Quality Control of Polymer Production Processes

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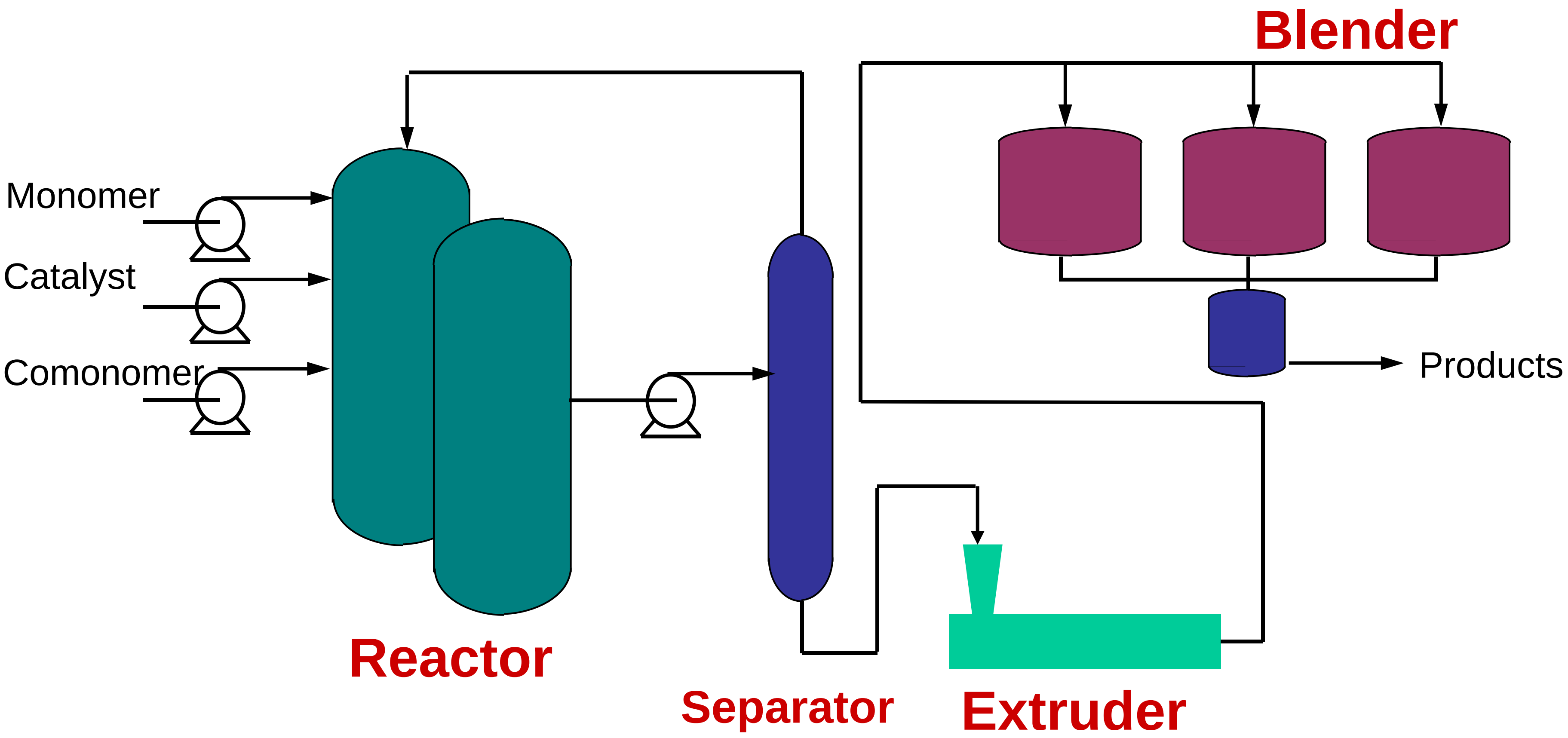
Introduction

- Polymer plant operation
  - Grade transition
  - Maximizing production
  - Safe operation of reactor

