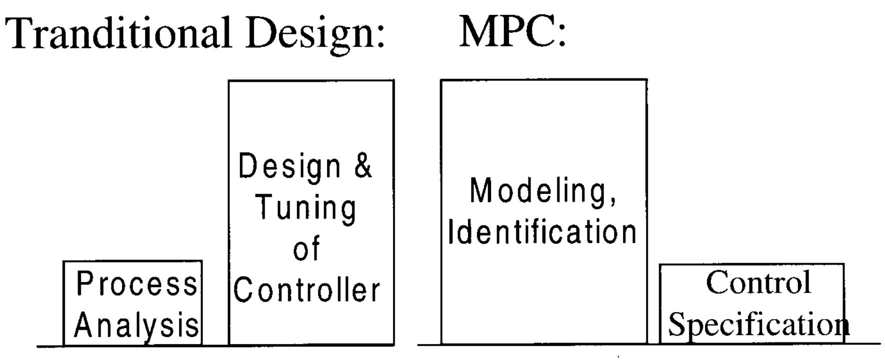
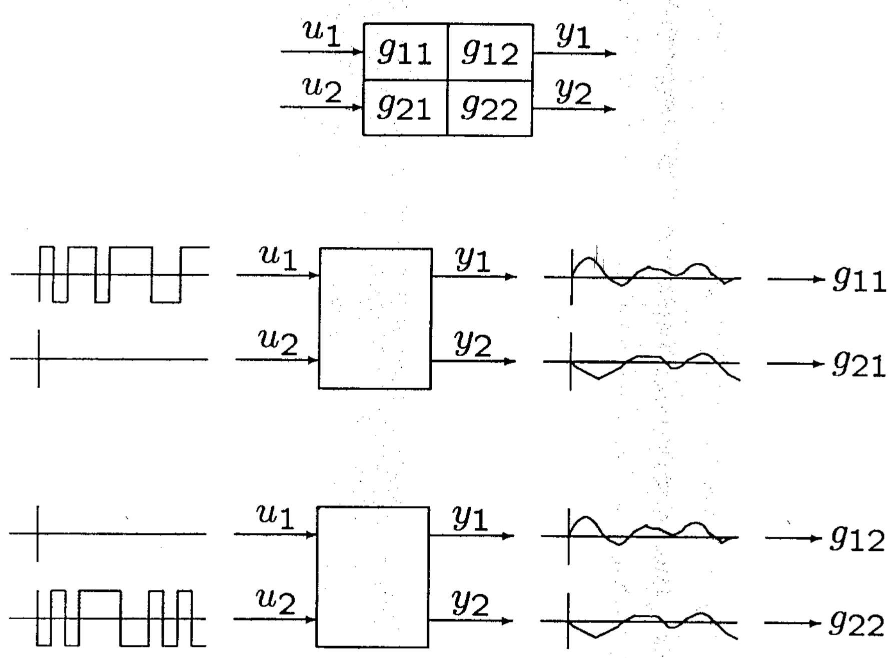
- most models for MPC design came from identification rater than fundamental modeling.
- system ID takes up to 80-90% of the cost and time in a typical implementation of a model based controller.



Current Practice



- Example illustrating the difficulty in multivariable system identification

True plant(Model A)

$$\frac{1}{10s+1}\begin{bmatrix} 0.878 & -0.864 \\ 1.086 & -1.092 \end{bmatrix}$$

