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DEVELOPMENT OF FUZZY CONTROL CHARTS FOR MONITORING MANUFACTURING PROCESS WITH UNCERTAIN AND VAGUE OBSERVATIONS

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Chairman: Assoc. Prof. Mohd Khairol Anuar Mohd Ariffin, PhD
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Quality characteristics measurement may include uncertainty due to randomness and fuzziness. Conventional control charts only consider the uncertainty due to randomness. Therefore, the application of fuzzy control charts becomes inevitable when quality characteristics are measured with vagueness, or affected by uncertainty, incomplete information or human subjectivity. To date, several researches have been directed to develop various types of fuzzy control charts, but the application of fuzzy $\bar{X}$-S control charts for monitoring mean and variability of the process is restricted to biased estimation of population standard deviation. A review of the literature on fuzzy control charts also shows that the application of fuzzy set theory to develop fuzzy cumulative sum control charts has not been considered.

In this research, unbiased estimation of population standard deviation for a triangular fuzzy random variable was introduced followed by the development of fuzzy $\bar{X}-S$ and FCUSUM control charts. Percentage of area as a methodology to determine the process state directly when the observations are in the form of triangular fuzzy random variable was developed and optimum γ-level when applying percentage of area to determine the process state in fuzzy $\bar{X}-S$ control charts for various sample was find using a simulation study based on average run length. Transformation techniques to determine the process state indirectly were modified and the optimum transformation techniques was introduced using a comparison study based on average run length when applying fuzzy $\bar{X}-S$ and FCUSUM charts. A simulation study was then made to verify the proposed technique by comparing its performance based on average run length with previous techniques in the literature. Finally, the

proposed fuzzy control charts were validated in a case study that monitored the cooking quality characteristic of chicken nuggets in B.A. Food Production Group and texture quality of noodle preparation in a food laboratory. The proposed fuzzy control charts detected the shift in the process immediately after changing the raw material (wheat) in preparing the noodles, while, conventional control could not detect this shift.

From this study, it was observed that the proposed fuzzy $\bar{X} - S$ and FCUSUM charts could improve the quality through reduction of the variability from 0.1% to as much as 68% compare to the conventional Shewhart control charts and previous techniques in the literature. Fuzzy median is the optimum transformation technique when applying fuzzy $\bar{X} - S$ control charts, while fuzzy median and fuzzy average are the optimum transformation techniques when applying FCUSUM control chart.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN CARTA KAWALAN SAMAR UNTUK PEMANTAUAN PROSES PEMBUATAN DENGAN PEMERHATIAN TIDAK PASTI DAN KABUR ROUTING

Oleh

SEYED MOJTABA ZABIHINPOUR JAHROMI

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Kualiti pengukuran ciri-ciri mungkin termasuk ketidakpastian kerana rambang dan kekaburan. Carta kawalan konvensional hanya mempertimbangkan ketidakpastian kerana rambang. Oleh itu, penggunaan carta kawalan kabur menjadi tidak dapat dielakkan apabila ciri-ciri kualiti diukur dengan kesamaran, atau terjejas oleh ketidaktentuan, maklumat yang tidak lengkap atau subjektiviti manusia. Setakat ini, beberapa kajian telah diarahkan untuk membangunkan pelbagai jenis carta kawalan kabur, tetapi pemakaian X kabur¯-S carta kawalan untuk memantau min dan kepelbagaian proses adalah terhad kepada anggaran berat sebelah standard sisihan populasi. Kajian semula kesusasteraan pada carta kawalan kabur juga menunjukkan bahawa penggunaan teori set kabur untuk membangunkan kabur terkumpul carta kawalan jumlah belum dipertimbangkan.

Dalam kajian ini, anggaran berat sebelah standard sisihan populasi bagi pembolehubah rawak kabur segi tiga telah diperkenalkan diikuti oleh pembangunan carta kawalan kabur dan FCUSUM. Peratus kawasan sebagai kaedah bagi menentukan keadaan proses yang secara langsung apabila pemerhatian adalah dalam bentuk segi tiga pembolehubah rawak kabur dibangunkan dan γ-tahap optimum apabila memohon peratusan kawasan bagi menentukan keadaan proses dalam carta kawalan kabur untuk pelbagai sampel telah mendapati menggunakan kajian simulasi berdasarkan purata panjang larian. Teknik transformasi bagi menentukan keadaan proses yang secara tidak langsung telah diubahsuai dan teknik transformasi optimum diperkenalkan menggunakan kajian perbandingan berdasarkan purata panjang larian apabila memohon carta kabur dan FCUSUM. Satu kajian simulasi kemudiannya dibuat untuk mengesahkan teknik yang dicadangkan dengan membandingkan prestasinya berdasarkan purata panjang larian dengan teknik sebelum ini dalam

kesusasteraan. Akhir sekali, carta kawalan kabur dicadangkan telah disahkan dalam satu kajian kes yang dipantau ciri kualiti memasak ketulan ayam dalam BA Makanan Kumpulan Pengeluaran dan kualiti tekstur penyediaan mi di makmal makanan. Carta kawalan kabur yang dicadangkan dikesan peralihan dalam proses dengan segera selepas menukar bahan mentah (gandum) dalam menyediakan mi, manakala, kawalan konvensional tidak dapat mengesan perubahan ini.

Dari kajian ini, ia telah diperhatikan bahawa carta kabur dan FCUSUM dicadangkan itu boleh meningkatkan kualiti melalui pengurangan kepelbagaian dari 0.1% kepada sebanyak 68% berbanding dengan konvensional carta kawalan Shewhart dan teknik sebelum ini dalam kesusasteraan. Median kabur adalah teknik transformasi yang optimum apabila memohon carta kawalan kabur, manakala median kabur dan purata kabur adalah teknik transformasi optimum apabila memohon carta kawalan FCUSUM.