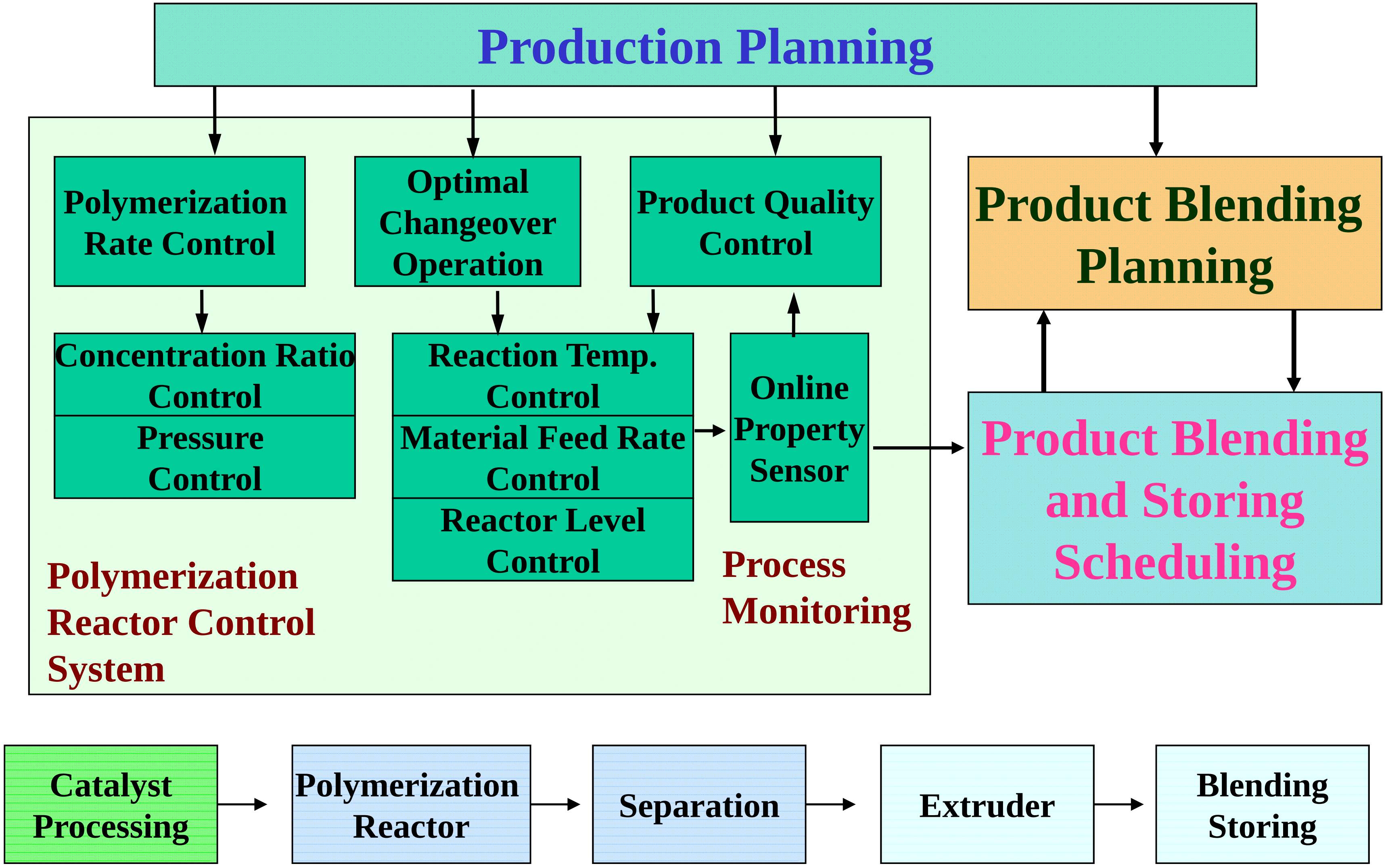
- Quality control for the objectives

- On-line soft sensing and optimal grade changeover control

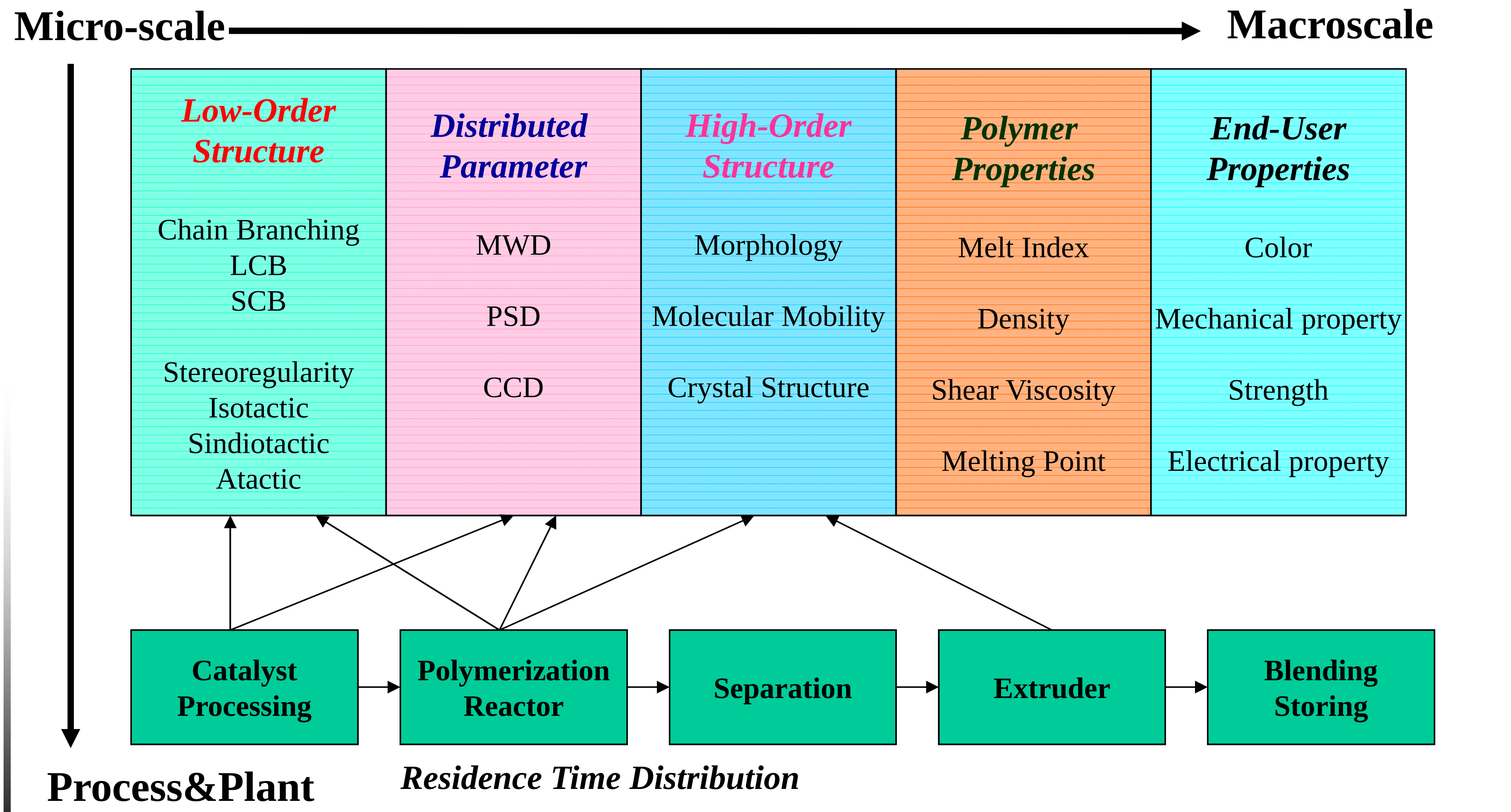
Polymer Production Plant



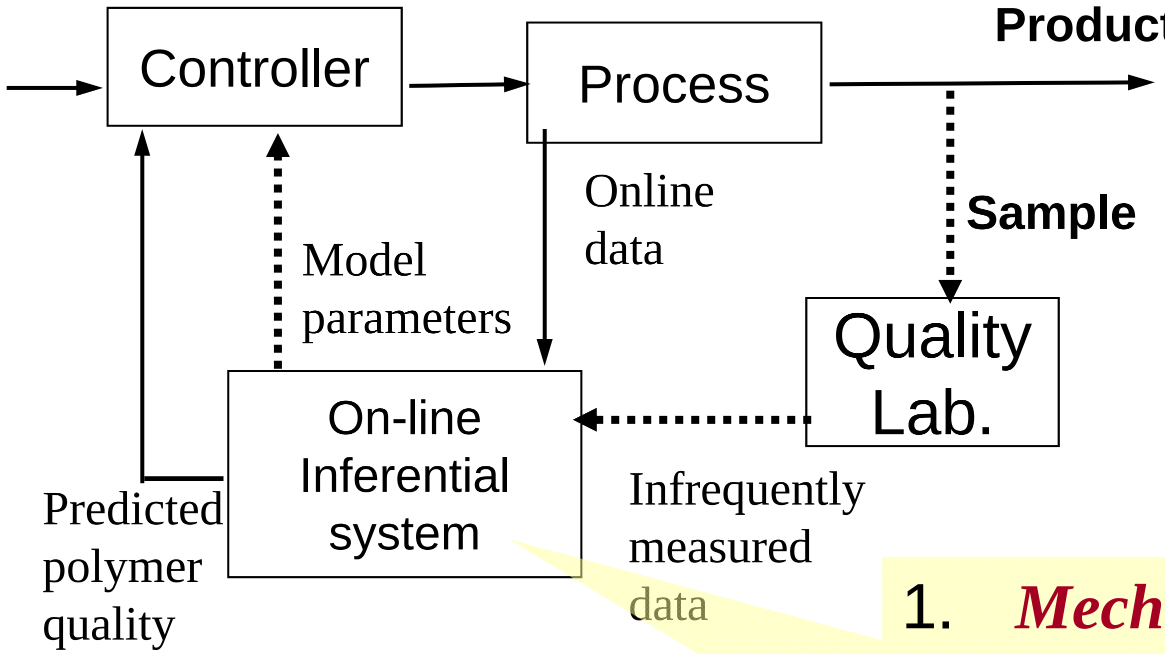
Prospective Control System



Needs for Quality Modeling



Basic Structure of Inferential System



1. ***Mechanistic model*** derived from first principles
2. ***Empirical model*** derived from lab. data
3. ***Black box model*** by neural nets & statistical methods

An Examples of Three Kinds Model

- Mechanistic model (McAuley & MacGregor, 1991)

