

Detection of Mean Shifts by Statistical Approaches. Part 2: Context of Non-Gaussian or Autocorrelated Observations

Teodor TIPLICA

UNAM Université, Laboratoire Angevin de Recherche en Ingénierie de Systèmes (LARIS), EA
7315, France
teodor.tiplica@univ-angers.fr

Abstract

This article is the second part of a global overview of the research on the detection of mean shifts through statistical techniques. Various categories of control charts used in the field of Statistical Process Control (SPC) are reviewed in the particular context represented by autocorrelated observations or distributed under non-Gaussian distributions.

Keywords: SPC, APC, control charts, detection, autocorrelated observations, non-Gaussian distributions.

References:

- [1] B. Adams and I. Tseng, Robustness of Forecast-based Monitoring Systems. *Journal of Quality Technology*, 30, 328-339, 1998.
- [2] L. C. Alwan, Effects of Autocorrelation on Control Chart Performance. *Communications in Statistics: Theory and Methods*, 21, 1025–1049, 1992.
- [3] L. C. Alwan and D. Radson, Time-Series Investigation of Subsample Mean Charts. *IIE Transactions*, 24 (5), 66-80, 1992.
- [4] L. C. Alwan and H. V. Roberts, Time-Series Modeling for Statistical Process Control. *Journal of Business and Economic Statistics*, 6, 87-95, 1988.
- [5] R. W. Amin, M. R. Reynolds and S. Bakir, Non parametric Quality Control Charts Based on the Sign Test. *Communications in Statistics. Theory and Methods*, 24, 1597-1624, 1995.
- [6] D. Apley and H. Lee, Robustness Comparison of Exponentially Weighted Moving-Average Charts on Autocorrelated Data and on Residuals. *Journal of Quality Technology*, 40(4), 428-447, 2008.
- [7] D. Apley and J. J. Shi, The GLRT for Statistical Process Control of Autocorrelated Processes. *IIE transactions*, 31, 1123–1134, 1999.
- [8] D. Apley and F. Tsung, The Autoregressive T2 Chart for Monitoring Univariate Autocorrelated Processes. *Journal of Quality Technology*, 34(1), 80-96, 2002.
- [9] O. O. Atienza, L. L. Tang and B. W. Ang, A SPC Procedure for Detecting Level Shifts of Autocorrelated Processes. *Journal of Quality Technology*, 30, 340–351, 1998.
- [10] O. O. Atienza, L. L. Tang and B. W. Ang, A CUSUM scheme for autocorrelated observations, *Journal of Quality Technology*, 34 (2), 187–199, 2002.
- [11] F. Babus, Contrôle de processus industriels complexes et instables par le biais des techniques statistiques et automatiques. Thèse de doctorat à l’Institut des Sciences et Techniques de l’Ingénieur (ISTIA) – Université d’Angers, 2008.

