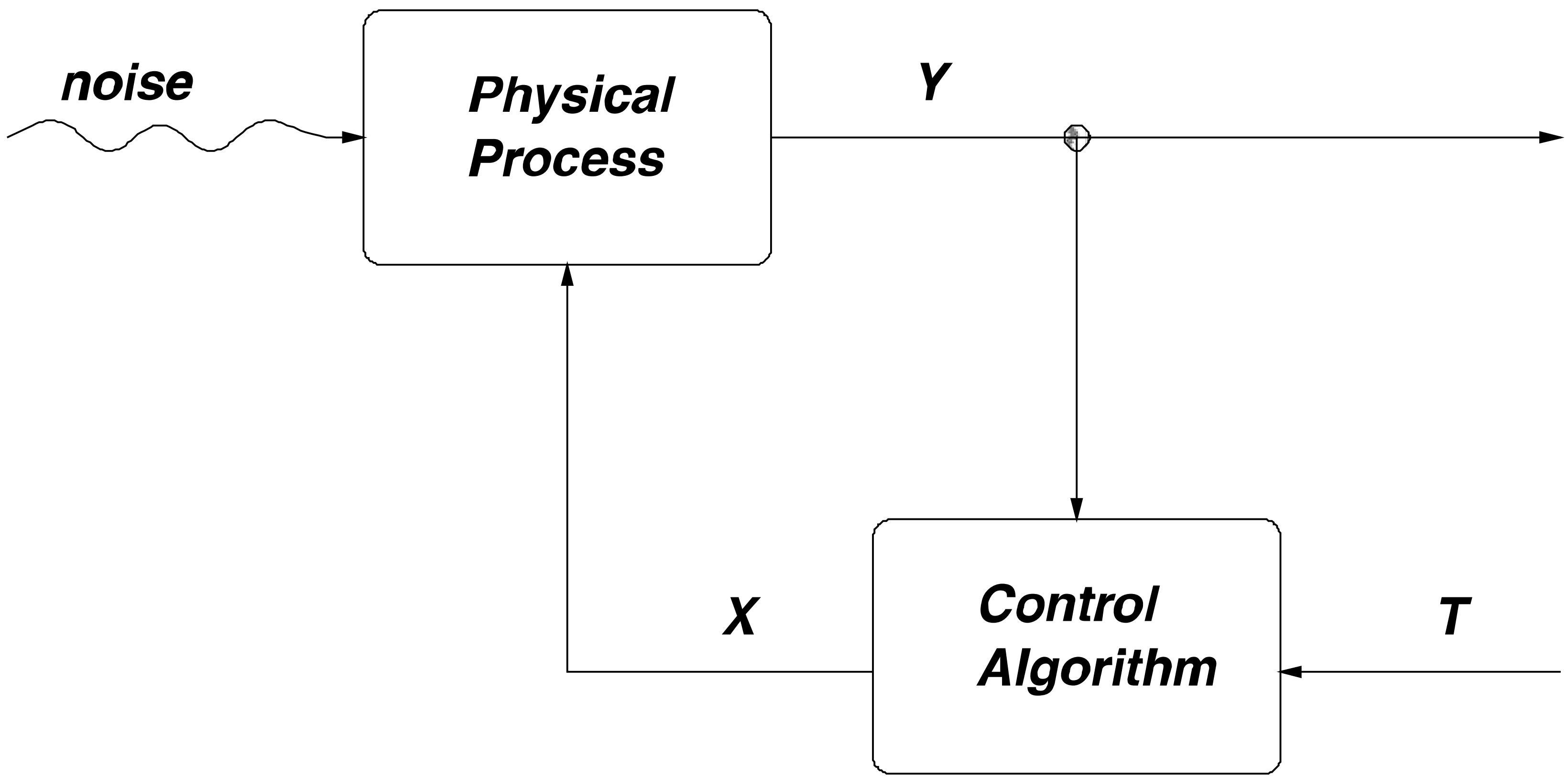
EFC and SPM

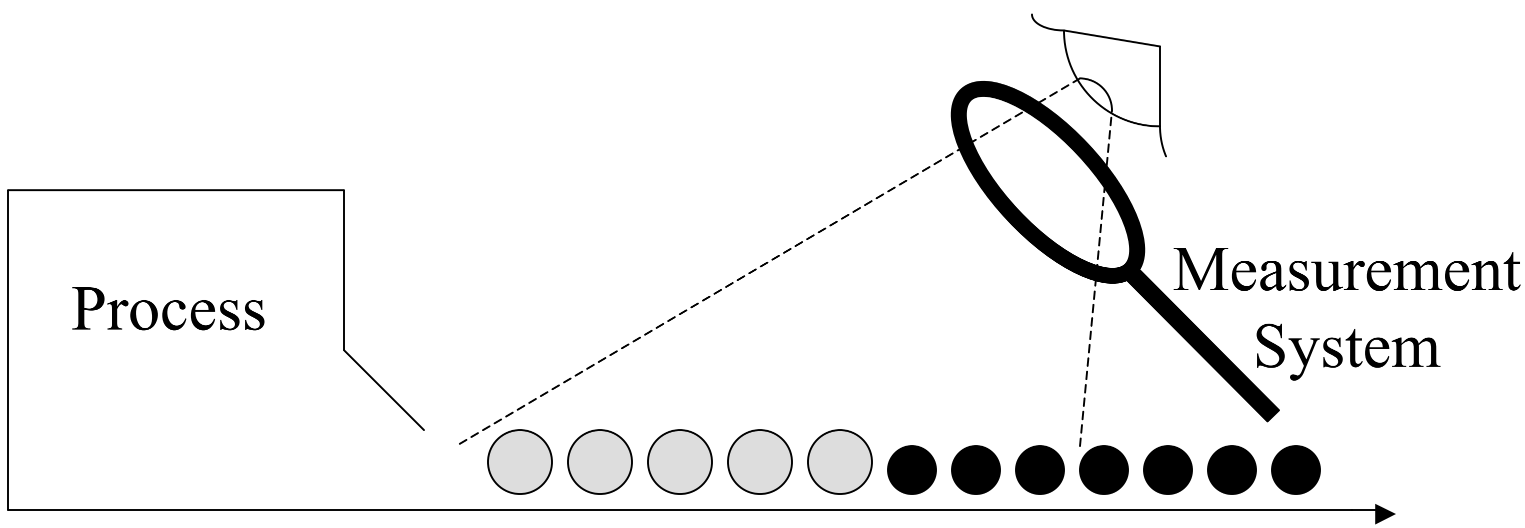
(Engineering Feedback Control and Statistical Process Monitoring)