$$\ln(MI_i) = 3.5\ln\left(k_0 + k_1\frac{[H_2]}{[C_2]} + k_2\frac{[C_3]}{[C_2]} + k_3\frac{[C_4]}{[C_2]} + k_4\frac{[R]}{[C_2]}\right) + k_5\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

$$\frac{\mathrm{d}\,MI_C(t)^{-0.286}}{\mathrm{d}t} = \frac{1}{\tau(t)}MI_i(t)^{-0.286} - \frac{1}{\tau(t)}MI_C(t)^{-0.286}$$

- Empirical model (Watanabe et. al., 1993)

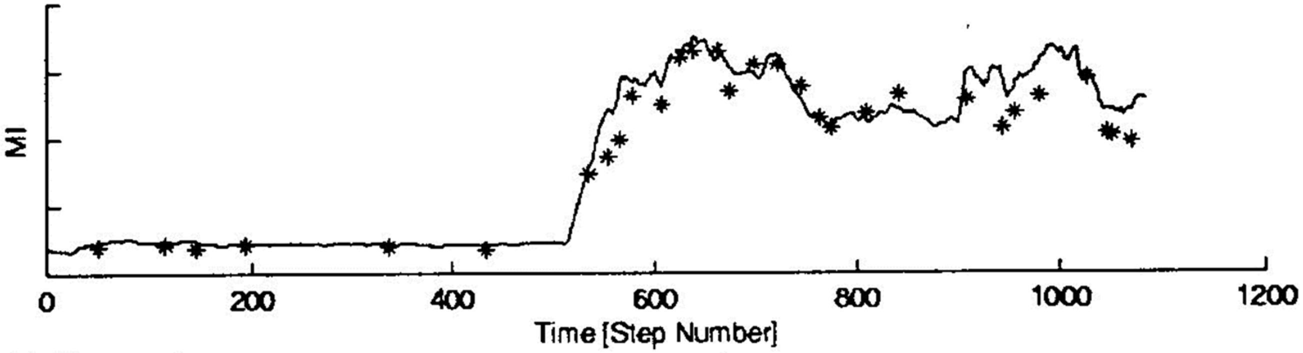
$$\log(MI_i) = \beta + \alpha_1\log\frac{[H_2]}{[C_2]} + \alpha_2\log\frac{[H_2]}{[C_2]} + \alpha_3\log\frac{[C_3]}{[C_2]} + \alpha_3\log\frac{[C_4]}{[C_2]} + \alpha_4\log[R] + \alpha_5\log(T)$$

$$\frac{\mathrm{d}\log(MI_C(t))}{\mathrm{d}t} = \frac{1}{\tau(t)}\log(MI_i(t)) - \frac{1}{\tau(t)}\log(MI_C(t))$$

