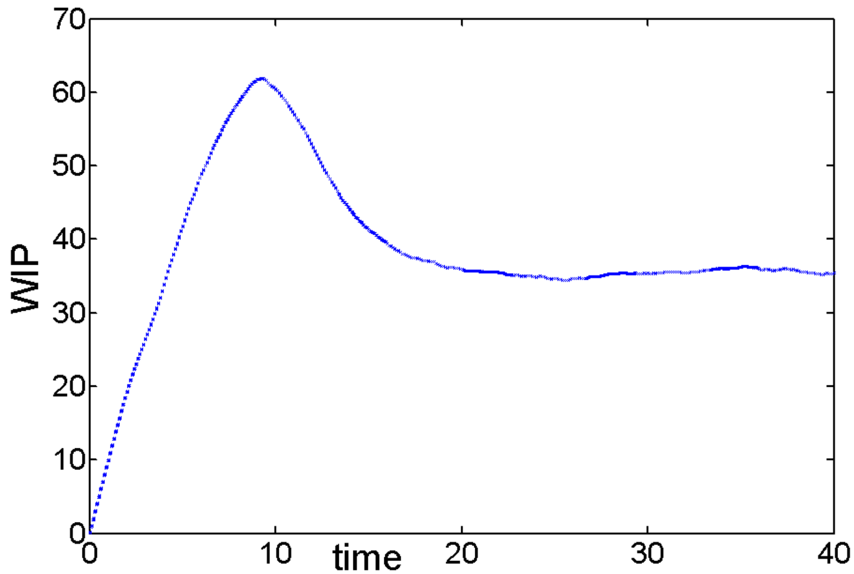
Coarse projective integration

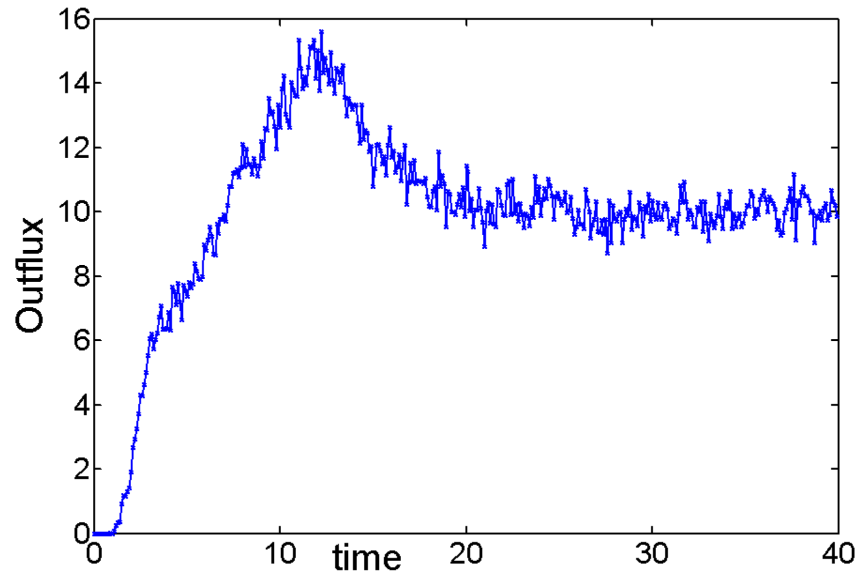


Coarse projective integration



Numerical results