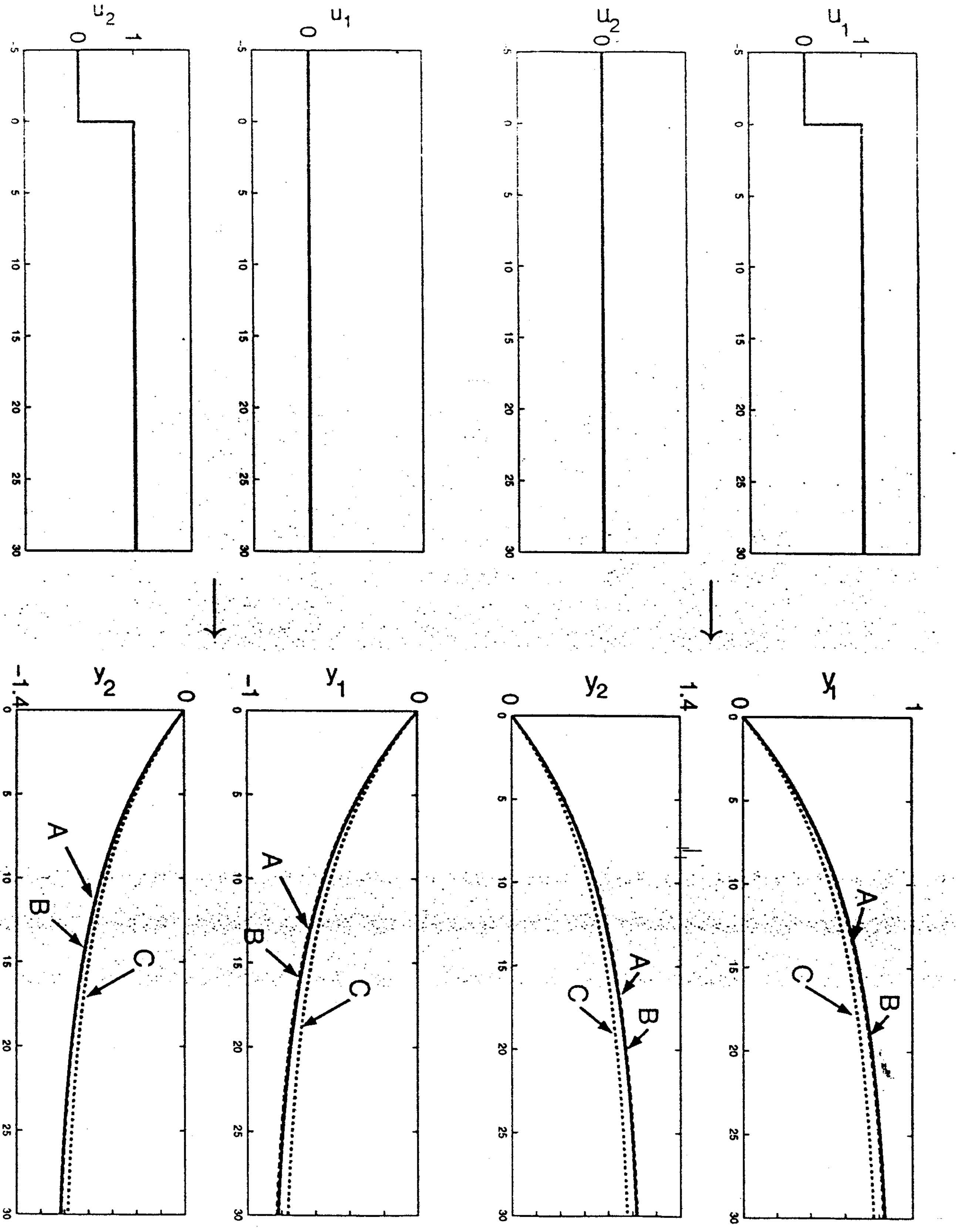
Model B

$$\frac{1}{10s+1}\begin{bmatrix} 0.867 & -0.875 \\ 1.095 & -1.083 \end{bmatrix}$$