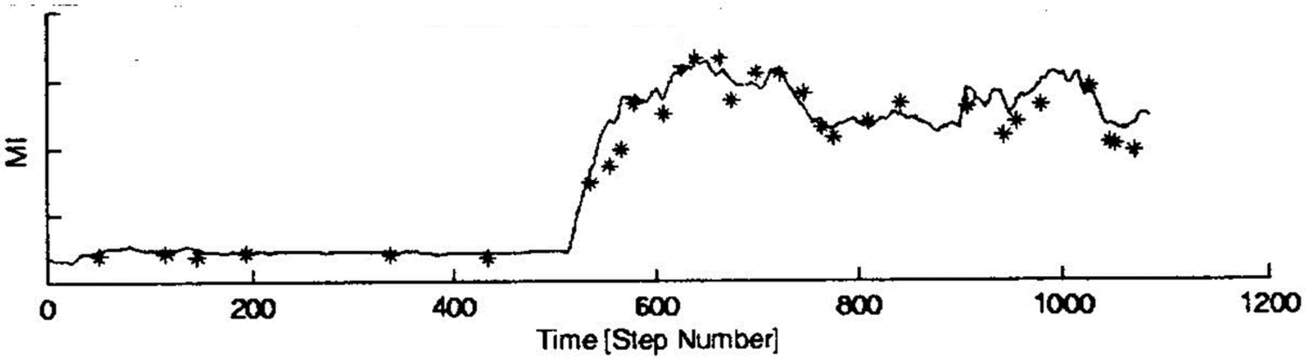
- Neural net model (Koulouris, 1995)

$$MI_i^{-0.286} = \mathrm{Wave-Net}\left(\frac{[\mathrm{H}_2]}{[\mathrm{C}_2]}, \frac{[C_2]}{[C_2]}, \frac{[C_6]}{[C_2]}, \frac{[R]}{[C_2]}\right)$$