(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

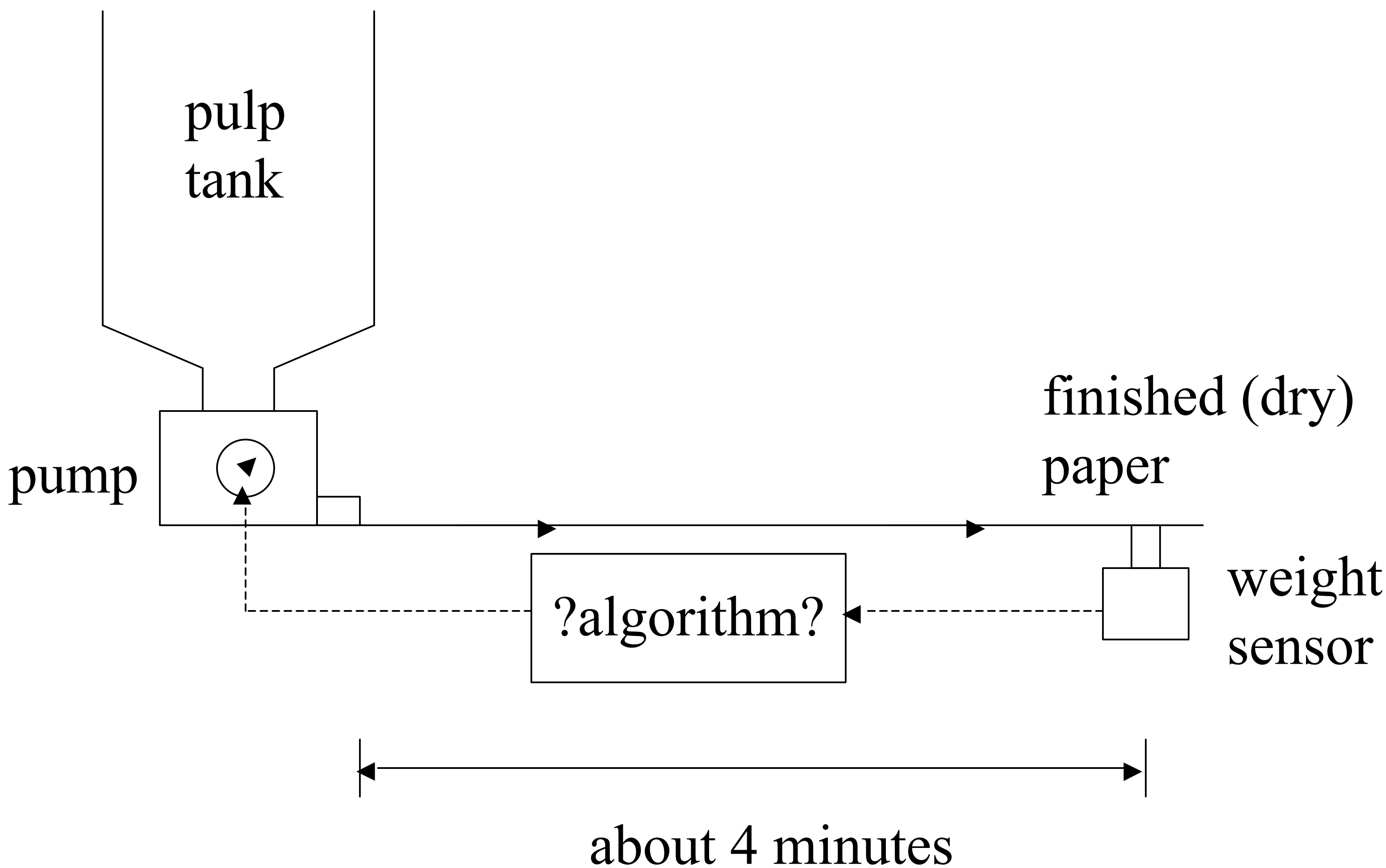
Contrasts (V&J Table 3.10)

EFC	SPM
“automatic”	often manual
compensation-oriented	detection-oriented
expects process “drift”	expects “stability”
on-going “tweaking”	triggers intervention
typically computer controlled	typically a human agent intervenes
maintains optimal adjustment	warns of “special cause” changes
tactical	strategic
can exploit models	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)