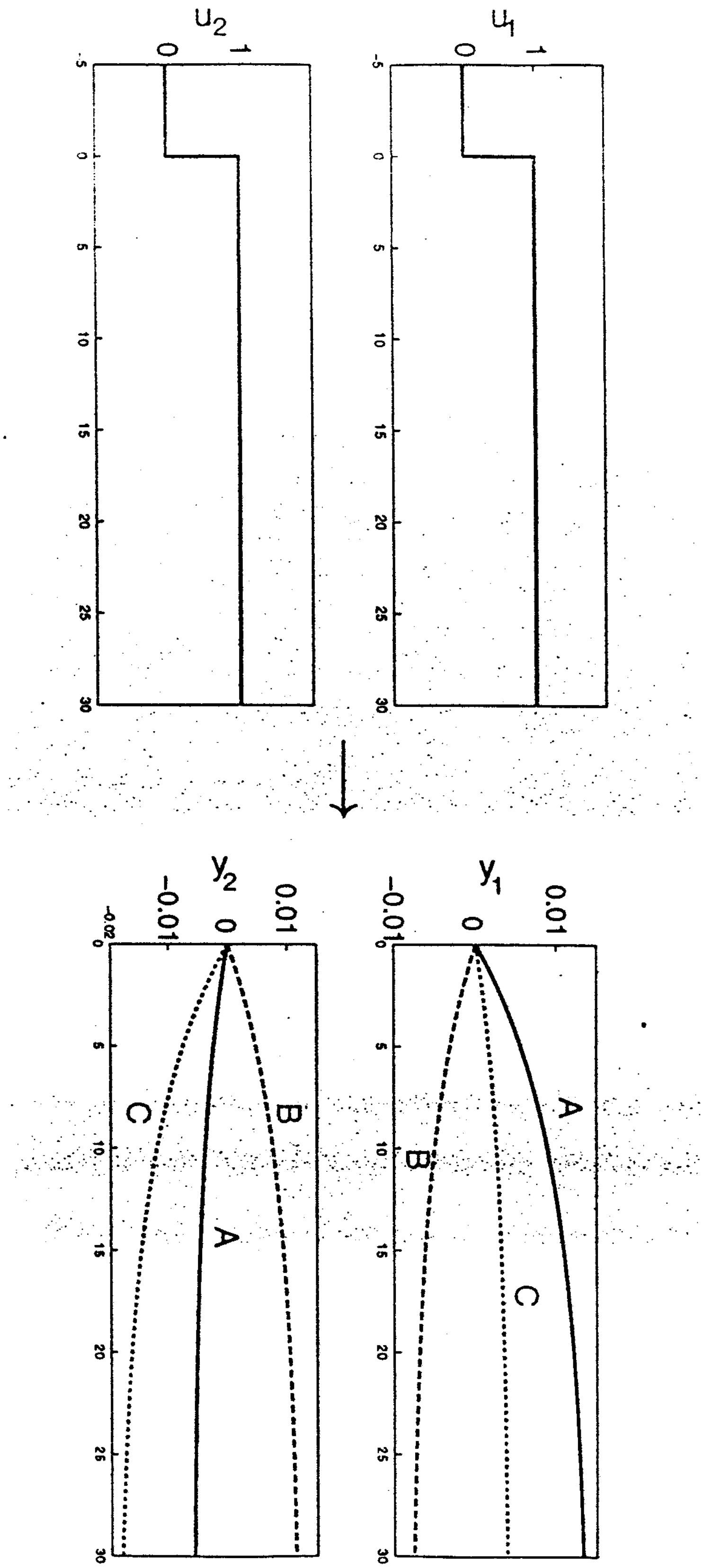
Model C

$$\frac{1}{10s+1}\begin{bmatrix} 0.808 & -0.804 \\ 1.006 & -1.025 \end{bmatrix}$$