- [12] M. Basseville and I. Nikiforov, *Detection of Abrupt Changes: Theory and Applications*. Englewood Cliffs: NJ: Prentice-Hall, 1993.
- [13] P. M. Berthouex, W. G. Hunter and L. Pallesen, *Monitoring Sewage Treatment Plants: Some Quality Control Aspects*. *Journal of Quality Technology*, 10, 139–149, 1978.
- [14] C. M. Borrer, C. W. Champ and S. E. Rigdon, *Poisson EWMA Control Charts*. *Journal of Quality Technology*, 30, 352–361, 1998.
- [15] C. M. Borrer, D. C. Montgomery and G.C. Runger, *Robustness of the EWMA control chart to non-normality*. *Journal of Quality Technology*, 31, (3), 1999.
- [16] G. E. Box and D. R. Cox, *An Analysis of Transformations*. *Journal of the Royal Statistical Society*, B 26, 211–243, 1964.
- [17] G. E. Box and T. Kramer, *Statistical Process Monitoring and Feedback Adjustment – A Discussion*. *Technometrics*, 34, 251–285, 1992.
- [18] R. Boyles, *Phase I Analysis for Autocorrelated Processes*. *Journal of Quality Technology*, 32, 395–409, 2000.
- [19] P. Castagliola, C. Giovanni and S. Psarakis, *Monitoring the coefficient of variation using EWMA charts*. *Journal of Quality Technology*, 43(3), 249 – 265, 2011.
- [20] Y.-M. Chu, A. M. Polansky and R. L. Mason, *Transforming Non-Normal Data to Normality in Statistical Process Control*. *Journal of Quality Technology*, 30(2), 133-141, 1998.
- [21] J. N. Deyer, *Evaluation of Control Charting Techniques for Monitoring Autocorrelated Processes*. Ph.D. Dissertation, University of Alabama, Tuscaloosa, AL, 1997.
- [22] J. N. Deyer, B. Adams and M. Conerly, *The Reverse Moving Average Control Chart for Monitoring Autocorrelated Processes*. *Journal of Quality Technology*, 35(2), 139-152, 2003.
- [23] E. Duclos, *Contribution à la Maîtrise Statistique des Procédés. Cas des procédés non normaux*. Thèse de doctorat à l'École Supérieure d'Ingénieurs d'Annecy (ESIA) – Université de Savoie, 1997.
- [24] J. R. Fricker, M. C. Knitt and C. X. Hu, *Comparing Directionally Sensitive MCUSUM and MEWMA Procedures with Application to Biosurveillance*. *Quality Engineering*, 20(4), 478 — 494, 2008.
- [25] F. W. Faltin, C. Mastrangelo, G. Runger and T. Ryan, *Considerations in the Monitoring of Autocorrelated and Independent Data*. *Journal of Quality Technology*, 29(2), 131-133, 1997.
- [26] F. W. Faltin and W. T. Tucker, *On-Line Quality Control for the Factory of the 1990's and Beyond*. Dans J. Keats, & D. C. Montgomery, *Statistical Process Control In Manufacturing*. New York, NY.: Marcel-Dekker, 1991.
- [27] J. Fu, F. Spiring and H. Xie, *On the average run lengths of quality control schemes using a Markov chain approach*. *Statistics and Probability Letters*, 56(4), 369-380, 2002.
- [28] F. F. Gan, *Design of Optimal Exponential CUSUM Charts*. *Journal of Quality Technology*, 26, 109–124, 1994.
- [29] F. F. Gan, *Designs of One- and Two-Sided Exponential EWMA Charts*. *Journal of Quality Technology*, 30, 55–69, 1998.
- [30] F. F. Gan and K. P. Choi, *Computing Average Run Length for Exponential CUSUM Schemes*. *Journal of Quality Technology*, 26, 134–139, 1994.
- [31] F. A. Graybill, *The Theory and Applications of the Linear Model*. London: Duxbury Press, 1976.
- [32] W. Jiang, *Multivariate Control Charts for Monitoring Autocorrelated Processes*. *Journal of Quality Technology*, 36(4), 367-379, 2004.
- [33] W. Jiang and K.-L. Tsui, *SPC Monitoring of MMSE- and PI-Controlled Processes*. *Journal of Quality Technology*, 34(4), 384-398, 2002.
- [34] W. Jiang, K.-L. Tsui and W. H. Woodall *A New SPC Monitoring Method: the ARMA Chart*. *Technometrics*, 42, 399–410, 2000.
- [35] J. A. John and N. R. Draper, *An alternative family of transformations*. *Applied Statistics*, 29, 190-197, 1980.