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This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory committee were as follows:

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This is to confirm that:

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LIST OF ABBREVIATIONS

SPC	Statistical process control
DOE	Design of experiments
FRV	Fuzzy random variable
ARL	Average run length
CUSUM	Cumulative sum
PA	Percentage of area
OC	Operation characteristic

CHAPTER 1

INTRODUCTION

1.1. Background

A control chart is a graphical display of a quality characteristics measurement obtained from a random sample versus time or sample number. However, quality characteristics are sometimes measured with a combination of two kinds of uncertainty; randomness and fuzziness (Faraz and Shapiro, 2010). In practice, uncertainty due to randomness comes from random sampling and uncertainty due to fuzziness arises in many situations such as measurement error, costly skilled inspectors, sophisticated measurement instruments, environmental conditions and imprecise specification limits. Conventional control charts can properly handle the uncertainty due to randomness. Developing fuzzy control charts, which have the ability to handle both kinds of uncertainty in quality characteristics measurements have been considered by several researchers since 1990 (Wang & Raz, 1990; Raz & Wang, 1990; Kanagawa *et al.*, 1993; Cheng, 2005; Gulbay & Kahraman, 2004, 2006, 2007; Senturk & Erginel, 2009; Faraz & Shapiro, 2010; Alizadeh & Ghomi, 2011). Reviewing the literature on fuzzy control charts revealed the following problems.

1.2. Problem statement

When dealing with a fuzzy quality characteristic, it is necessary to monitor both the fuzzy mean and fuzzy variability. Faraz and Shapiro (2010) and Senturk and Erginel (2009) introduced a framework of fuzzy variable control charts, but their models were based on a biased estimation of population standard deviation. Biased estimation of population standard deviation has a negative impact on the control charts performance which is unable to detect shift immediately (Cryer and Ryan, 1990; Derman and Ross, 1995; Jensen *et al.*, 2006). For instance, if the sample size is 5, after 50 sample it could detect the shift (Faraz and Shapiro, 2010). This shift detection in certain condition is not acceptable. This is especially true for the food industry due to vagueness in quality characteristic. In order to avoid this, the author proposed to develop unbiased estimation of population standard deviation that would improve the quality detection process by integrating fuzzy in $\bar{X} - S$ control charts.

If small variations in quality control become an issue and sample size only consists of one unit, it is recommended to utilize a cumulative sum control chart (Hawkins and Olwell, 1998; Oakland, 2008). A cumulative sum control chart could incorporate information from several samples in order to detect small shifts in the process (Montgomery, 2009). Hence, for small variation control charts measured with the combination of randomness and fuzziness, it is necessary to apply a fuzzy cumulative sum (FCUSUM) control chart. FCUSUM can provide more information from the process by considering uncertainty due to fuzziness in addition to the uncertainty due to randomness. Up to date, the application of fuzzy set theory to construct fuzzy cumulative sum control charts has not been considered in quality control.

Determining the process state indirectly through transformation techniques and directly through percentage of area are two existed methodology to determine the process state when applying fuzzy control charts (Wang and Raz, 1990; Taleb and Limam, 2002; Gulbay and Kahraman, 2004, 2006, 2007; Erginel, 2008, Faraz and Shapiro, 2010; Senturk and Erginel, 2009, Alizadeh and Ghomi, 2011). The disadvantage of determination process using transformation techniques is that it is difficult for the users to select the best transformation technique that can detect shifts more quickly (Taleb and Limam, 2002; Alizadeh and Ghomi, 2011). In this research, the authors present the parametric equation of transformation techniques and find optimum transformation technique for determining the process state which resulted in minimum ARL by introducing the fuzzy control chart.

Selecting the optimum value for γ to determine the process state directly through percentage of area is very important (Gulbay and Kahraman, 2007). Increasing the value of γ will result in decreasing the risk of type I error but at the same time will increase the risk of type II error. Therefore, it is crucial to develop a theoretical or numerical method for γ-level determination so that the risk will be minimized. However, based on the literature there is little evidence of a logical procedure being used to decide the optimum value for γ. In this research, the authors develop percentage of area for proposed fuzzy control charts and find the optimum value for γ to determine the process state.

1.3. Research objective

The aim of this research is to develop fuzzy control charts for monitoring manufacturing processes with uncertain and vague observations.

The objectives of this research focus on four aspects:

I. To develop fuzzy $\bar{X}-S$ control charts based on the proposed unbiased estimation of standard deviation of a fuzzy random variable.
II. To develop fuzzy cumulative sum (*FCUSUM*) control charts.
III. To determine the process state for the developed fuzzy $\bar{X}-S$ and FCUSUM control charts.
IV. To verify and validate the proposed fuzzy $\bar{X}-S$ and FCUSUM control charts.

The major body of this research consists of work to address these four aspects.

1.4. Scope of the research

This research is focused on construction, validation and implementing fuzzy $\bar{X}-S$ and FCUSUM control charts for monitoring product quality when uncertainties caused by fuzziness, imprecision, ambiguity and/or incomplete information in addition to the inherent uncertainties due to randomness emerge in quality characteristics measurements.

For this purpose, the principle of Shewhart control charts, CUSUM control chart and fuzzy random variable are applied to introduce an unbiased estimation of fuzzy population standard deviation and develop a mathematical model for the fuzzy $\bar{X}-S$ and FCUSUM control charts.

A simulation study was performed to compare and validate the proposed fuzzy control charts based on the average run length (ARL) as an important performance measurement of control charts. All of the simulation studies were developed through MATLAB release 2012a. The simulation model proposed by Semnani and Moghadam (2013) was used for generating the fuzzy random variable. Repeated measures ANOVA, independent-sample t-test and paired-sample t-test were utilized to compare the proposed approach to other similar approaches.

Finally, a case study on the food industry was applied to validate the model. Process parameters in food processing are mostly physical, physico-chemical and bio-chemical, whereby the uncertainty, ambiguity and fuzziness are obviously associated with such measurements. For example, texture, porosity or color, are the most important quality parameters in food industries, which always are measured with fuzziness. In this research, the texture of noodles has been selected and measured through the texture analysis to validate the model. The texture quality of partially cooked noodles was determined by compression test (Lim, 2006) with some modifications using a texture profile analyzer (TA-TX2, Stable Micro Systems, Ltd., Surrey, UK). Proposed fuzzy control charts could also be applied in other industries, where the quality characteristics are measured with the combination of randomness and fuzziness.