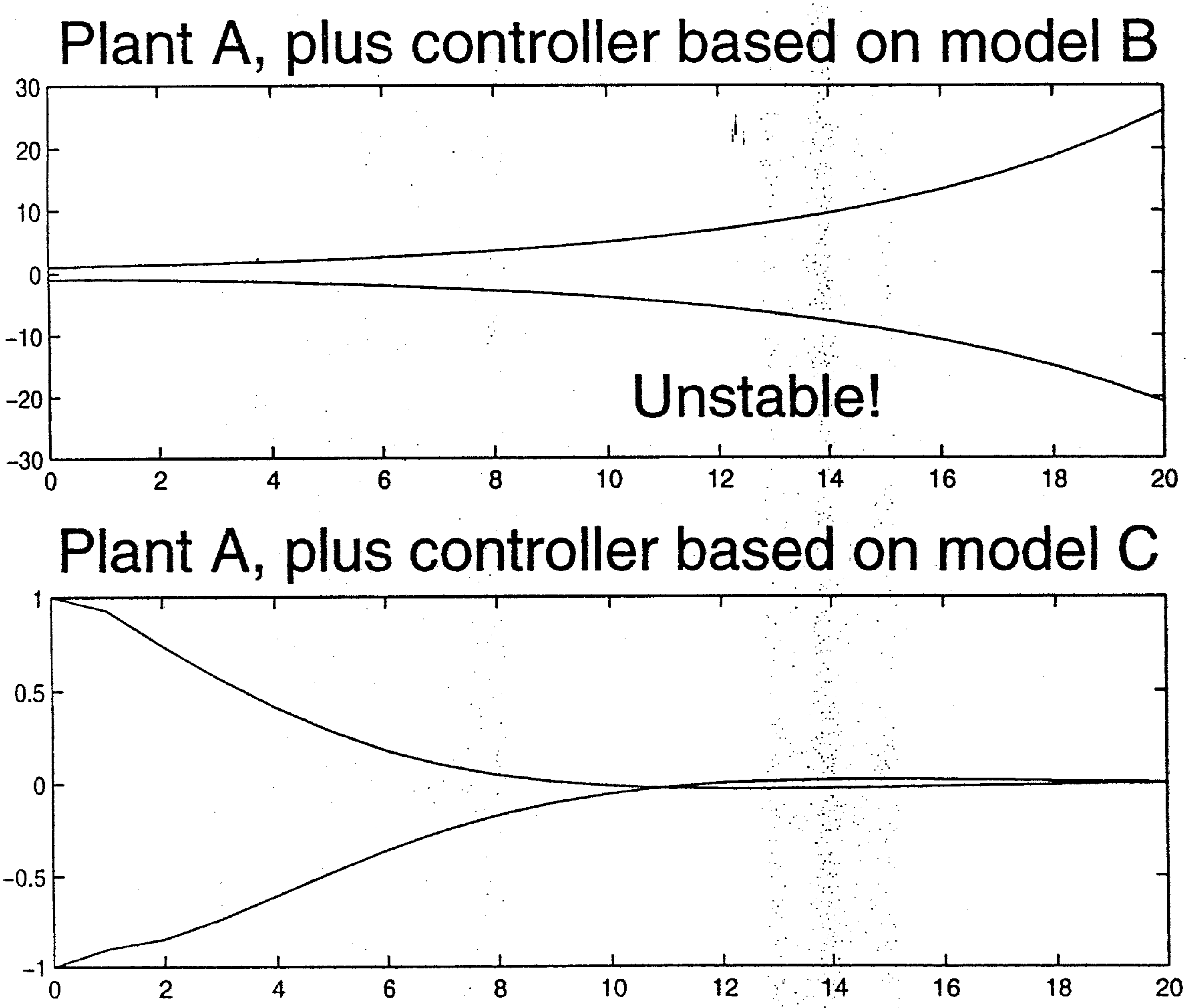
Open-loop response fits



Open-loop step response fits with simultaneous input change.



Close-loop responses



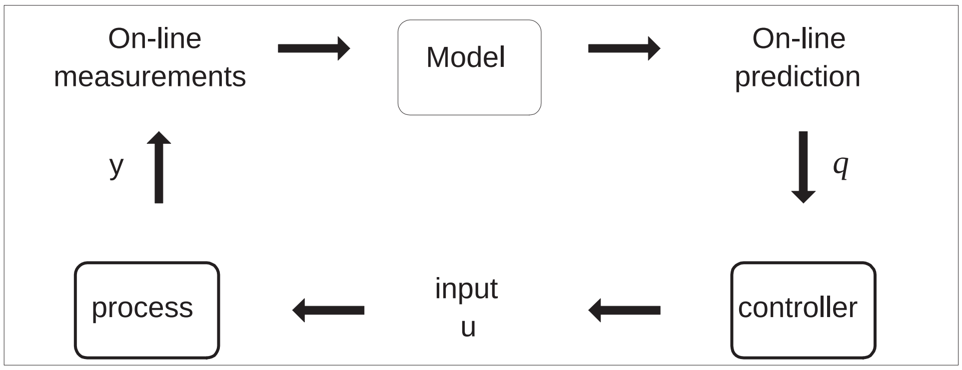
1.6.2 INCORPORATION OF STATISTICAL CONCEPTS

- *Improved Disturbance Rejection:*
  One can capture the temporal / spatial correlations of disturbance effects in the form of statistical models, using historical data, and use them for better prediction / control.

