IE 361 Module 12

EFC and SPM ... One Thing Control Charting is Not

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Reading: Section 3.6, *Statistical Quality Assurance Methods for Engineers*

In this short module, we try to make explicit the difference between "engineering control" (as, for example, understood by EE's and ME's) and "SPC." Recall from Module 10 the basic insight that Shewhart "control charting" is about process watching for purposes of change detection as illustrated in the figure below repeated from that module.

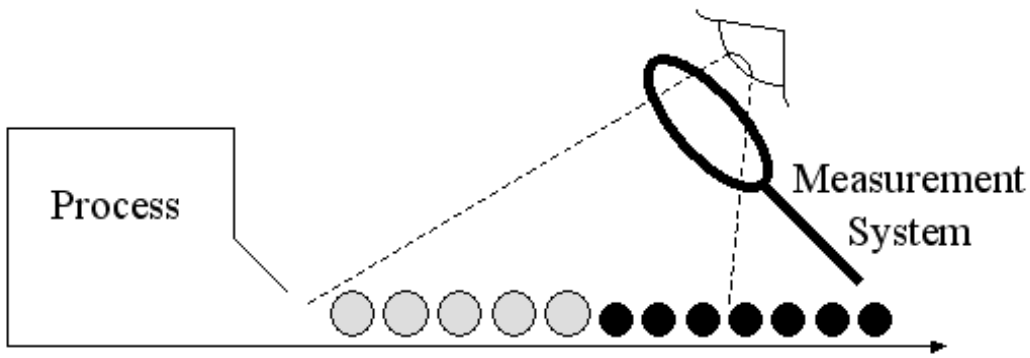

Figure 1: Statistical Process *Monitoring*

EFC and SPM (Control Charts are NOT Process-Tweaking Tools)

Engineering Feedback Control is process guidance/on-line adjustment.

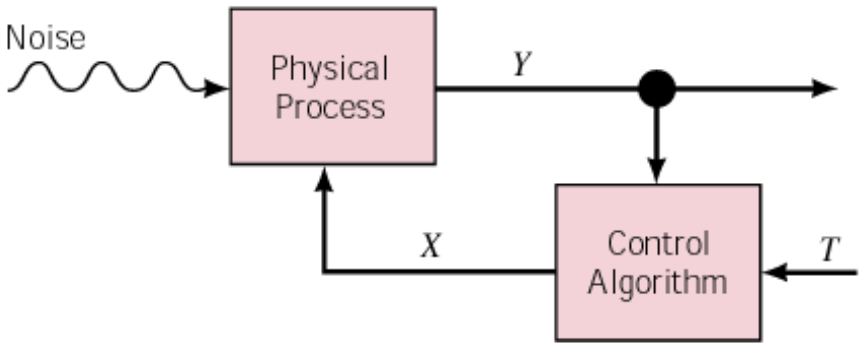

Figure 2: Schematic of an Engineering Control Scheme

This is not the same thing as 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 that SPM monitors

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

The technologies of EFC and SPM are quite different. SPM deals in "control charts" (Shewhart and others). EFC deals in feedback algorithms that prescribe how adjustment variables are to be manipulated on the basis of process data. "PID" control algorithms are a common variety of these (see Section 3.6 for a few details on PID control).

Example (Paper Making from Section 3.6 of *SQAME*) Prof. Jobe worked with the Miami U. Paper Science Department on the control of a paper-making machine.