1.5. Research contributions

This research provided a mathematical equation for calculating the unbiased estimation of population standard deviation when the observations are in the form of triangular fuzzy numbers, and then applied it to develop fuzzy $\bar{X}-S$ control charts and successfully evaluated. From this research, a new technique using fuzzy random variable for monitoring individual fuzzy observations when detecting small shifts has been developed and verified successfully. A logical procedure to decide on the γ-level and also to select the best transformation technique when determining the process state directly or indirectly was introduced.

1.6. Organization of the thesis

The thesis is organized in six chapters.

Chapter 2 reviews the literature related to Shewhart control charts, CUSUM control charts, performance measurement of control charts, fuzzy set theory, fuzzy random variable, and simulation of the fuzzy random variable. Furthermore, the works published in the area of fuzzy control charts are discussed.

Chapter 3 presents the methodology applied in this study to develop fuzzy $\bar{X}-S$ control charts. The development of unbiased estimation of population standard deviation and fuzzy $\bar{X}-S$ control charts are explained. The parametric equations of fuzzy transformation techniques for a triangular fuzzy random variable are modified. The procedure of specifying the process state through percentage of area is illustrated. Four different transformation techniques were modified and applied in fuzzy $\bar{X}-S$ control charts, and their performance was studied in a comparison study based on ARL by means of repeated measure ANOVA. A detailed study was performed to determine the optimum *accepted out-of-control level* (γ) for various sample sizes when applying percentage of area in fuzzy $\bar{X}-S$ control charts. A comparison study was done to validate the proposed mathematical model by comparing the proposed fuzzy control charts to other similar approaches based on ARL and by means of paired-sample t-test.

In chapter 4, FCUSUM control charts were developed based on the principle of fuzzy random variable and cumulative sum value. Four different transformation techniques were modified and applied in FCUSUM control charts, and their performance was studied in a comparison study based on ARL by means of repeated measure ANOVA. A comparison study was done to validate the proposed mathematical model by comparing the proposed fuzzy control charts to other similar approaches based on ARL and by means of independent-sample t-test.

In chapter 5, the proposed fuzzy control charts were validated in two case studies of the food industry. The first case study is about monitoring the cooking quality of chicken nugget producing in B.A. production group, located in Iran. The second case study considered monitoring the texture quality of noodle preparing in food laboratory.

Chapter 6 concludes this thesis with a discussion of the results of this research study. Suggestions on the scope of future research in this area are also outlined.

REFERENCES

Alipour, H., and Noorossana, R. (2010). Fuzzy multivariate exponentially weighted moving average control chart. *The International Journal of Advanced Manufacturing Technology, 48*(9), 1001-1007.

Alizadeh, H., and Ghomi, S. (2011). Fuzzy development of Mean and Range control charts using statistical properties of different representative values. *Journal of Intelligent and Fuzzy Systems, 22*(5), 253-265.

Alizadeh, H. M., and Ghomi, S. F. (2011). Fuzzy development of Mean and Range control charts using statistical properties of different representative values. *Journal of Intelligent and Fuzzy Systems, 22*(5), 253-265.

Alizadeh, H. M., Khamseh, A. R. A., and Ghomi, S. M. T. F. (2010). Fuzzy Development of Multivariate Variable Control Charts Using the Fuzzy Likelihood Ratio Test. *Scientia Iranica, 17*(2), 150-163.

Almond, R. G. (1995). Discussion: Fuzzy Logic: Better Science? Or Better Engineering? *Technometrics, 37*(3), 267-270.

Alwan, L. C. (1992). Effects of autocorrelation on control chart performance. *Communications in Statistics-Theory and Methods, 21*(4), 1025-1049.

Alwan, L. C., and Roberts, H. V. (1988). Time-series modeling for statistical process control. *Journal of Business & Economic Statistics, 6*(1), 87-95.

Amiri, A., and Allahyari, S. (2012). Change point estimation methods for control chart postsignal diagnostics: a literature review. *Quality and Reliability Engineering International, 28*(7), 673-685.

Amiri, A., Eyvazian, M., Zou, C., and Noorossana, R. (2012). A parameters reduction method for monitoring multiple linear regression profiles. *The International Journal of Advanced Manufacturing Technology, 58*(5-8), 621-629.

Amirzadeh, V., Mashinchi, M., and Parchami, A. (2009). Construction of p-charts using degree of nonconformity. *Information Sciences, 179*(1-2), 150-160.

Baudrit, C., Hélias, A., and Perrot, N. (2009). Joint treatment of imprecision and variability in food engineering: Application to cheese mass loss during ripening. *Journal of Food Engineering, 93*(3), 284-292. doi: 10.1016/j.jfoodeng.2009.01.031

Baykasoglu, A., Dereli, T., and Das, S. (2007). Project team selection using fuzzy optimization approach. *Cybernetics and Systems: An International Journal, 38*(2), 155-185.

Berthouex, P., Hunter, W., and Pallesen, L. (1978). Monitoring sewage treatment plants: some quality control aspects. *Journal of Quality Technology, 10*(4), 139-149.

Bezdek, J. C., Keller, J., Krisnapuram, R., and Pal, N. R. (2005). *Fuzzy models and algorithms for pattern recognition and image processing* (Vol. 4): Springer.

Black, G., Smith, J., and Wells, S. (2011). The impact of Weibull data and autocorrelation on the performance of the Shewhart and exponentially weighted moving average control charts. *International Journal of Industrial Engineering Computations, 2*(3), 575-582.

Blockley, D. I. (1980). *The nature of structural design and safety*: Ellis Horwood Chichester.

Bradshaw, C. W. (1983). A fuzzy set theoretic interpretation of economic control limits. *European Journal of Operational Research, 13*(4), 403-408.