- *Inferential Control of Composition / Quality Variables*
  Many quality variables (e.q., variables directly related to end-use property) and compositions are not on-line measurable or difficult to measure on-line. Delays and large sample time involved in the laboratory analysis can make tight control impossible. In this case, correlations with other more easily measurable variables can be captured and utilized for inferencing.

- *Control System Performance Monitoring / Failure Diagnosis*
  The concept of Statistical Process Control (SPC) can be used to detect unusual behavior and also diagnose the cause of performance deterioration of MPC.

Motivational Example: Batch Pulp Digester

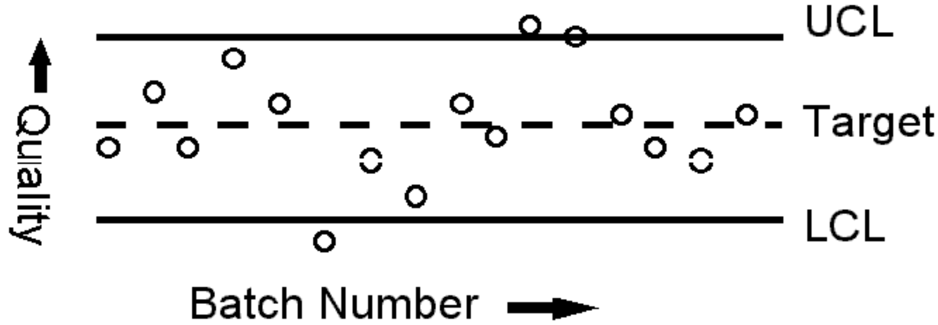


Key Aspects of the Problem

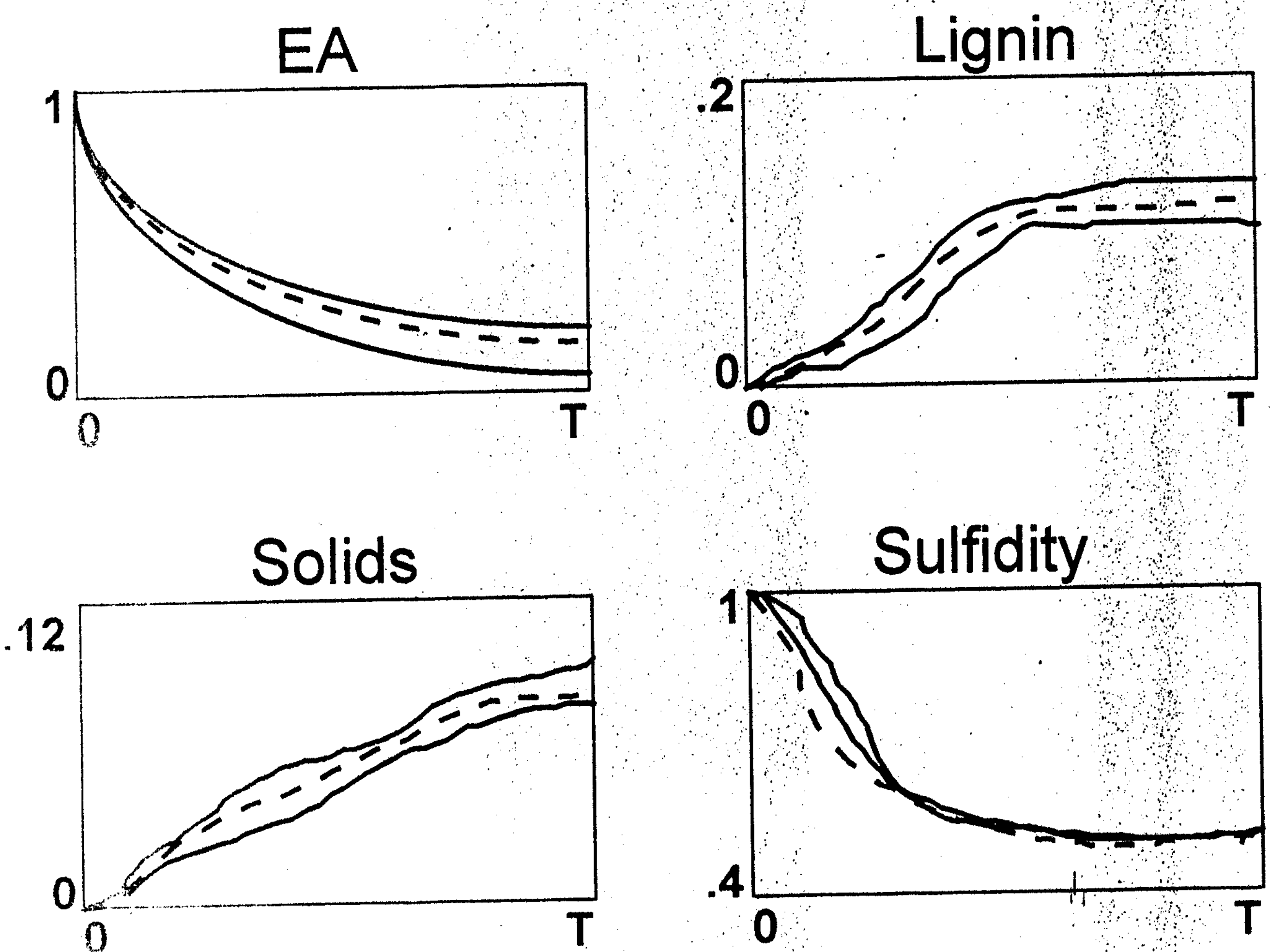
- Frequent Batch-to-Batch Variations in Operating Conditions
  - Feed conditions
  - Process parameters
    - → heat transfer coefficients
    - → reaction rate parameters
- Lack of On-Line Quality Measurements
  - Prohibits real-time feedback control

