EFC and SPM
(Engineering Feedback Control and Statistical Process Monitoring)

(Section 3.6 of Vardeman and Jobe)
EFC is Process Guidance/On-Line Adjustment
SPM is “Process Watching” for Purposes of Change Detection
SPM and EFC are NOT Competing Technologies

• Both have their places
• Both can be badly done
• Both can contribute to variation reduction in an industrial process
• Neither is a “weak version” of the other
• In many applications EFC creates the physical stability SPM monitors
Contrasts (V&J Table 3.10)

**EFC**
- “automatic”
- compensation-oriented
- expects process “drift”
- on-going “tweaking”
- typically computer controlled
- maintains optimal adjustment
- tactical
- can exploit models

**SPM**
- often manual
- detection-oriented
- expects “stability”
- triggers intervention
- typically a human agent intervenes
- warns of “special cause” changes
- strategic
- warns of departure from model
SPM and EFC Technologies

• SPM
  – Well known Shewhart control charts (assumed today)
  – Some fancier monitoring schemes (multivariate, EWMA, CUSUM)

• EFC
  – Huge literature and highly specialized discipline
  – Simplest version is probably “PID” control (example here for sake of concreteness)
Paper Making (Example 3.6)

- pulp tank
- pump
- ?algorithm?
- finished (dry) paper
- weight sensor
- about 4 minutes
Issues in Algorithm Development

• Pulp mix thickness WILL vary ... pump speed can be used to compensate
• This is NOT an SPC problem! (it is an automated compensation problem)
• Target is 70 g/m²
• 1 “tick” on pump dial changes density about .3 g/m²
• Time delay and potential for over-compensation/oscillation are serious issues
Algorithm Development

• To remove the time delay issue, a 5-minute sampling/adjustment interval was adopted

• Problem 3.38 gives baseline/no-adjustment data
More Algorithm Development

• PID control algorithm is

\[ \Delta X(t) = \kappa_1 \Delta E(t) + \kappa_2 E(t) + \kappa_3 \Delta^2 E(t) \]

for \( Y(t) = \) density at time \( t \)

\[ \Delta X(t) = \text{knob change after seeing } Y(t) \]

\[ E(t) = \text{"error" at time } t = T(t) - Y(t) \]

\[ \Delta E(t) = E(t) - E(t - 1) \]

\[ \Delta^2 E(t) = \Delta(\Delta E(t)) = \Delta E(t) - \Delta E(t - 1) \]
Interpretation

• “Integral” part of the algorithm
  \[ \kappa_2 E(t) \]
  reacts to deviations from target/offset

• “Proportional” part of the algorithm
  \[ \kappa_1 \Delta E(t) \]
  reacts to changes in error (/level)

• “Derivative” part of the algorithm
  \[ \kappa_3 \Delta^2 E(t) \]
  reacts to curvature on plots of error
Example Calculations

\[(\Delta X(t) = .83 \Delta E(t) + 1.66 E(t) + .83 \Delta^2 E(t))\]

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More Algorithm Development
(See Problems 3.39-3.43)

• Tuning constants/“control gains” were developed through a series of experimental trials (essentially sequential DOX)

• Starting point was with

\[ \Delta X(t) = 3.33E(t) \]

motivated by the “1 tick produces .3 g/m² change” information
Final Weight Consistency was Much Improved … SPM?

• Compare the last 6 periods of Table 3.9 with the baseline behavior on slide 9 (BTW, this is much better than the manufacturer’s algorithm!)

• To this point, we have an EFC success story

• SPM now could have a role in monitoring for unexpected changes from this behavior!
Workshop Exercise

\[ \Delta X(t) = 2\Delta E(t) + 4E(t) + 1\Delta^2 E(t) \]

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