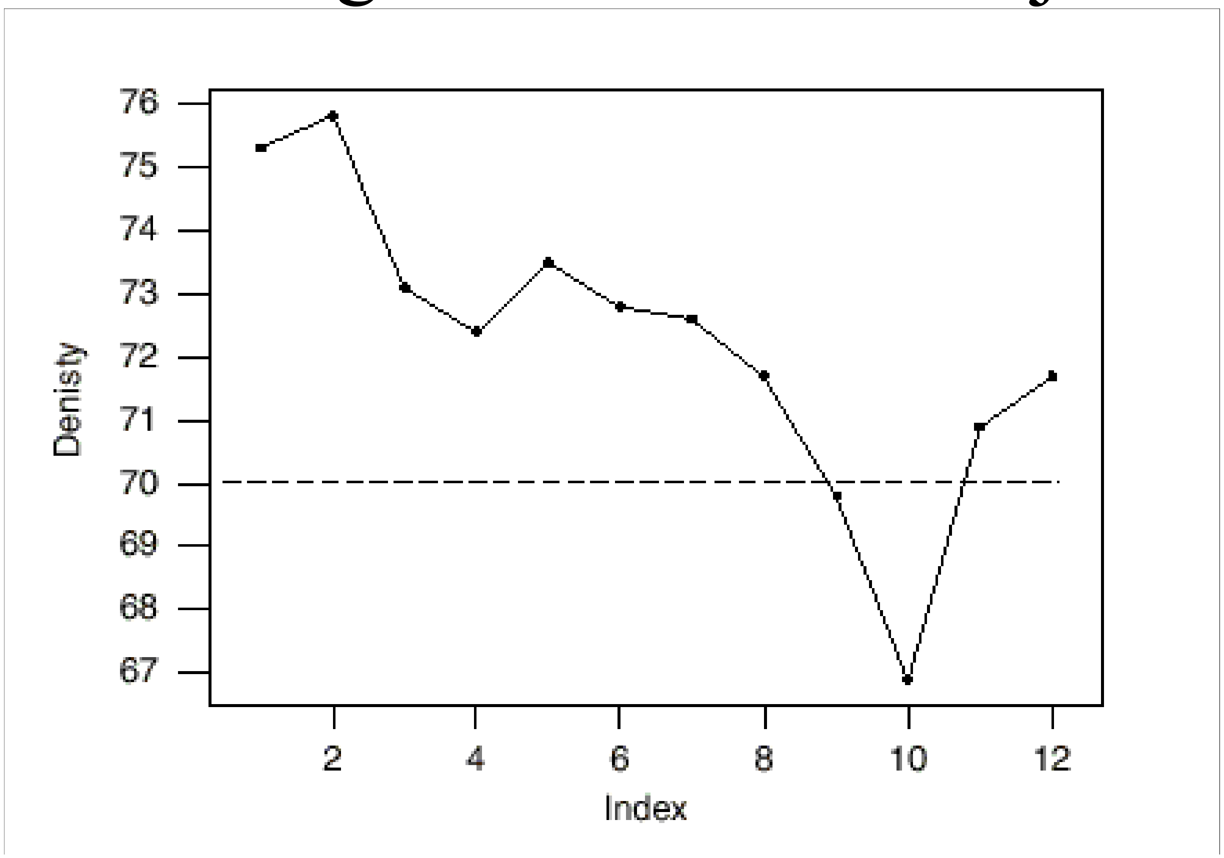


Issues in Algorithm Development

- 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/m^2
- 1 "tick" on pump dial changes density about .3 g/m^2
- 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

$$\Delta X(t) = k_1 \Delta E(t) + k_2 E(t) + k_3 \Delta^2 E(t)$$

for $Y(t) = \text{density at time } t$

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

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

$$\Delta E(t) = E(t) - E(t-1)$$

$$\Delta^2 E(t) = \Delta(\Delta E(t)) = \Delta E(t) - \Delta E(t-1)$$

Interpretation

- "Integral" part of the algorithm

$$k_2 E(t)$$

reacts to deviations from target/offset

- "Proportional" part of the algorithm

$$k_1 \Delta E(t)$$

reacts to changes in error (/level)

- "Derivative" part of the algorithm

$$k_3 \Delta^2 E(t)$$

reacts to curvature on plots of error

Example Calculations

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

t	$T(t)$	$Y(t)$	$E(t)$	$\Delta E(t)$	$\Delta^2 E(t)$	$\Delta X(t)$
1	70.0	65.0	5.0			
2	70.0	67.0	3.0	-2.0		
3	70.0	68.6	1.4	-1.6	.4	1.328
4	70.0	68.0	2.0	.6	2.2	5.644
5	70.0	67.8	2.2	.2	-.4	3.486
6	70.0	69.2	.8	-1.4	-1.6	-1.162

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/m^2 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

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

t	$T(t)$	$Y(t)$	$E(t)$	$\Delta E(t)$	$\Delta^2 E(t)$	$\Delta X(t)$
1	4	0				
2	4	2				
3	4	2				
4	4	3				
5	5	3				
6	5	4				