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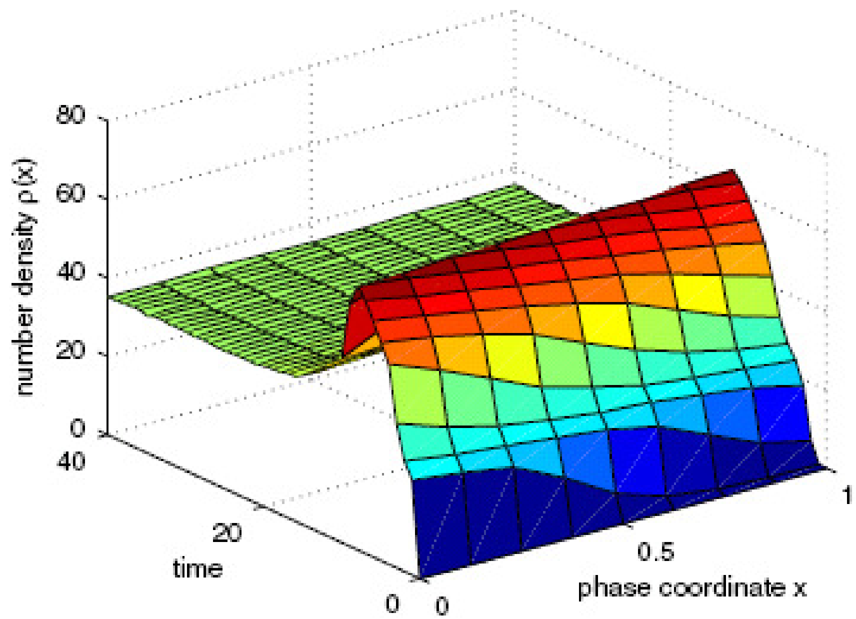
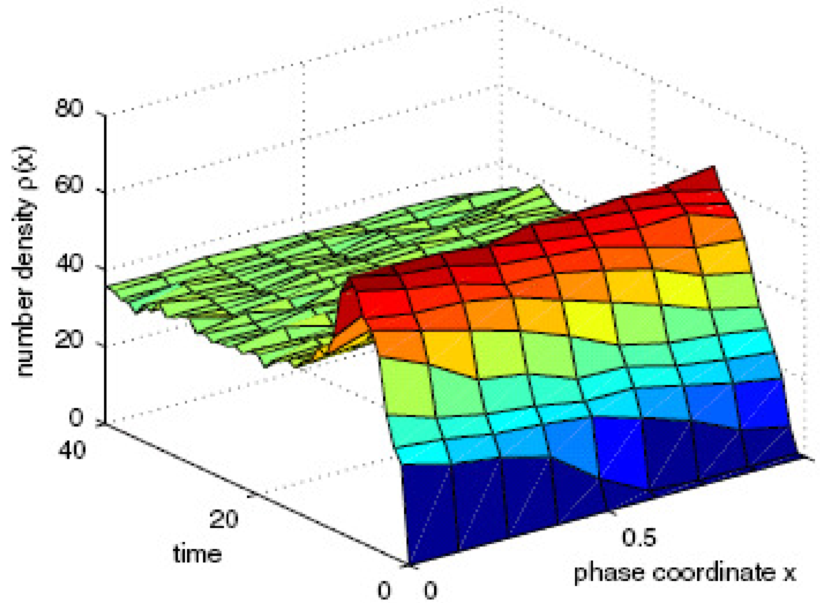
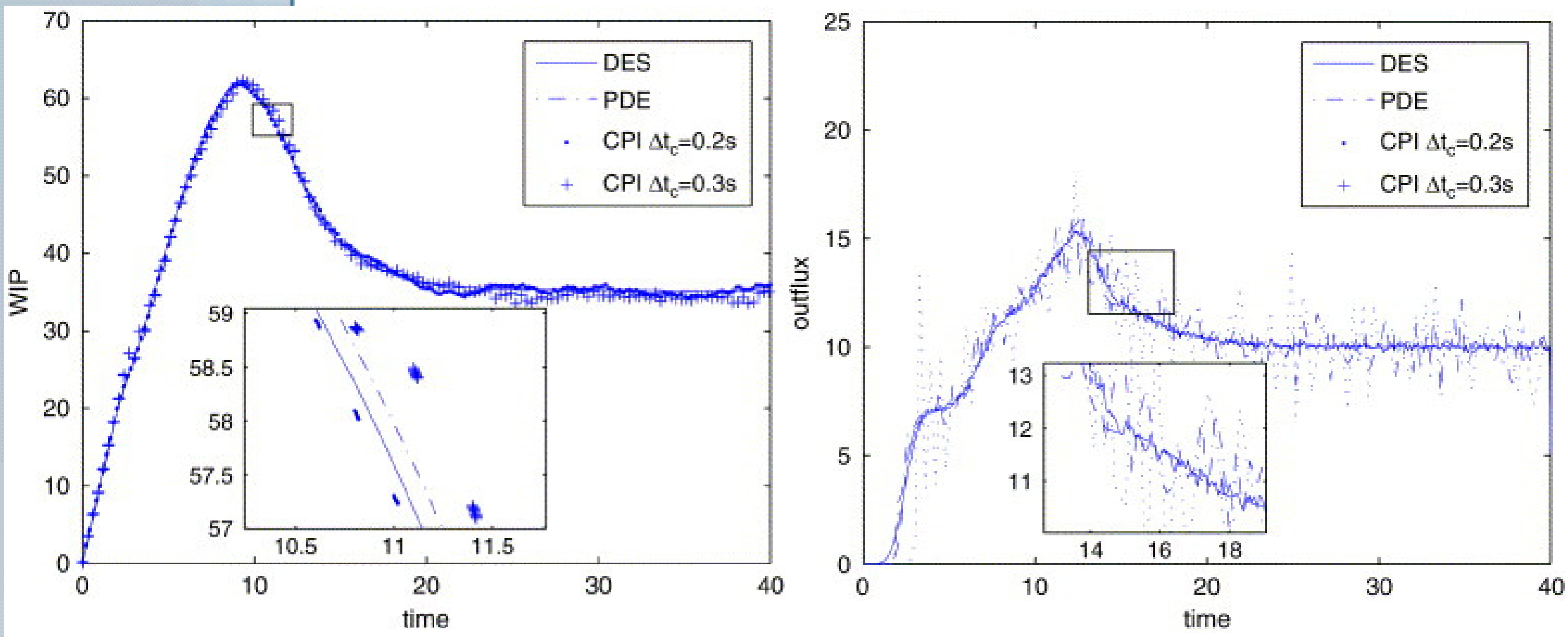