Traditional Control Method: Statistical Quality Control

- SPC Based on On-Line Measurements



Batch Digester Example



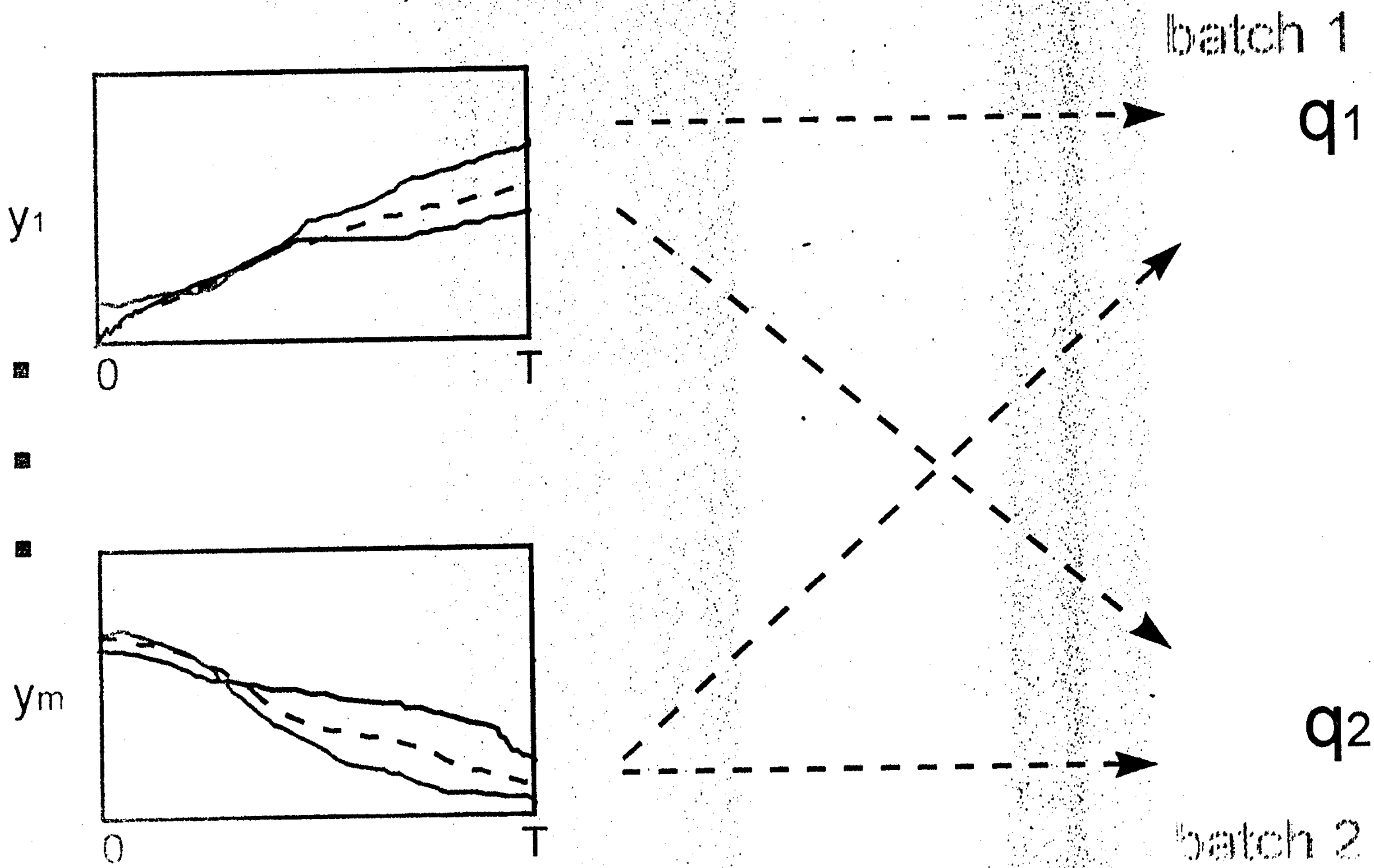
Kappa #

40 - target

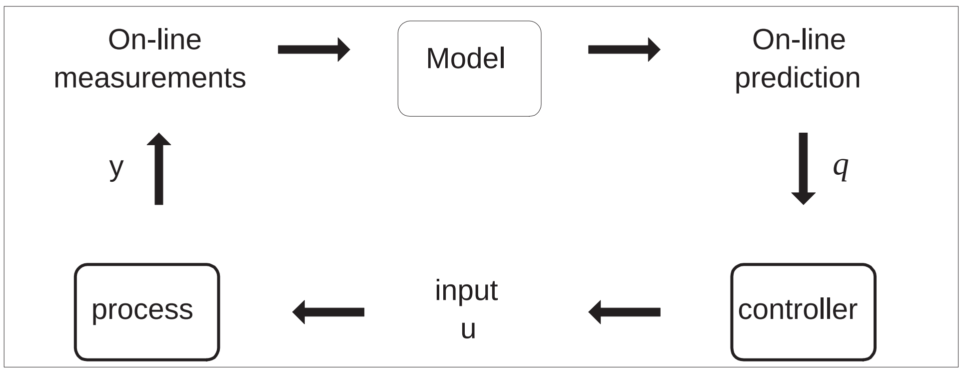
41

50

Relating On-line Data to Final Product Quality



Inferential Prediction and Control of Product Quality



1.6.3 NONLINEAR CONTROL

Linear model-based control can be inadequate for

- highly nonlinear processes (reactors, high-purity distillation column, batch processes, etc)
- process with large operating windows

MPC is a promising approach, but difficulties are in

- obtaining models (esp. through identification)
- computational complexity (NLP must be solved on-line)
- lack of theoretical understanding on the stability and robustness.

1.6.4 OTHER ISSUES

- control system maintenance
- integration with on-line optimization
- discrete-event systems, hybrid systems(e.q., start up)