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Letters

Process-Monitoring-for-Quality—Applications

Carlos A. Escobar [a,b,*], Michael A. Wincek [a], Debejyo Chakraborty [a], Ruben Morales-Menendez [b]

[a] Global Research & Development, General Motors, Warren, MI, USA
[b] Tecnológico de Monterrey, Monterrey, NL, Mexico

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ABSTRACT

Innovation and the marketplace have been pushing *Statistical Process Control (SPC)* outside its comfort zone, which requires a mature understanding of the product and process and a methodology for verifying the quality of each manufactured item. Especially when a new technology is proven to work and customer interest is high, companies want manufacturing to respond to the uncertainties. *Process Monitoring for Quality (PMQ)* is a strategy, based on the empirical learning and data gather capabilities of the Big Data environment, that addresses this challenge while verifiably producing quality product. *PMQ* offers opportunities for learning and quality improvement: it enhances the quality movement by addressing three quality problems that SPC or traditional quality control techniques cannot; and by illuminating future applications.

1. Introduction

Big data [1], Industrial Internet of Things [2], acsensorization [3], artificial intelligence [4], machine learning [5], and cyber-physical systems [6] are propelling smart manufacturing. Many technical and organizational challenges of smart manufacturing must be addressed in order to realize gains over the entire value network [1,7]. This letter identifies some challenges to traditional quality control that can now be addressed by *PMQ*, which was first introduced in [3].

PMQ is a big data-driven quality philosophy that makes a limited statement about the quality of a manufactured item when a direct measurement of the quality is not practical or not possible. The strategy originated from the *Big Data–Big Model* (*BDBM*) point of view described in [3] that was used to develop an initial quality monitoring process for the ultrasonic welding of battery tabs in the Chevrolet® Volt. The strategy uses real time manufacturing process data to declare an item as either "good" or "suspect". Though the context of the development and application of PMQ were very specific, the potential applications are broader. Application of standard *SPC* has three requirements: a mature understanding of the process, an observable relevant quality characteristic with associated quality criteria, and a strategy and process to verify the quality criteria at the plant in real time. Today's innovative manufacturing environment and competitive business environment sometimes force the launching of a product even though the above three requirements for an *SPC* program cannot be satisfied. Fig. 1 shows how standard *SPC* is "brittle"; it "breaks" if not all steps are possible or not all steps are successfully completed. The purpose of this letter is to indicate how *PMQ* enhances and extends standard *SPC* by addressing three incomplete background knowledge situations that *SPC* or *traditional quality control* [8] cannot.

2. Background

SPC uses first principle knowledge, engineering technology, and statistical tools to control a manufacturing process under a well-understood cause and effect framework. When this framework is missing or incomplete, *PMQ* supplements it with an empirical predictive framework based on statistics, machine learning, and optimization. *SPC* requires known product quality characteristics that are measurable within the temporal and physical constraints of the manufacturing plant environment. Fig. 2 provides a taxonomy of quality features in manufacturing and relates them in a path diagram, which is list of the numbered nodes separated by an arrow, "→". The path that describes a conventional quality control initiative is $(1 \rightarrow \{3,4\} \rightarrow 6 \rightarrow 9 \rightarrow 12)$. This path relies on a quality characteristic that is known and physically observable either by

Abbreviations: BDBM, Big Data–Big Models; NDE, non-destructive evaluation; PMQ, process monitoring for quality; SPC, statistical process control; UMQ, usage monitoring for quality.

* Corresponding author at: Global Research & Development, General Motors, Warren, MI, USA.

E-mail address: carlos.1.escobar@gm.com (C.A. Escobar).