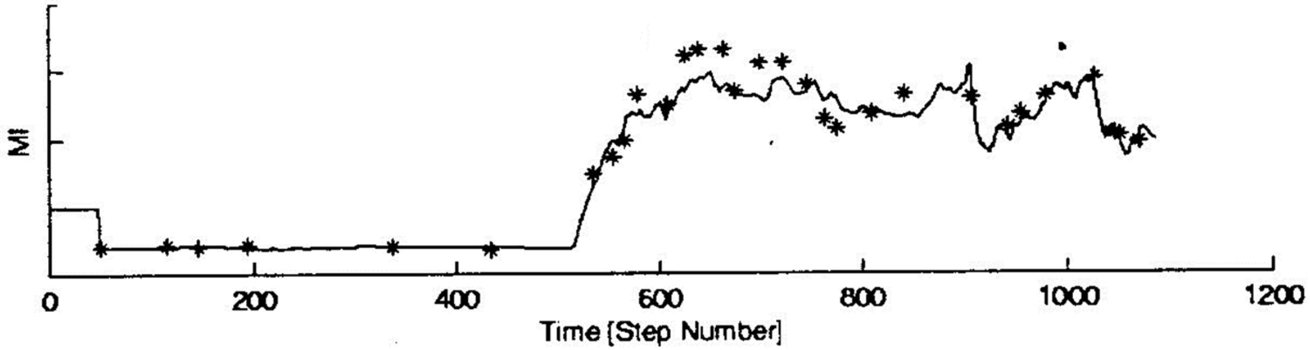
MI Estimation by Models



Mechanistic model

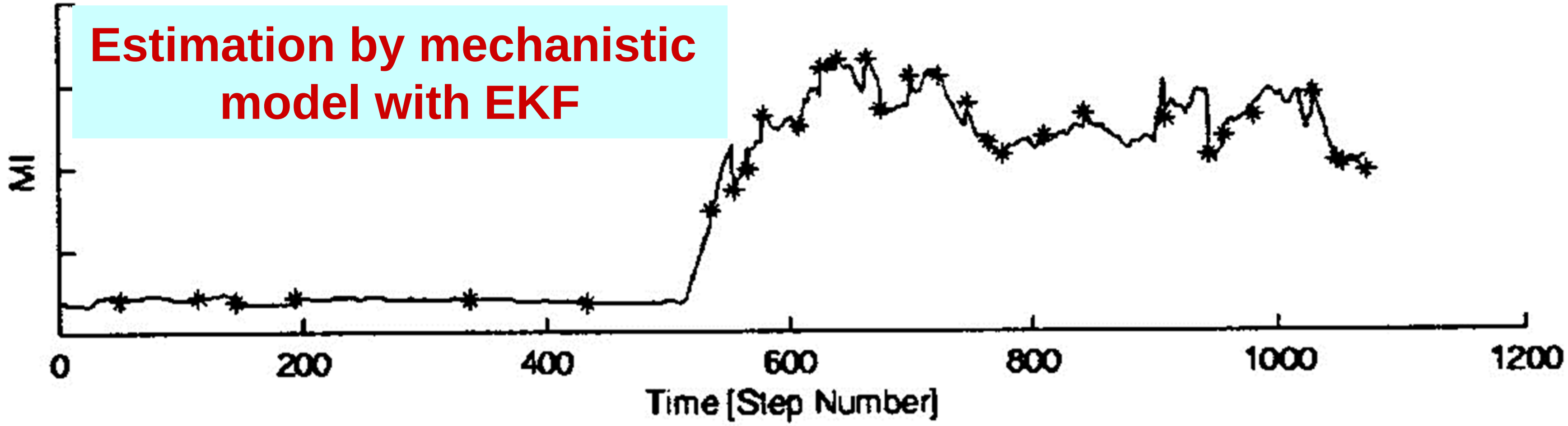


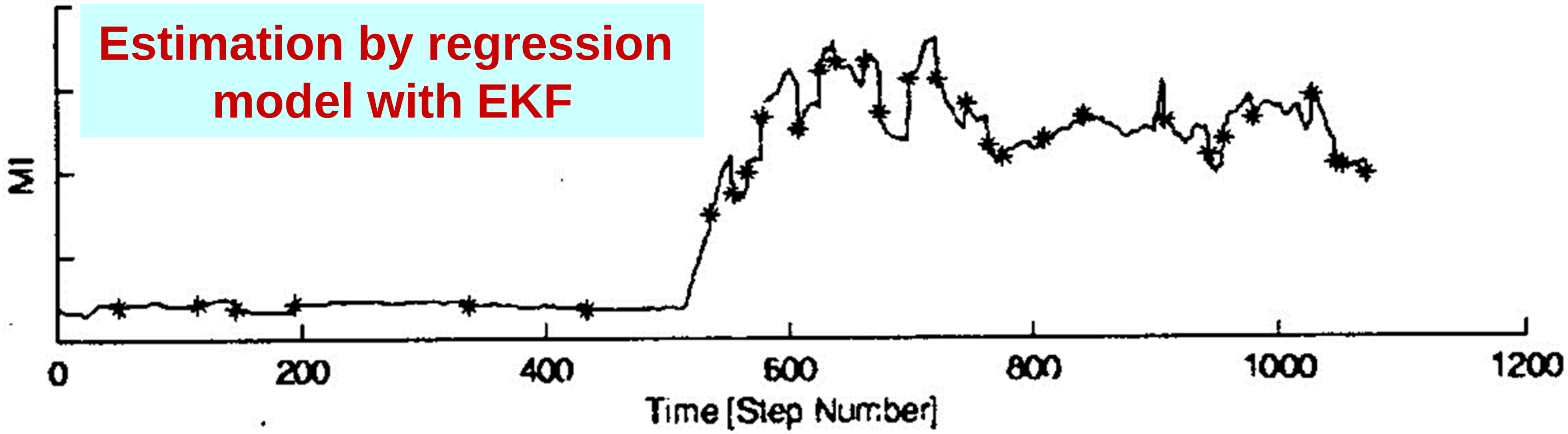
Regression model



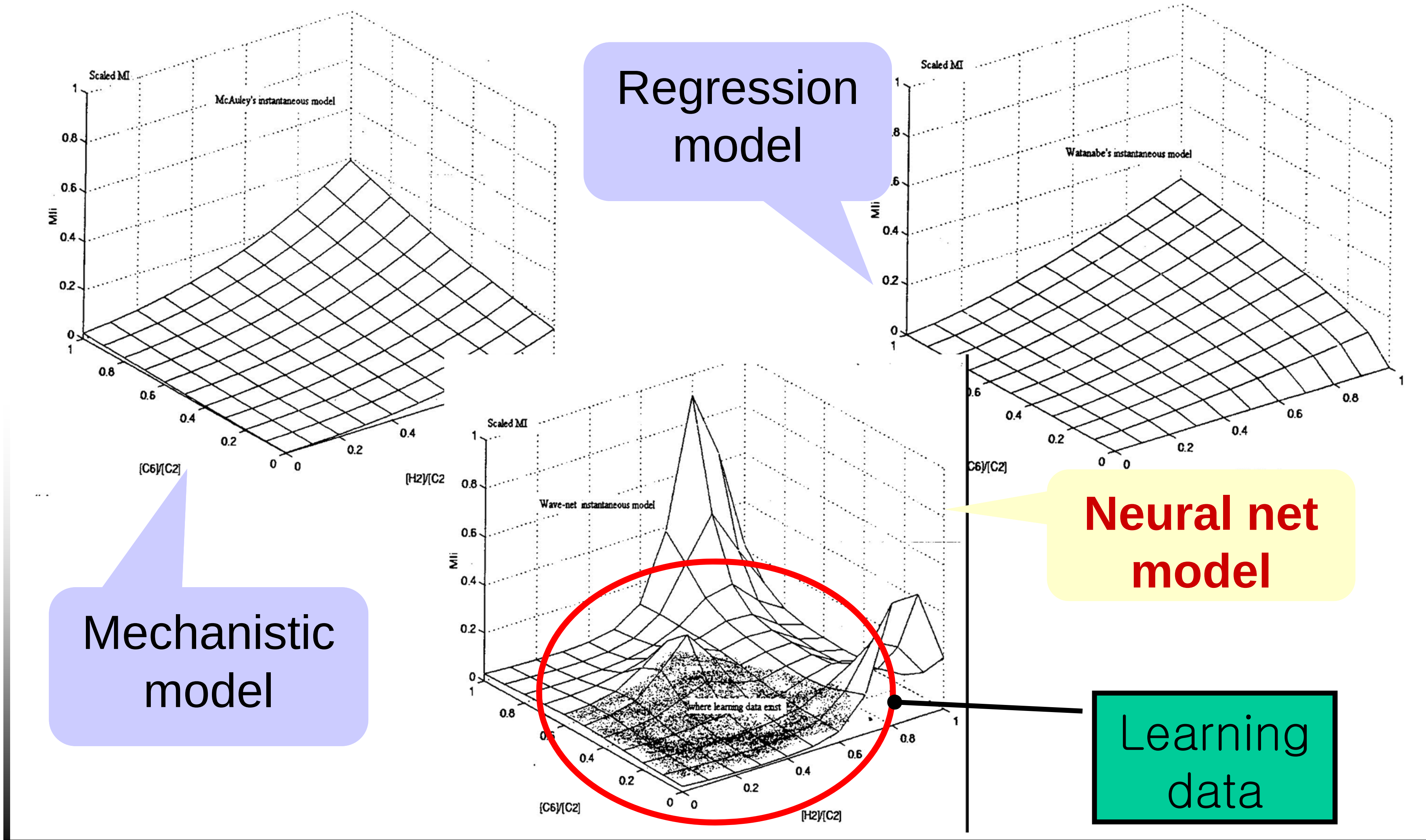
Neural net model

MI Estimation with EKF

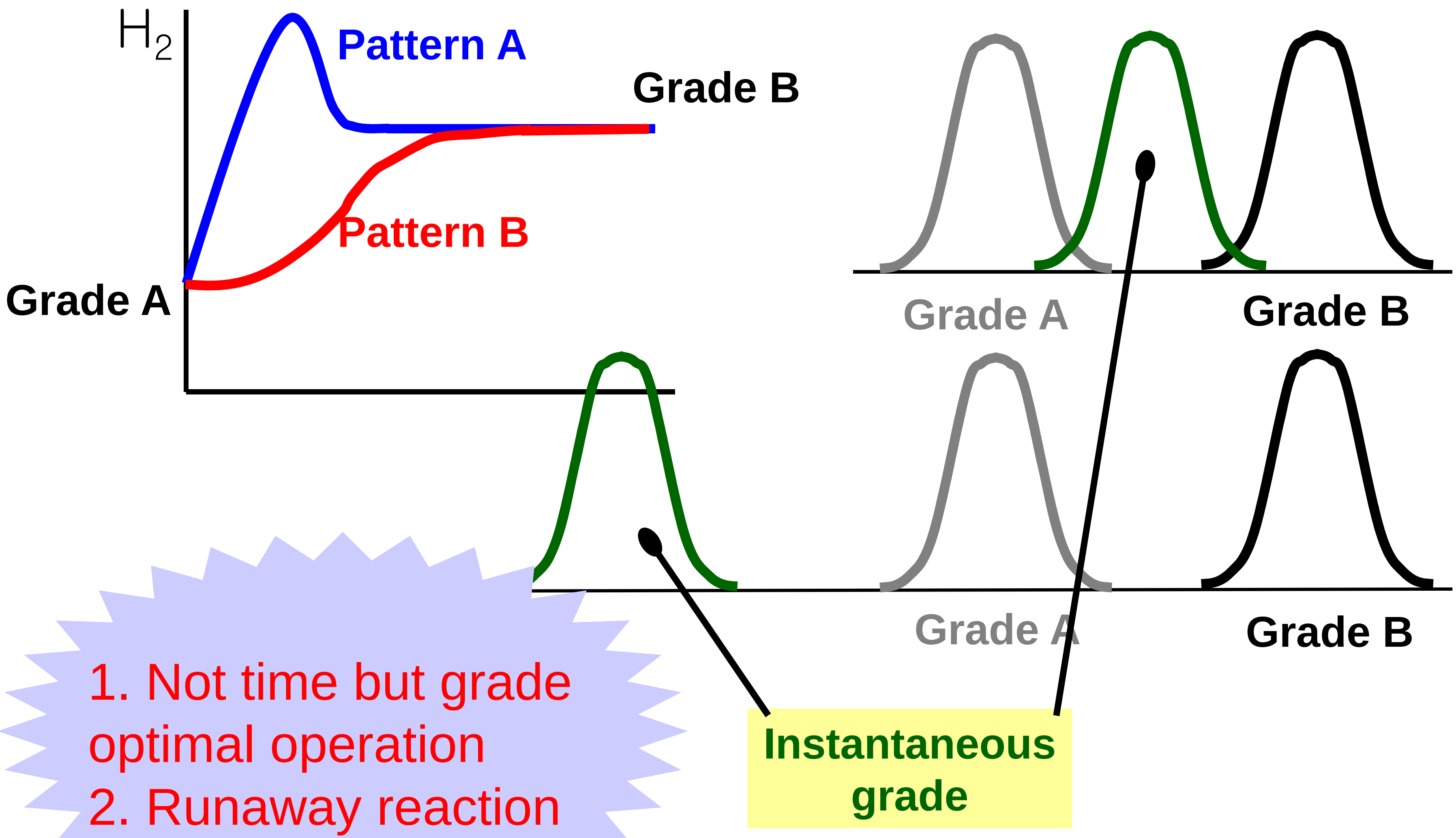