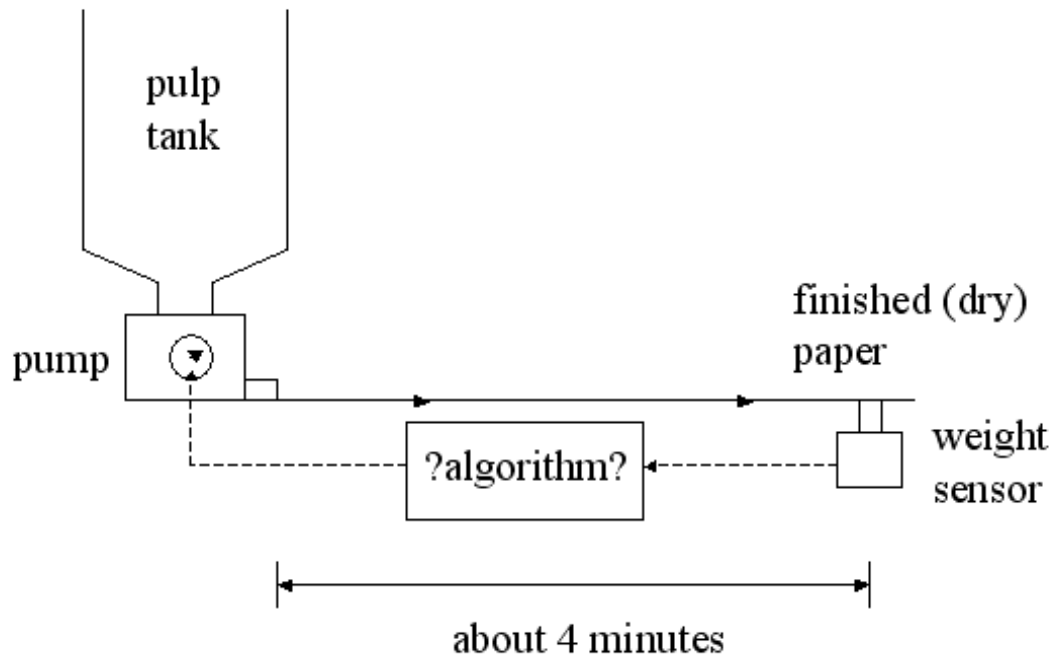

Figure 3: Schematic of a Paper-Making Process

Issues in developing an appropriate control algorithm included:

- pulp mix thickness WILL vary, but pump speed can be used to compensate
- this is NOT an SPC problem! (it is an automated compensation problem)
- target paper density 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

To remove the time delay issue, a 5-minute sampling/adjustment interval was adopted. Through a series of experiments, an appropriate PID control algorithm was developed (see *SQAME* exposition and problems and the appendix to this module for details). The following shows "uncontrolled"/baseline density data for 12 periods and data from 6 periods after the final algorithm was implemented and had been allowed to take effect.

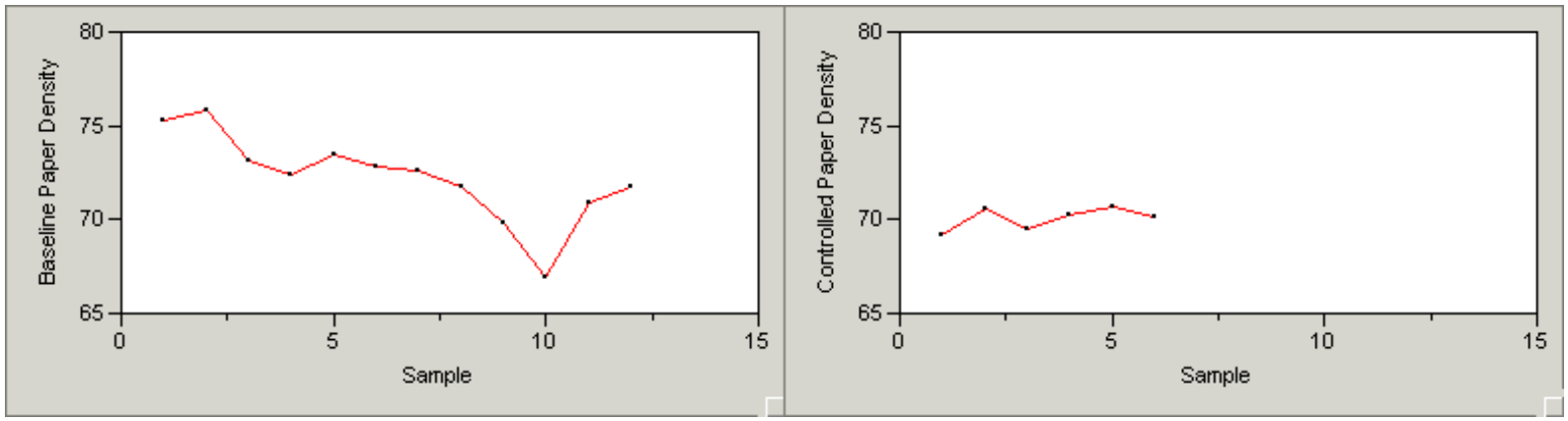

Figure 4: "Before" and "After" Paper Density

To this point, we have an EFC success story. SPM now could have a role in monitoring for unexpected changes from this behavior.

Appendix (Some Details on a PID Controller for the Paper Machine)

A PID (proportional/integral/derivative) control algorithm for the paper making example is

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

for

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

$$\Delta X(t) = \text{the knob position change (in "ticks") after observing } Y(t)$$

$$\begin{aligned} E(t) &= \text{the "error" at time } t \\ &= T(t) - Y(t) \end{aligned}$$

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

and

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

The

- "Integral" part of the algorithm, $\kappa_2 E(t)$, reacts to deviation 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

Jobe's final control algorithm was

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

The following table shows some hypothetical values for $Y(t)$ and computation of corresponding values of $\Delta X(t)$ for Jobe's control algorithm.

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