Cao, H., and Chen, G. (1983). Some applications of fuzzy sets to meteorological forecasting. *Fuzzy Sets and Systems, 9*(1), 1-12.

Casella, G., and Berger, R. L. (2002). *Statistical inference* (Vol. 2): Duxbury Pacific Grove, CA.

Castagliola, P., Celano, G., Fichera, S., and Nenes, G. (2013). The variable sample size t control chart for monitoring short production runs. *The International Journal of Advanced Manufacturing Technology*, 1-14.

Castillo, E. D., Grayson, J. M., Montgomery, D. C., and Runger, G. C. (1996). A review of statistical process control techniques for short run manufacturing systems. *Communications in Statistics--Theory and Methods, 25*(11), 2723-2737.

Castillo, E. D., and Montgomery, D. C. (1994). Short-run statistical process control: Q-chart enhancements and alternative methods. *Quality and Reliability Engineering International, 10*(2), 87-97.

Celano, G., Castagliola, P., Trovato, E., and Fichera, S. (2011). Shewhart and EWMA t control charts for short production runs. *Quality and Reliability Engineering International, 27*(3), 313-326.

Chen, G. (1997). The mean and standard deviation of the run length distribution of X charts when control limits are estimated. *Statistica Sinica, 7*, 789-798.

Chen, K., Rys, M., and Lee, E. (2006). Modeling of thermal comfort in air conditioned rooms by fuzzy regression analysis. *Mathematical and computer modelling, 43*(7), 809-819.

Chen, Y. K., Chang, H. H., and Chiu, F. R. (2008). Optimization design of control charts based on minimax decision criterion and fuzzy process shifts. *Expert Systems with Applications*, *35*(1-2), 207-213.

Colubi, A., Fernández-García, C., and Gil, M. Á. (2002). Simulation of random fuzzy variables: an empirical approach to statistical/probabilistic studies with fuzzy experimental data. *Fuzzy Systems, IEEE Transactions on, 10*(3), 384-390.

Couso, I., and Dubois, D. (2009). On the variability of the concept of variance for fuzzy random variables. *Fuzzy Systems, IEEE Transactions on, 17*(5), 1070-1080.

Couso, I., Dubois, D., Montes, S., and Sánchez, L. (2007). *On various definitions of the variance of a fuzzy random variable.* Paper presented at the Fifth International Symposium on Imprecise Probabilities: Theory and Applications (ISIPTA 07) Prague (Czech Republic).

Crosier, R. B. (1988). Multivariate generalizations of cumulative sum quality-control schemes. *Technometrics, 30*(3), 291-303.

Crowder, S. V. (1992). An SPC model for short production runs: minimizing expected cost. *Technometrics, 34*(1), 64-73.

Cruthis, E. N., and Rigdon, S. E. (1992). Comparing Two Estimates of the Variance to determine the Stability of a Process. *Quality Engineering, 5*(1), 67-74.

Cryer, J. D., and Ryan, T. P. (1990). The estimation of sigma for an X chart: MR| d2 or S| c4? *Journal of Quality Technology, 22*(3), 187-192.

Davidson, V., Brown, R., and Landman, J. (1999). Fuzzy control system for peanut roasting. *Journal of Food Engineering, 41*(3), 141-146.

Demirli, K., and Vijayakumar, S. (2010). Fuzzy logic based assignable cause diagnosis using control chart patterns. *Information Sciences, 180*(17), 3258-3272.

Derman, C., and Ross, S. (1995). An improved estimator of σ in quality control. *Probability in the Engineering and Informational Sciences, 9*(03), 411-415.

Diamond, P., and Kloeden, P. (1994). Metric Spaces of Fuzzy Sets. 1994: World Scientific, Singapore.

Dohnal, M., Vystrcil, J., Dohnalova, J., Marecek, K., Kvapilik, M., and Bures, P. (1993). Fuzzy food engineering. *Journal of Food Engineering, 19*(2), 171-201.

Dubois, D., and Prade, H. (1979). Fuzzy real algebra: some results. *Fuzzy Sets and Systems, 2*(4), 327-348.

Dubois, D., Prade, H. M., Farreny, H., Martin-Clouaire, R., and Testemale, C. (1988). *Possibility theory: an approach to computerized processing of uncertainty* (Vol. 2): Plenum press New York.

Duncan, A. (1950). A chi-square chart for controlling a set of percentages. *Industrial Quality Control, 7*, 11-15.

Duncan, A. J. (1956). The economic design of X charts used to maintain current control of a process. *Journal of the American Statistical Association, 51*(274), 228-242.

Duncan, A. J. (1986). *Quality control and industrial statistics*. Irwin: Homewood, IL: Richard D.

El-Midany, T. T., El-Baz, M., and Abd-Elwahed, M. (2010). A proposed framework for control chart pattern recognition in multivariate process using artificial neural networks. *Expert Systems with Applications, 37*(2), 1035-1042.

Erginel, N. (2008). Fuzzy individual and moving range control charts with α-cuts. *Journal of Intelligent & Fuzzy Systems, 19*(4), 373-383.

Ewan, W. D. (1963). When and how to use Cu-sum charts. *Technometrics, 5*(1), 1-22.

Faraz, A., Kazemzadeh, R. B., Moghadam, M. B., and Bazdar, A. (2010). Constructing a fuzzy Shewhart control chart for variables when uncertainty and randomness are combined. *Quality & Quantity, 44*(5), 905-914.

Faraz, A., and Saniga, E. (2012). Multiobjective Genetic Algorithm Approach to the Economic Statistical Design of Control Charts with an Application to X-bar and S2 Charts. *Quality and Reliability Engineering International*.

Faraz, A., and Shapiro, A. F. (2010). An application of fuzzy random variables to control charts. *Fuzzy sets and systems, 161*(20), 2684-2694.

Feng, Y., Hu, L., and Shu, H. (2001). The variance and covariance of fuzzy random variables and their applications. *Fuzzy Sets and Systems, 120*(3), 487-497.