Risk of Extrapolation



Grade Changeover Operation

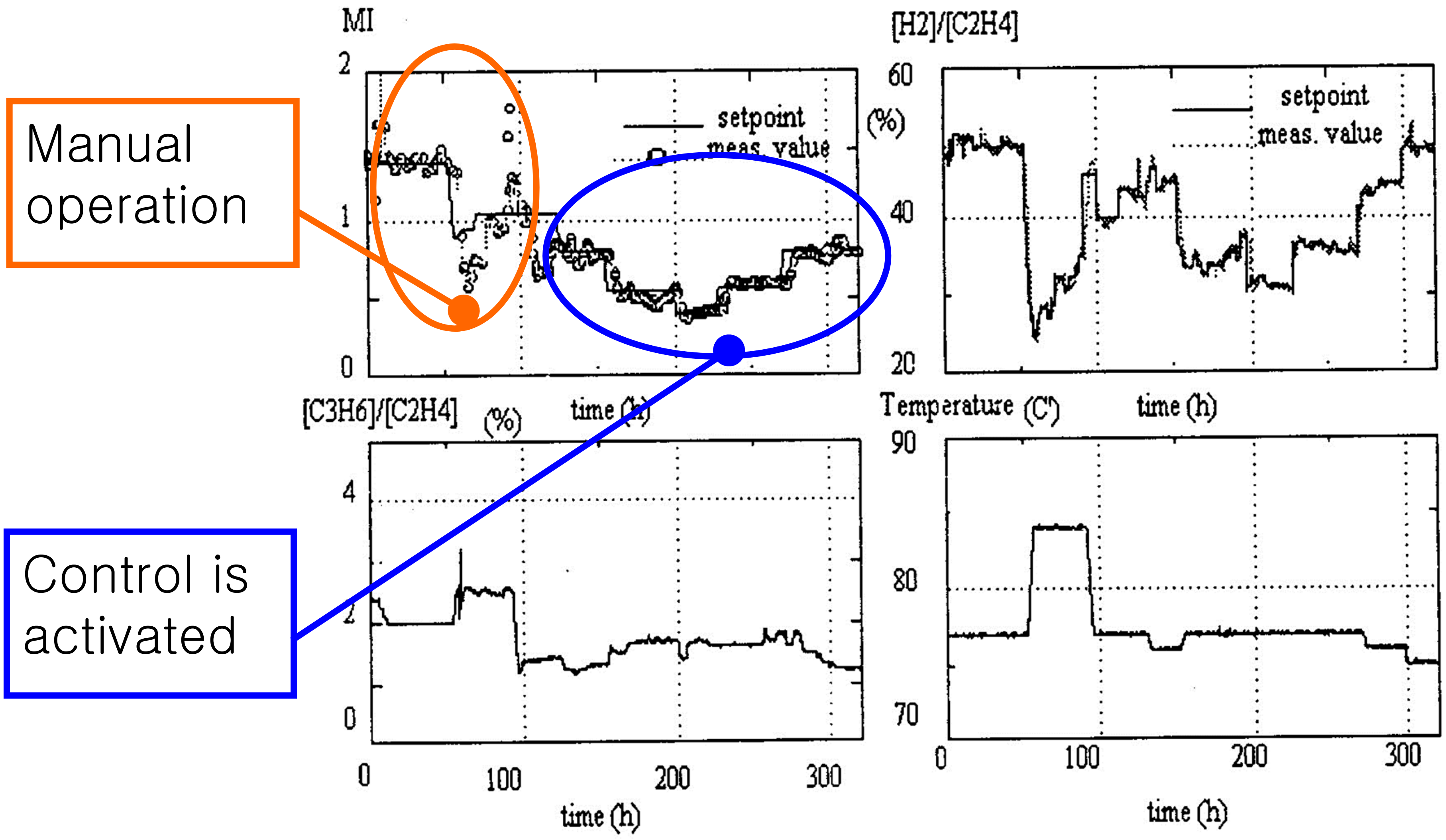


1. Not time but grade optimal operation
2. Runaway reaction

Control System

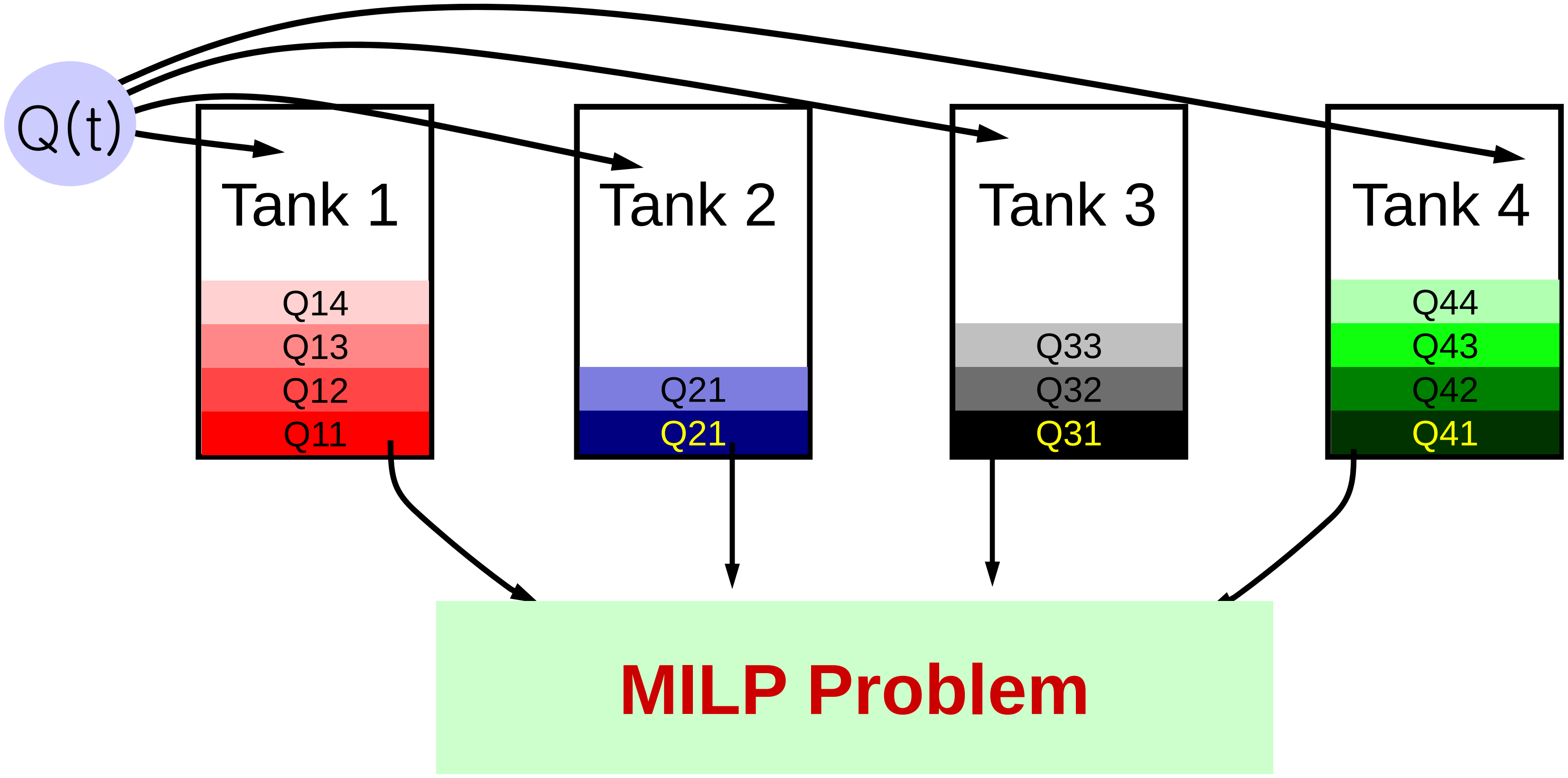
- Iterative open-loop optimization
  - A new optimal trajectory is recomputed
  - The first input action is implemented at every new measurements
- Combination of FF&FB controllers
  - A optimal trajectory is pre-calculated of both MV & CV
  - MV is introduced to the plant in a FF manner
  - **CV is deviated from the desired optimal trajectory, FB controller is activated to compensate the deviation**