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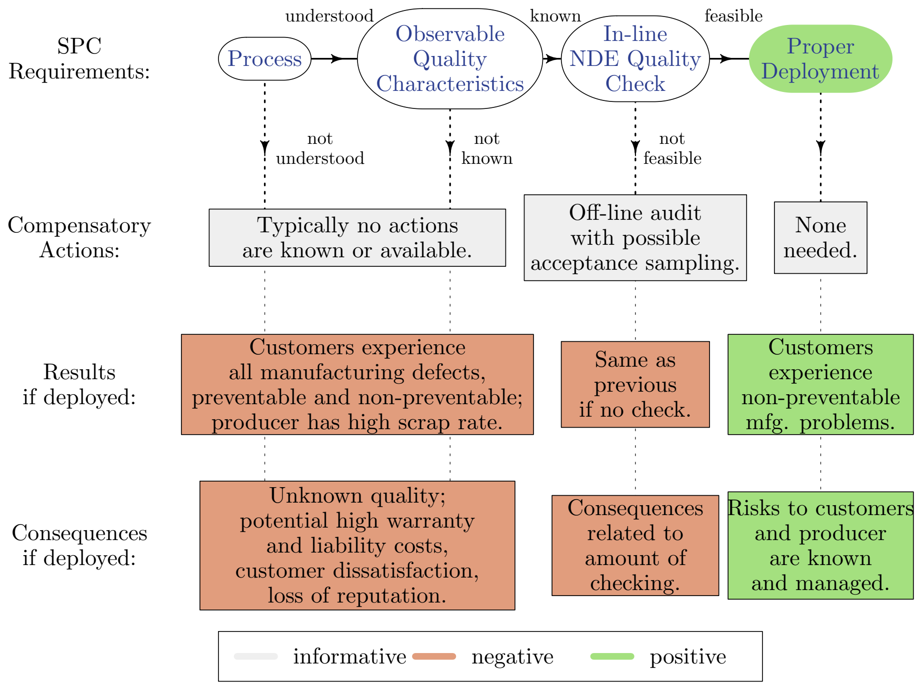

Fig. 1. Challenges to *SPC*.

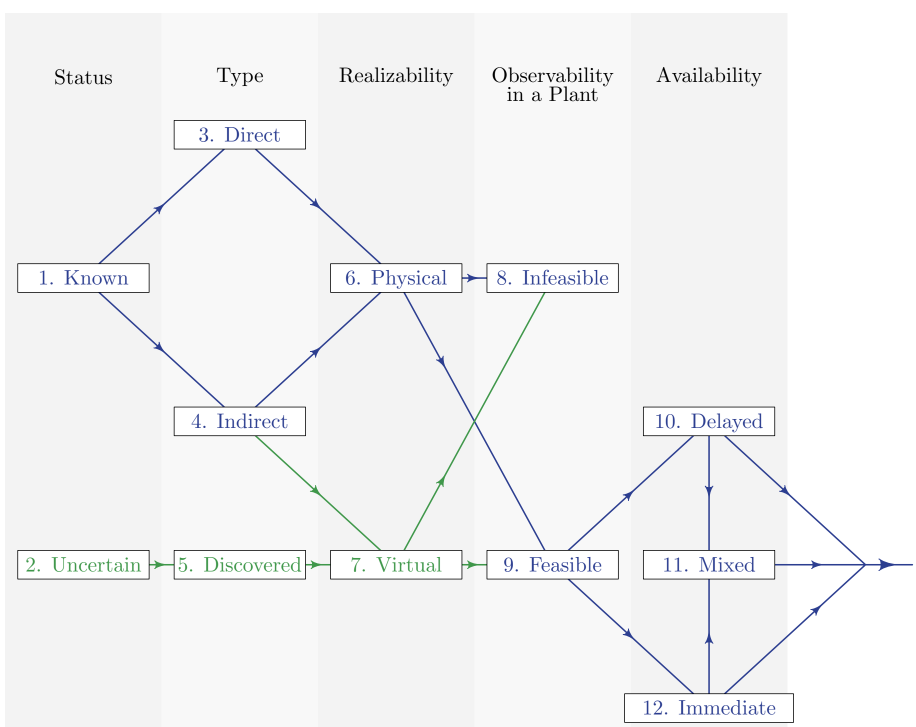

Fig. 2. Taxonomy of quality features in manufacturing.

direct or indirect means such that it is feasible in a manufacturing line and can immediately provide a good/bad quality status. Sometimes the characteristic cannot be measured directly. This situation can occur when the value of the characteristic involves destroying the item. When the characteristic cannot be measured directly, theory or engineering practice often provide a proxy through which the desired value can be obtained indirectly.

Even when a physical characteristic exists and is measurable, it may not be feasible to measure it within the time constraints of the manufacturing process. We call this the *infeasible measurement problem*: $(1 \rightarrow \{3,4\} \rightarrow 6 \rightarrow 8)$. The preferred scenario is for the characteristic to be measured immediately after the item is produced, $(1 \rightarrow \{3,4\} \rightarrow 6 \rightarrow 9 \rightarrow 12 \rightarrow)$. When there is a delay in the time of measurement and the buffer has a large capacity, all