Féron, R., and Fortet, R. (1976). *Théorie des probabilités: Ensembles aléatoires flous*: CR Acad Sc. Paris.

Firdevs Dogan, S., Sahin, S., and Sumnu, G. (2005). Effects of soy and rice flour addition on batter rheology and quality of deep-fat fried chicken nuggets. *Journal of Food Engineering, 71*(1), 127-132. doi: 10.1016/j.jfoodeng.2004.10.028

Gamble, M., Rice, P., and Selman, J. (1987). Relationship between oil uptake and moisture loss during frying of potato slices from cv Record UK tubers. *International Journal of Food Science & Technology, 22*(3), 233-241.

Gan, C.-Y., Ong, W.-H., Wong, L.-M., and Easa, A. M. (2009). Effects of ribose, microbial transglutaminase and soy protein isolate on physical properties and in-vitro starch digestibility of yellow noodles. *LWT-Food Science and Technology, 42*(1), 174-179.

Gan, F. (1991). An optimal design of CUSUM quality control charts. *Journal of Quality Technology, 23*(4).

Ghiasabadi, A., Noorossana, R., and Saghaei, A. (2013). Identifying change point of a non-random pattern on control chart using artificial neural networks. *The International Journal of Advanced Manufacturing Technology*, 1-8.

Ghosh, B., Reynolds Jr, M. R., and Yer, V. H. (1981). Shewhart X-charts with estimated process variance. *Communications in Statistics-Theory and Methods, 10*(18), 1797-1822.

Gil, M. Á., López-Díaz, M., and Ralescu, D. A. (2006). Overview on the development of fuzzy random variables. *Fuzzy Sets and Systems, 157*(19), 2546-2557.

Goguen, J. A. (1967). L-fuzzy sets. Journal of mathematical analysis and applications, 18(1), 145-174.

Goguen, J. A. (1969). The logic of inexact concepts. *Synthese, 19*(3), 325-373.

Gong, Z., and Wang, L. (2007). The numerical calculus of expectations of fuzzy random variables. *Fuzzy Sets and Systems, 158*(7), 722-738.

González-Rodríguez, G., Colubi, A., and Ángeles Gil, M. (2006). A fuzzy representation of random variables: an operational tool in exploratory analysis and hypothesis testing. *Computational statistics & data analysis, 51*(1), 163-176.

González-Rodríguez, G., Colubi, A., and Gil, M. Á. (2012). Fuzzy data treated as functional data: a one-way ANOVA test approach. *Computational statistics & data analysis, 56*(4), 943-955.

González-Rodríguez, G., Colubi, A., and Trutschnig, W. (2009). Simulation of fuzzy random variables. *Information Sciences, 179*(5), 642-653.

Grzegorzewski, P., and Hryniewicz, O. (2000). Soft methods in statistical quality control. *Control and Cybernetics, 29*(1), 119-140.

Gulbay, M., and Kahraman, C. (2004). α-Cut fuzzy control charts for linguistic data. *International Journal of Intelligent Systems, 19*(12), 1173-1195.

Gulbay, M., and Kahraman, C. (2006). Development of fuzzy process control charts and fuzzy unnatural pattern analyses. *Computational statistics & data analysis, 51*(1), 434-451.

Gulbay, M., and Kahraman, C. (2007). An alternative approach to fuzzy control charts: Direct fuzzy approach. *Information Sciences, 177*(6), 1463-1480.

Gupta, S., Montgomery, D., and Woodall, W. (2006). Performance evaluation of two methods for online monitoring of linear calibration profiles. *International Journal of Production Research*, *44*(10), 1927-1942.

Gwee, B., Lim, M., and Soong, B. (1996). Self-adjusting diagnostic system for the manufacture of crystal resonators. *Industry Applications, IEEE Transactions on, 32*(1), 73-79.

Harris, T. J., and Ross, W. H. (1991). Statistical process control procedures for correlated observations. *The Canadian Journal of Chemical Engineering*, *69*(1), 48-57.

Hawkins, D. M. (1981). A CUSUM for a scale parameter. *Journal of Quality Technology, 13*(4), 228-235.

Hawkins, D. M. (1987). Self-starting CUSUM charts for location and scale. *The Statistician*, 299-316.

Hawkins, D. M. (1991). Multivariate Quality Control Based on Regression-Adiusted Variables. *Technometrics, 33*(1), 61-75.

Hawkins, D. M. (1993a). Cumulative sum control charting: an underutilized SPC tool. *Quality Engineering, 5*(3), 463-477.

Hawkins, D. M. (1993b). Regression adjustment for variables in multivariate quality control. *Journal of Quality Technology*, *25*(3), 170-182.

Hawkins, D. M., and Olwell, D. H. (1998). *Cumulative sum charts and charting for quality improvement*. New York, NY: Springer.

Hicks, C. (1955). Some applications of hotelling's T2. *Industrial Quality Control, 11*, 27-39.

Ho, C., and Case, K. (1994). Economic design of control charts: a literature review for 1981-1991. *Journal of Quality Technology, 26*(1).

Hoppner, J., and Wolff, H. (1995). *The Design of a Fuzzy Shewhart Control Chart*: Inst. fÌ¼r Angewandte Mathematik und Statistik.

Hotelling, H. (1947). Multivariate quality control. *Techniques of statistical analysis*.

Hryniewicz, O. (2003). User-preferred solutions of fuzzy optimization problems--an application in choosing user-preferred inspection intervals. *Fuzzy Sets and Systems, 137*(1), 101-111.

Hsieh, K. L., Tong, L. I., and Wang, M. C. (2007). The application of control chart for defects and defect clustering in IC manufacturing based on fuzzy theory. *Expert Systems with Applications, 32*(3), 765-776.

Hsu, H. M., and Chen, Y. K. (2001). A fuzzy reasoning based diagnosis system for X control charts. *Journal of Intelligent Manufacturing, 12*(1), 57-64.

