Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

AUTOCORRELATION EFFECTS IN MANUFACTURING SYSTEMS PERFORMANCE: A SIMULATION ANALYSIS

Diego Crespo Pereira
David del Rio Vilas
Nadia Rego Monteil
Rosa Rios Prado
Alejandro Garcia del Valle

University of A Coruna
C. Mendizabal s/n
Ferrol (A Coruna) 15403, SPAIN

ABSTRACT

Autocorrelation has been pointed out as one of the most challenging issues in manufacturing systems modeling. Numerical experimentation has shown that it may either enhance or harm performance. Furthermore, there is not yet a general agreement in what a realistic autocorrelation model is or whether it is actually relevant for practical applications. This paper provides a simulation analysis of the effects on performance caused by manufacturing process parameters following autoregressive (AR) processes. AR time series are employed for modeling variations in parameters that happen at a time scale different from the corresponding to process cycle execution. Three basic configurations are analyzed: serial line, assembly process and a disassembly process. A case study from the natural slate tiles industry is presented showing the differences obtained in simulation results between a model in which independent and identically distributed (i.i.d.) assumptions are adopted and one in which autocorrelation effects are considered.

1 INTRODUCTION

Autocorrelation is defined as the correlation between successive observations of a time series. Positive autocorrelation in event streams causes a "bursty behavior" in which events seem to be clustered. Negative autocorrelation, on the other hand, causes an alternation between short and long time periods between events.

Results from queuing theory show that autocorrelation in service or inter-arrival times may severely affect queue lengths and waiting times (Livny, 1993). Some works have shown examples of autocorrelation in data from industrial plants. However, Hejn Nielsen (2007) casts doubts on the practical relevance of some of the autocorrelation models employed by the authors previously mentioned. Circumstances present in manufacturing plants may reduce its importance; for example, due to the adoption of certain process control rules. Also, the effects might either be favorable or unfavorable depending on the autocorrelation pattern.

2 AUTOCORRELATION IN CYCLE TIMES AND AT DIFFERENT TIME SCALES

A first simulation experiment was conducted in order to illustrate the complexity in process behavior caused by autocorrelation. A serial line consisting of ten machines with intermediate limited capacity buffers was simulated in Quest V5R20. Machines cycle times were modeled as an autoregressive process

978-1-4673-4781-5/12/$31.00 ©2012 IEEE

(AR) of order up to 5. Coefficients were arranged so that the coefficient of variation was equal to $1/3$ for all the cases. Results show that positive autocorrelation scenarios deteriorate performance when compared to a base scenario with independence in cycle times, irrespective of buffer size. Scenarios with negative first order autocorrelations demonstrate an enhanced performance. Scenarios with a low order positive autocorrelation and high order negative autocorrelation deteriorate performance for small buffer capacities and increase it for higher buffer capacities. Autocorrelation is shown to have a relevant and complex effect in line performance.

Another simulation experiment consisted of studying the effect of autocorrelation present in a time scale higher than process cycle execution. A serial line, an assembly line and a disassembly line of 3 machines each were considered. Cycle times were calculated as $t_{i,c} = \mu_i \cdot \varepsilon_{i,c}$ where $t_{i,c}$ is the duration of cycle c in the time period i, μ_i is the cycle time average in the period *i* and $\varepsilon_{i,c}$ follows a lognormal distribution with average 1 and standard deviation $\sigma_\varepsilon = 1/3$. Every T time units the average cycle time μ_i is generated following a first order autoregressive model (AR1) as shown in equation 1: $\mu_i = \mu + \beta \cdot (\mu_{i-1} - \mu) + \delta_i$, where $\mu = 1$ is average and δ_i is a white noise process with standard deviation σ_δ.
In this case, negative effects in performance were also found, becoming more acute as the considered time series step increased. In this case, both negative and positive autocorrelation diminished performance. However, for a disassembly process, autocorrelation in the product downstream routing probabilities did not seem to have a noticeable effect.

3 AUTOCORRELATION IN CYCLE TIMES AND AT DIFFERENT TIME SCALES

A case study from the slate tiles manufacturing sector presented in (Crespo Pereira et al., 2012) is revisited and new validation results provided. the A manufacturing plant of natural slate tiles was analyzed by means of discrete events simulation. The process begins with the extraction of irregular pieces of slate from a quarry. After transportation to the plant, they are first sawed into blocks and then manually split into pieces of a standard thickness. The resulting piles of plates are cut into different shapes and sizes according to the commercial formats. Finally, tiles are classified by standardized grades of quality and then packed in crate pallets.

Irregularity in the input material conditions cause a high variability in the process performance. Seven key process parameters were identified and data collected from production records. A principal components analysis of these parameters showed four main components of variation which were fitted by means of first order autoregressive processes (AR1) to account for the autocorrelation in daily variations. In order to validate the developed model, results from the model which included the fitted time series (M2) were compared to results from the real plant and from a model which did not include AR1 model (M1).

It was found that M2 matched better the data from the real plant in terms of standard deviation and autocorrelation coefficients of output variables time series. M2 also displayed behavior observed in the real plant such as a the saturation of intermediate buffers during irregular periods of several days which M1 could not reproduce. This case provides a practical example on how considering autocorrelation may enhance the accuracy of a model.

REFERENCES

Crespo Pereira, D., del Rio Vilas, D., Rego Monteil, N., & Rios Prado, R. (2012). Simulation and Highly Variable Environments: A Case Study in a Natural Roofing Slates Manufacturing Plant. *Use Cases of Discrete Event Simulation* (pp. 147-178)

Hejn Nielsen, E. (2007). Autocorrelation in queuing network-type production systems—Revisited. *International Journal of Production Economics*, *110*(1-2), 138-146.

Livny, M., Melamed, B., & Tsiolis, A. K. (1993). The Impact of Autocorrelation on Queuing Systems. *Management Science*, *39*(3), 322-339