- [36] T. J. Harris and W. H. Ross, Statistical Process Control Procedures for Correlated Observations. *The Canadian Journal of Chemical Engineering*, 69, 48-57, 1991.
- [37] E. Hong, C. Kang, J. W. Baek and H. Kang, Development of CV Control Chart Using EWMA Technique. *Journal of the Society of Korea Industrial and Systems Engineering*, 31(4), 114-120, 2008.
- [38] N. L. Johnson, Systems of Frequency Curves Generated by Methods of Translation. *Biometrika*, 36, 149-176, 1949.
- [39] C. W. Kang, M. S. Lee, Y. J. Seong and D. M. Hawkins, A control chart for the coefficient of variation. *Journal of Quality Technology*, 39(2), 151-158, 2007.
- [40] B. Kim and G. S. May, An Optimal Neural Network Model for Plasma Etching. *IEEE Transactions on Semiconductor Manufacturing*, 7, 12–21, 1994.
- [41] H. Kramer and W. Schmid, Ewma charts for multivariate time series. *Sequential Analysis: Design Methods and Applications*, 16 (2), 131-154, 1997.
- [42] H. Kramer and W. Schmid, The Influence of Parameter Estimation on the ARL of Shewhart-Type Charts for Time Series. *Statistical Papers*, 41, 173-196, 2000.
- [43] Y. C. Lin and C. Y. Chou, On the design of variable sample size and sampling intervals X-bar charts under non-normality. *International Journal of Production Economics* 96: 249–261, 2005.
- [44] W. S. W. Lin and B. M. Adams, Combined Control Charts for Forecast-Based Monitoring Schemes. *Journal of Quality Technology* 28, pp. 289–302, 1996.
- [45] M. T. Longnecker and R. T. Rayan, Charting Correlated Process Data. Technical Report No. 166, Department of Statistics, Texas A & M University, College Station, TX, 1992.
- [46] C.-H. Lu and M. J. Raynolds, EWMA Control Charts for Monitoring the Mean of Autocorrelated Processes. *Journal of Quality Technology*, 31(2), 166-188, 1999.a.
- [47] C.-H. Lu and M. J. Raynolds, Control Charts for Monitoring the Mean and Variance of Autocorrelated Processes. *Journal of Quality Technology*, 31(3), 259-274, 1999.b.
- [48] C.-H. Lu and M. J. Raynolds, Cusum Charts For Monitoring An Autocorrelated Process. *Journal of Quality Technology*, 33(3), 316-334, 2011.
- [49] J. M. Lucas, Counted Data CUSUM's. *Technometrics*, 27, 129-144, 1985.
- [50] B. F. Manly, Exponential data transformation. *The Statistician*, 25, 37-42, 1976.
- [51] R. L. Mason and J. C. Young, The effect of dependent observations on process control. *Quality Progress* (4), 70-72, 2008.
- [52] D. C. Montgomery, *Introduction to Statistical Quality Control* (5th Edition). New York: John Wiley & Sons Ltd., 2005.
- [53] D. C. Montgomery and C. M. Mastrangelo, Some Statistical Process Control Methods for Autocorrelated Data. *Journal of Quality Technology*, 23, 179-193, 1991.
- [54] R.R. Mortel and G.C. Runge, Statistical Process Control of Multiple Stream Process. *Journal of Quality Technology*, 27 (1), 1995.
- [55] L. S. Nelson, A Control Chart for Parts-per-Million Nonconforming Items. *Journal of Quality Technology*(26), 239–240, 1994.
- [56] B. D. Notohardjono and D. S. Ermer, Time Series Control Charts for Correlated and Contaminated Data. *Journal of Engineering for Industry*, 108, 219–226, 1986.
- [57] C. S. Padgett, L. A. Thombs and W. J. Padgett, On the a-risks for Shewhart Control Charts. *Communications in Statistics-Simulation and Computation*, 21, 1125-1147, 1992.
- [58] A. M. Polansky, Y.-M. Chu and R. L. Mason, An Algorithm for Fitting Johnson Transformations to Non-normal Data. *Journal of Quality Technology*, 31(3), 345-350, 1999.
- [59] M. R. Reynolds, J. C. Arnold and J. W. Baik, Variable Sampling Interval X Charts in the Presence of Correlation. *Journal of Quality Technology*, 28, 12-30, 1996.
- [60] G. C. Runger, T. Willemain and S. Prabhu, Average Run Lengths for CUSUM Control Charts Applied to Residuals. *Communications in Statistics- Theory and Methods*, 24, 273-282, 1995.
- [61] E. Sachs, A. Hu and A. Ingolfsson, Run by run process control: combining SPC and feedback control. *Semiconductor Manufacturing, IEEE Transactions* 8 (1), 26-43, 1995.