Huang, Y.-C., and Lai, H.-M. (2010). Noodle quality affected by different cereal starches. *Journal of Food Engineering, 97*(2), 135-143. doi: 10.1016/j.jfoodeng.2009.10.002

Hubbard, M. R. (2003). Statistical quality control for food industry: Springer.

ISIRI. (2007). Ready to Use Chicken Nugget-Code of Practice Processing-Production and Packaging *9869* (1st ed.). Tehran: Institude of Standards and Industrial Research of Iran.

Jackson, J. E. (1956). Quality control methods for two related variables. *Industrial Quality Control, 12*(7), 4-8.

Jackson, J. E. (1959). Quality control methods for several related variables. *Technometrics, 1*(4), 359-377.

Jackson, J. E. (1985). Multivariate quality control. *Communications in Statistics-Theory and Methods, 14*(11), 2657-2688.

Jayasena, V., Leung, P., Nasar-Abbas, S. M., Palta, J., and Berger, J. (2008). *Development and quality evaluation of lupin-fortified instant noodles.* Paper presented at the Proceedings of the 12th International Lupin Conference: Lupins for Health and Wealth Fremantle, Western Australia: International Lupin Association, Canterbury, New Zealand.

Jensen, W. A., Jones-Farmer, L. A., Champ, C. W., and Woodall, W. H. (2006). Effects of parameter estimation on control chart properties: a literature review. *Journal of Quality Technology, 38*(4), 349-364.

Jin, J., and Shi, J. (2001). Automatic feature extraction of waveform signals for in-process diagnostic performance improvement. *Journal of Intelligent Manufacturing, 12*(3), 257-268.

Johnson, R. A., Miller, I., and Freund, J. E. (2011). *Probability and statistics for engineers*: Prentice-Hall.

Kahraman, C., Ertay, T., and Büyüközkan, G. (2006). A fuzzy optimization model for QFD planning process using analytic network approach. *European Journal of Operational Research, 171*(2), 390-411.

Kahraman, C., Tolga, E., and Ulukan, Z. (1995). Using triangular fuzzy numbers in the tests of control charts for unnatural patterns.

Kanagawa, A., Tamaki, F., and Ohta, H. (1993). Control charts for process average and variability based on linguistic data. *THE INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, 31*(4), 913-922.

Kandel, A., Martins, A., and Pacheco, R. (1995). Discussion: on the very real distinction between fuzzy and statistical methods. *Technometrics*, 276-281.

Keats, J. B., Del Castillo, E., Von Collani, E., and Saniga, E. M. (1997). Economic modeling for statistical process control. *Journal of Quality Technology, 29*(2), 144-147.

Kerre, E. E., and Nachtegael, M. (2000). *Fuzzy techniques in image processing* (Vol. 52): Springer.

Khashei, M., Zeinal Hamadani, A., and Bijari, M. (2012). A fuzzy intelligent approach to the classification problem in gene expression data analysis. *Knowledge-Based Systems, 27*, 465-474.

Khatri, Y., and Collins, R. (2007). Impact and status of HACCP in the Australian meat industry. *British Food Journal, 109*(5), 343-354.

Kim, K., Mahmoud, M. A., and Woodall, W. H. (2003). On the monitoring of linear profiles. *Journal of Quality Technology, 35*(3), 317-328.

Klement, E., Puri, M., and Ralescu, D. (1986). Limit theorems for fuzzy random variables. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences, 407*(1832), 171-182.

Körner, R. (1997). On the variance of fuzzy random variables. *Fuzzy Sets and Systems, 92*(1), 83-93.

Krätschmer, V. (2001). A unified approach to fuzzy random variables. *Fuzzy Sets and Systems, 123*(1), 1-9.

Kruse, R. (1987). On the variance of random sets. *Journal of mathematical analysis and applications*, *122*(2), 469-473.

Kruse, R., and Meyer, K. (1987). Statistics with vague data, Reidel Publ. *Co., Dordrecht*.

Kwakernaak, H. (1978). Fuzzy random variables—I. Definitions and theorems. *Information Sciences, 15*(1), 1-29.

Kwakernaak, H. (1979). Fuzzy random variables—II. Algorithms and examples for the discrete case. *Information Sciences, 17*(3), 253-278.

Latva-Kayra, K. (2001). TMP pulp quality observer. *Measurement, 29*(2), 147-156.

Laviolette, M. (1995). Bayesian monitoring of multinomial processes. *The Journal of the Industrial Mathematics Society, 45*, 41-49.

Laviolette, M., Seaman Jr, J. W., Barrett, J. D., and Woodall, W. H. (1995). A probabilistic and statistical view of fuzzy methods. *Technometrics*, 249-261.

Li, H., Liu, H., Gao, H., and Shi, P. (2012). Reliable fuzzy control for active suspension systems with actuator delay and fault. *Fuzzy Systems, IEEE Transactions on, 20*(2), 342-357.

Li, M., Luo, L.-J., Zhu, K.-X., Guo, X.-N., Peng, W., and Zhou, H.-M. (2012). Effect of vacuum mixing on the quality characteristics of fresh noodles. *Journal of Food Engineering, 110*(4), 525-531. doi: 10.1016/j.jfoodeng.2012.01.007

Li, Z., Dai, Y., and Wang, Z. (2013). Multivariate Change Point Control Chart Based on Data Depth for Phase I Analysis. *Communications in Statistics-Simulation and Computation*(just-accepted).

Lin, S.-Y., Guh, R.-S., and Shiue, Y.-R. (2011). Effective recognition of control chart patterns in autocorrelated data using a support vector machine based approach. *Computers & Industrial Engineering, 61*(4), 1123-1134.

Liu, Y.-K., and Liu, B. (2003). A class of fuzzy random optimization: expected value models. *Information Sciences, 155*(1), 89-102.

Loewe, R. (1993). Role of ingredients in batter systems. *Cereal foods world, 38*.

López-Diaz, M., and Gil, M. A. (1997). Constructive definitions of fuzzy random variables. *Statistics & probability letters, 36*(2), 135-143.

