Integrating Product-Process-Production (PPP) Flexibility, Agility and Evolution (FAE)

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SUMMARY

• Introduction
• PPP modeling: statics
• PPP modeling: dynamics
• Integrating FAE
• Conclusions
INTRODUCTION

• Global turbulent environment
  • New markets
  • Emerging competition
  • Exchange rate
  • Energy costs
  • Raw materials supply

• Flexibility, Agility, and Evolution (FAE) are key factors of profitability
 PPP MODELING: statics

- Define model at each level

\[ u, x \rightarrow \text{Global management model} \rightarrow y \]

- \( u, x \) and \( y \) are vectors of PPP variables
  - Product variables (Colors, size, power…)
  - Process variables (Acuracy, repeatability, speed…)
  - Production variables (Rates, model mix, shifts…)

Management states, \( n \) PPP variables

Plant states, \( m \) PPP variables, \( m \gg n \)

Global Turbulent Environment

Profitability Survival

Global management

Site and plant management

Planning and scheduling

Supervisory control

Process control

Data collection and actuation

Weeks

Msecs
PPP MODELING: statics

- Different models might be required

\[ y = (y_1, y_2, \ldots) = \text{outputs (measured)} \]
\[ u = (u_1, u_2, \ldots) = \text{inputs (manipulated)} \]
\[ x = (x_1, x_2, \ldots) = \text{turbulence} \]

PPP MODELING: statics

- Define models and interactions at each level
PPP MODELING: statics

• Final state: instance of the model at some time as defined by final values of PPP variables at that time

- Spatial model (final values only)

PPP MODELING: dynamics

- Global Turbulent Environment
- Profitability Survival

- Management states, n PPP variables
- Plant states, m PPP variables, m>>n

- Global management
- Site and plant management
- Planning and scheduling
- Supervisory control
- Process control
- Data collection and actuation

- Weeks
- Msecs
PPP MODELING: dynamics

- Transient state: instance of the model at some time as defined by transient values of PPP variables between two final states

- Spatio-temporal model (both transient and final values)

PPP MODELING: dynamics

- Different trajectories = same final states
- Good response to turbulence (reactive control)
- Best response to turbulence (predictive control)
INTEGRATING FAE

Global Turbulent Environment

Profitability Survival

Management states, \( n \) PPP variables

Plant states, \( m \) PPP variables, \( m \gg n \)

Weeks

Msecs

Data collection and actuation

Supervisory control

Planning and scheduling

Site and plant management

Global management

FAE

INTEGRATING FAE

• Flexible response

\[
\begin{align*}
\text{Ideal} & \quad y(t) \\
\text{Real} & \quad y(t)
\end{align*}
\]

• Lack of flexibility

\[
\begin{align*}
\text{Ideal} & \quad y(t) \\
\text{Real} & \quad y(t)
\end{align*}
\]
INTEGRATING FAE

- Agile response

- Lack of agility

INTEGRATING FAE

- Evolution as bounds on spatial intervals
INTEGRATING FAE

• Evolution as bounds on temporal intervals

CONCLUSIONS

• PPP-FAE integration requires dynamic models
  • Agility metric has a dynamic component
  • Optimal response to turbulence requires dynamic predictions over some planning horizon

• PPP-FAE integration requires simulation
  • Must solve PPP models to obtain optimal dynamic predictions
  • Real production environment can have thousands of PPP variables

• PPP-FAE integration requires data reconciliation
  • Must confront simulated FAE scenarios with real plant data

• PPP-FAE integration requires validation
  • Developed concepts will be implemented and tested at CIPP
CONCLUSIONS

• CIPP: new pilot plant on campus: 11 800 m², 80M$ cdn
• 3000 I/Os, 800 loops, flexible hardware, MMPCs

CONCLUSIONS

• Pulping sector
CONCLUSIONS

• Paper making sector

CONCLUSIONS

• New research topic?
  • Local Evolution Planning is Easy
    • ↑ production rate = ↑ MRR = ↑ motor kW = buy new CNC
  • Global Evolution Planning is Complex
  • Assuming simulation is available to pinpoint saturated variables:
    • How to plan evolution scenarios?
    • What if many PPP bounds are reached at the same time?
      • On the same layer
      • On different layers
    • What are the ROI of different evolution plans?
  • Universality of these concepts opens the door for:
    • Integrated discrete-continuous simulation
QUESTION PERIOD

???

UNIFYING CONCEPT: MMPCs

• Multivariate Model Predictive Control
• 2 ingredients:
  • Dynamic model: makes predictions
  • Optimizer: finds optimal future control moves
UNIFYING CONCEPT: MMPCs

- Cascading MMPCs for interactions

PPP MODELING: statics

- Final states are essential for setpoints identification
PPP MODELING: statics

- State transitions are essential for setpoints achievement in both value and time

INTRODUCTION

- Universal concept
OBJECTIVES OF THIS PRESENTATION

- To propose a simulation framework that integrates PPP-FAE in response to external turbulence factors
- To show how to validate the concepts in a real production environment