- [62] R. M. Sakia, The Box-Cox transformation technique: a review. *The Statistician*, 41, 169-178, 1992.
- [63] E. G. Schilling and P. R. Nelson, The Effect of Non-Normality on the Control Limits of Charts. *Journal of Quality Technology*, 8, 183-188, 1976.
- [64] W. Schmid, CUSUM Control Schemes for Gaussian Processes. *Statistical Papers*, 38, 191-217, 1997.a.
- [65] W. Schmid, On EWMA Charts for Time Series. Vol. *Frontiers of Statistical Quality Control*, H. H. J. Lenz and P.-Th. Wilrich. Physica-Verlag, Ed., 1997.b.
- [66] W. Schmid and A. Schone, Some Properties of the EWMA Control Chart in the Presence of Autocorrelation. *Annals of Statistics*, 25, 1277-1283, 1997.
- [67] L. Shu, W. Jiang and K.-L. Tsui, A Weighted Cusum Chart for Detecting Patterned Mean Shifts. *Journal of Quality Technology*, 40, 194–213, 2008.
- [68] L. Shu, W. Jiang and K.-L. Tsui, A Comparison of Weighted CUSUM Procedures that Account for Monotone Changes in Population Size. *Statistics in Medicine*, 2011.
- [69] A. E. Smith, Predicting Product Quality with Back-propagation: A Thermoplastic Injection Molding Case Study. *International Journal of Advanced Manufacturing Technology*, 8, 252–257, 1993.
- [70] R. S. Sparks, CUSUM Charts for Signaling Varying Location Shifts. *Journal of Quality Technology*, 32, 157–171, 2000.
- [71] C. Superville and B. Adams, An Evaluation of Forecast-Based Quality Control Schemes. *Communications in Statistics: Simulation and Computation*, 23, 645–661, 1994.
- [72] D. Timmer, J. Pignatiello and M. Longnecker, The Development and Evaluation of CUSUM-Based Control Charts for an AR(l) Process. *IIE Transactions*, 30, 525-534, 1998.
- [73] F. Tsung, J. Shi and C. F. Wu, Joint Monitoring of PID-Controlled Processes. *Journal of Quality Technology*, 31, 275–285, 1999.
- [74] F. Tsung and K.-L. Tsui, A Mean Shift Pattern Study on Integration of SPC and APC for Process Monitoring. *IIE Transactions*, 2001.
- [75] F. Tsung and K.-L. Tsui, A Mean Shift Pattern Study on Integration of SPC and APC for Process Monitoring. *IIE Transactions*, 35, 231-242, 2003.
- [76] L. N. Vanbrackle and M. R. Reynolds, EWMA and CUSUM Control Charts in the Presence of Correlation. *Communications in Statistics-Simulation and Computation*, 26, 979-1008, 1997.b.
- [77] S. A. Vander Weil, Modeling Processes That Wander Using Moving Average Models. *Technometrics*, 38, 139- 151, 1996.
- [78] S. Vardeman and D. Ray, Average Run Lengths for CUSUM Schemes when Observations are Exponentially Distributed. *Technometrics*, 27, 145-150, 1985.
- [79] D. G. Wardell, H. Moskowitz and R. D. Plante, Control Charts in the Presence of Data Correlation. *Management Science*, 38, 1084-1105, 1992.
- [80] D. G. Wardell, H. Moskowitz and R. D. Plante, Run Length Distributions of Special-Cause Control Charts for Correlated Processes. *Technometrics*, 36, 3-17, 1994.
- [81] Q. Xia, M. Rao, X. Shan and H. Shu, Adaptive Control of a Paperboard Machine. *Pulp and Paper Canada*, 95, 51–55, 1994.
- [82] M. Xie, T. Goh and V. Kuralmani, *Statistical Models and Control Charts for High Quality Processes*. Boston: MA: Kluwer Academic Publisher, 2002.
- [83] Y. Xie, M. Xie and T. N. Goh, Two MEWMA Charts for Gumbel's Bivariate Exponential Distribution. *Journal of Quality Technology*, 43(1), 50-65, 2011.
- [84] E. Yashchin, Performance of CUSUM Control Schemes for Serially Correlated Observations. *Technometrics*, 35, pp. 37-52, 1993.
- [85] N. F. Zhang, Detection Capability of Residual Control Chart for Stationary Process Data. *Journal of Applied Statistics*, 24, 363-380, 1997.

[86] N. F. Zhang, A Statistical Control Chart for Stationary Process Data. *Technometrics* 40 (1), 24-38, 1998.

[87] Babus, Florina, Kobi, Abdessamad, Bacivarov, I.C, Bacivarov, Angelica, Control charts for non-Gaussian distributions, in *Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies III*, Proceedings SPIE, Volume: 6635 (2007), Pages: U134-U141, WOS:000248405900017, ISBN:978-0-8194-6779-9.