Lowry, C. A., and Montgomery, D. C. (1995). A review of multivariate control charts. *IIE Transactions, 27*(6), 800-810.

Lowry, C. A., Woodall, W. H., Champ, C. W., and Rigdon, S. E. (1992). A multivariate exponentially weighted moving average control chart. *Technometrics, 34*(1), 46-53.

Lubiano, M. a. A., Gil, M. a. A., López-Díaz, M., and López, M. a. T. (2000). The λ-mean squared dispersion associated with a fuzzy random variable. *Fuzzy Sets and Systems, 111*(3), 307-317.

Lucas, J. M. (1976). The design and use of V-mask control schemes. *Journal of Quality Technology, 8*(1).

Luning, P. A., Bango, L., Kussaga, J., Rovira, J., and Marcelis, W. J. (2008). Comprehensive analysis and differentiated assessment of food safety control systems: a diagnostic instrument. *Trends in Food Science & Technology, 19*(10), 522-534. doi: 10.1016/j.tifs.2008.03.005

M'Hallah, R., and Melloy, B. J. (2010). An adaptive control procedure for a fuzzy quality characteristic. *International Journal of Quality Engineering and Technology, 1*(3), 276-300.

M. Efstratiadis, A. C. K., Ioannis S. Arvanitoyannis, Michalis. (2000). Implementation of ISO 9000 to the food industry: an overview. *International journal of food sciences and nutrition, 51*(6), 459-473.

Mahmoud, M. A., Parker, P. A., Woodall, W. H., and Hawkins, D. M. (2007). A change point method for linear profile data. *Quality and Reliability Engineering International, 23*(2), 247-268.

Mamdani, E. H. (1977). Application of fuzzy logic to approximate reasoning using linguistic synthesis. *Computers, IEEE Transactions on, 100*(12), 1182-1191.

Maragah, H. D., and Woodall, W. H. (1992). The effect of autocorrelation on the retrospective X-chart. *Journal of Statistical Computation and Simulation, 40*(1-2), 29-42.

Marcucci, M. (1985). Monitoring multinomial processes. *Journal of Quality Technology, 17*(2), 86-91.

Mendenhall, W., Beaver, R., and Beaver, B. (2012). *Introduction to probability and statistics*: Cengage Learning.

Meyer, K. D., and Kruse, R. (1990). On calculating the covariance in the presence of vague data *Progress in fuzzy sets and systems* (pp. 125-133): Springer.

Mohamed, S., Hamid, N. A., and Hamid, M. A. (1998). Food components affecting the oil absorption and crispness of fried batter. *Journal of the Science of Food and Agriculture, 78*(1), 39-45.

Montgomery, D., Mastrangelo, C., Faltin, F. W., Woodall, W. H., MacGregor, J. F., and Ryan, T. P. (1991). Some statistical process control methods for autocorrelated data. *Journal of Quality Technology, 23*(3).

Montgomery, D. C. (2009). *introduction to statistical quality control*: john wiley & sons, new york, NY.

Montgomery, D. C., and Friedman, D. J. (1989). Statistical process control in a computer-integrated manufacturing environment. *Statistical Process Control in Automated Manufacturing*, 67-87.

Montgomery, D. C., and Wadsworth, H. (1972). *Some techniques for multivariate quality control applications.* Paper presented at the Technical Conference Transactions.

Moore, S. S., and Murphy, E. (2013). Process Visualization in Medical Device Manufacture: an Adaptation of Short Run SPC Techniques. *Quality Engineering*, *25*(3), 247-265.

Mortarino, C. (2010). Duncan's model for X-bar control charts: sensitivity analysis to input parameters. *Quality and Reliability Engineering International, 26*(1), 17-26.

Narukawa, Y., and Torra, V. (2007). Fuzzy measures and integrals in evaluation of strategies. *Information Sciences, 177*(21), 4686-4695.

Nelson, L. S. (1987). A chi-square control chart for several proportions. *Journal of Quality Technology, 19*(4), 229-231.

Noorossana, R., Eyvazian, M., Amiri, A., and Mahmoud, M. A. (2010). Statistical monitoring of multivariate multiple linear regression profiles in phase I with calibration application. *Quality and Reliability Engineering International, 26*(3), 291-303.

Noorossana, R., Farrokhi, M., and Saghaei, A. (2003). Using Neural Networks to Detect and Classify Out-of-control Signals in Autocorrelated Processes. *Quality and Reliability Engineering International, 19*(6), 493-504.

Oakland, J. S. (2008). *Statistical process control*: Routledge.

Page, E. (1954). Continuous inspection schemes. *Biometrika, 41*(1/2), 100-115.

Page, E. (1961). Cumulative sum charts. *Technometrics, 3*(1), 1-9.

Pedreschi, F., and Moyano, P. (2005). Effect of pre-drying on texture and oil uptake of potato chips. *LWT-Food Science and Technology, 38*(6), 599-604.

Perrot, N., Agioux, L., Ioannou, I., Mauris, G., Corrieu, G., and Trystram, G. (2004). Decision support system design using the operator skill to control cheese ripening—application of the fuzzy symbolic approach. *Journal of Food Engineering, 64*(3), 321-333.

Perrot, N., Ioannou, I., Allais, I., Curt, C., Hossenlopp, J., and Trystram, G. (2006). Fuzzy concepts applied to food product quality control: A review. *Fuzzy Sets and Systems, 157*(9), 1145-1154. doi: 10.1016/j.fss.2005.12.013

Pignatiello, J. J., and Runger, G. C. (1990). Comparisons of multivariate CUSUM charts. *Journal of Quality Technology, 22*(3), 173-186.

Pinthus, E., Weinberg, P., and Saguy, I. (1995). Oil uptake in deep fat frying as affected by porosity. *Journal of Food Science, 60*(4), 767-769.

Psarakis, S., Vyniou, A. K., and Castagliola, P. (2013). Some Recent Developments on the Effects of Parameter Estimation on Control Charts. *Quality and Reliability Engineering International*.