Results of Control

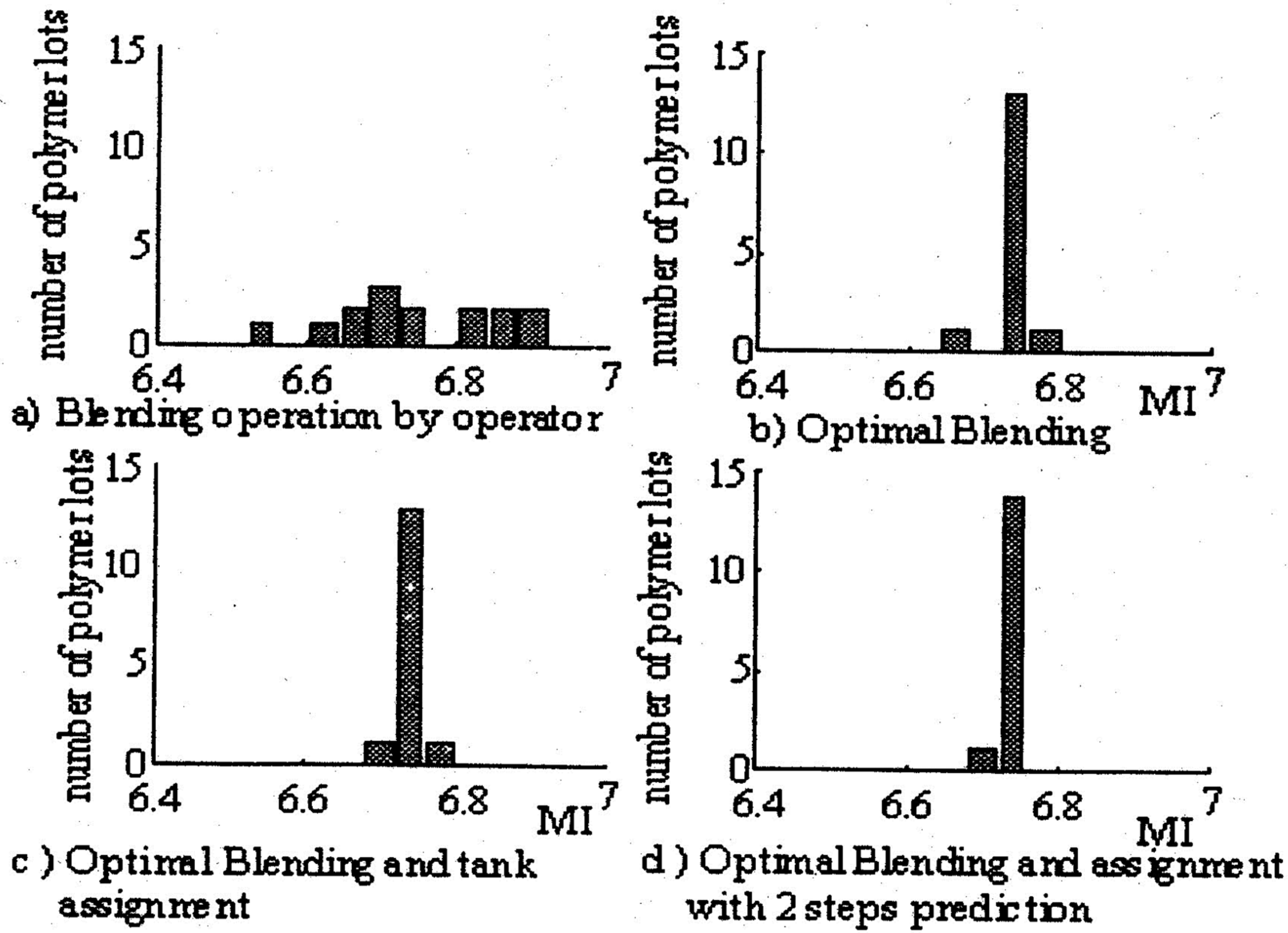


Optimal Blending

Reactor control is not good enough to satisfy the customer's demands



Blending Optimization Result



Conclusion

- ❑ Integration of process control, sensing and optimization is indispensable
- ❑ Most important factor is quality modeling