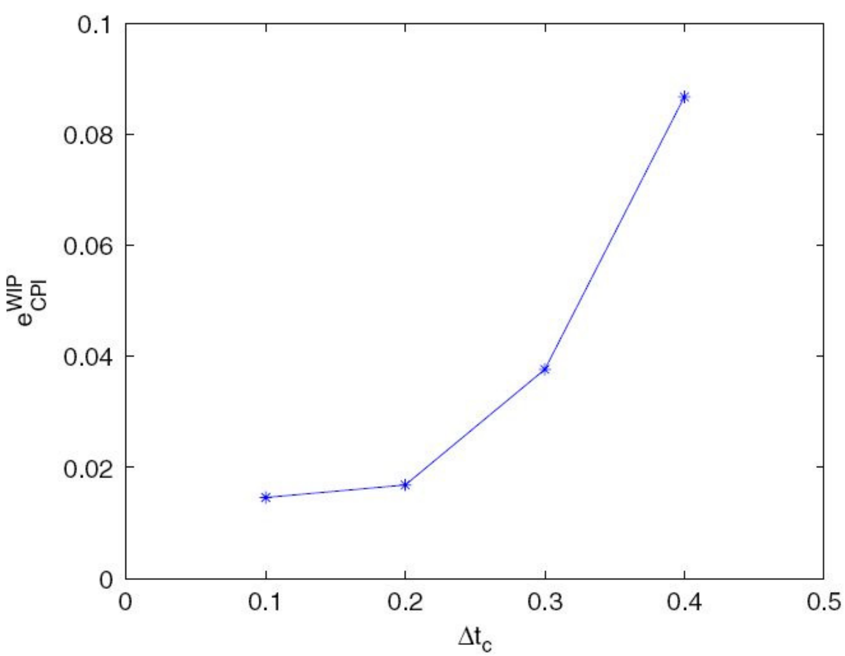


Coarse time step



Accuracy vs. calculation time

$$e_{CPI}^{WIP} = \frac{1}{K}\sum_{k=1}^{K}\frac{|WIP^{CPI}(t_k) - WIP^{DES}(t_k)|}{WIP^{DES}(t_k)}$$



Simulation type	Wall clock time (sec)
DES	9267
PDE	31
CPI $\Delta t_c = 0.1$s	5971
CPI $\Delta t_c = 0.2$s	2952
CPI $\Delta t_c = 0.3$s	1986
CPI $\Delta t_c = 0.4$s	1066

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Further research

- Factory (Kempf): 9 WS, 26 steps
- Chi discrete event simulation (Tom Geubels, Dominique Perdaen)
- Comparison made between PDE and DEM

- Use this Chi DEM as fine scale simulator for CPI algorithm