Puri, M. L., and Ralescu, D. A. (1986). Fuzzy random variables. *Journal of mathematical analysis and applications, 114*(2), 409-422.

Quesenberry, C. (1993). The effect of sample size on estimated limits for and X control charts. *Journal of Quality Technology, 25*(4).

Quesenberry, C. P. (1991a). SPC Q charts for a binomial parameter p: short or long runs. *Journal of Quality Technology, 23*(3), 239-246.

Quesenberry, C. P. (1991b). SPC Q charts for a Poisson parameter λ: short or lung runs. *Journal of Quality Technology, 23*(4), 296-303.

Quesenberry, C. P. (1991c). SPC Q charts for start-up processes and short or long runs. *Journal of Quality Technology, 23*(3), 213-224.

Raz, T., and Wang, J. H. (1990). Probabilistic and membership approaches in the construction of control charts for linguistic data. *Production Planning & Control, 1*(3), 147-157.

Ropkins, K., and Beck, A. J. (2000). Evaluation of worldwide approaches to the use of HACCP to control food safety. *Trends in Food Science & Technology, 11*(1), 10-21.

Ross, K. A., and Scanlon, M. G. (2004). A fracture mechanics analysis of the texture of fried potato crust. *Journal of Food Engineering, 62*(4), 417-423.

Saleh, N. A., Mahmoud, M. A., and Abdel-Salam, A. S. G. (2012). The performance of the adaptive exponentially weighted moving average control chart with estimated parameters. *Quality and Reliability Engineering International*.

Samuel, T. R., Pignatiello Jr, J. J., and Calvin, J. A. (1998). Identifying the time of a step change with X control charts. *Quality Engineering, 10*(3), 521-527.

Saniga, E. M. (1989). Economic statistical control-chart designs with an application to and R charts. *Technometrics, 31*(3), 313-320.

Semnani, M. M., and Moghadam, M. (2013). Simulation of LR Fuzzy Random Variables with Normal Distribution. *Middle-East Journal of Scientific Research, 15*(6), 768-779.

Senturk, S., and Erginel, N. (2009). Development of fuzzy and control charts using α-cuts. *Information Sciences, 179*(10), 1542-1551.

Senturk, S., and Erginel, N. (2009). Development of fuzzy X-R and X-S control charts using [alpha]-cuts. *Information Sciences, 179*(10), 1542-1551.

Şentürk, S., Erginel, N., Kaya, İ., and Kahraman, C. (2011). Design of Fuzzy ũ Control Charts. *Journal of Multiple-Valued Logic & Soft Computing, 17*.

Shal, E., and Morris, A. S. (2000). A fuzzy rule-based algorithm to improve the performance of statistical process control in quality systems. *Journal of Intelligent & Fuzzy Systems: Applications in Engineering and Technology, 9*(3), 4.

Shewhart, W. A. (1931). Economic control of quality of manufactured product.

Sousa, J. M., and Kaymak, U. (2002). *Fuzzy decision making in modeling and control* (Vol. 27): World Scientific Singapore.

Sullivan, J. H., and Woodall, W. H. (1996). A comparison of multivariate control charts for individual observations. *Journal of Quality Technology, 28*(4).

Sullivan, J. H., and Woodall, W. H. (1998). Adapting control charts for the preliminary analysis of multivariate observations. *Communications in Statistics-Simulation and Computation, 27*(4), 953-979.

Svoboda, L. (1991). Economic design of control charts: a review and literature survey (1979-1989). *Statistical Process Control in Manufacturing*, 331-330.

Taleb, H., and Limam, M. (2002). On fuzzy and probabilistic control charts. *International Journal of Production Research, 40*(12), 2849-2863.

Tanaka, K., and Sugeno, M. (1992). Stability analysis and design of fuzzy control systems. *Fuzzy Sets and Systems, 45*(2), 135-156.

Tracy, N., Young, J., and Mason, R. (1992). Multivariate control charts for individual observations. *Journal of Quality Technology, 24*(2).

Vargas N, J. A. (2003). Robust estimation in multivariate control charts for individual observations. *Journal of Quality Technology, 35*(4), 367-376.

Vila, M., and Delgado, M. (1983). On medical diagnosis using possibility measures. *Fuzzy Sets and Systems, 10*(1), 211-222.

Wang, J. H., and Raz, T. (1990). On the construction of control charts using linguistic variables. *The International Journal of Production Research, 28*(3), 477-487.

Wang, K., and Tsung, F. (2005). Using Profile Monitoring Techniques for a Data-rich Environment with Huge Sample Size. *Quality and Reliability Engineering International, 21*(7), 677-688.

Wang, L., and Rowlands, H. (2000). An approach of fuzzy logic evaluation and control in SPC. *Quality and Reliability Engineering International, 16*(2), 91.

Wang, R., and Chen, C. (1995). Economic statistical np-control chart designs based on fuzzy optimization. *International Journal of Quality & Reliability Management, 12*(1), 82-92.

Woodall, W., Tsui, K., and Tucker, G. (1997). A review of statistical and fuzzy control charts based on categorical data. *Frontiers in Statistical Quality Control, 5*, 83-89.

Woodall, W. H. (1986). Weaknesses of the economic design of control charts. *Technometrics, 28*(4), 408-409.

Woodall, W. H. (1987). Conflicts between Deming's philosophy and the economic design of control charts. *Frontiers in Statistical Quality Control, 3*, 242-248.

Woodall, W. H. (2007). Current research on profile monitoring. *Produção, 17*(3), 420-425.

Woodall, W. H., and Adams, B. M. (1993). The statistical design of CUSUM charts. *Quality Engineering, 5*(4), 559-570.

Woodall, W. H., Spitzner, D. J., Montgomery, D. C., and Gupta, S. (2004). Using control charts to monitor process and product quality profiles. *Journal of Quality Technology, 36*(3), 309-320.

Yager, R. R., and Zadeh, L. A. (1992). *An introduction to fuzzy logic applications in intelligent systems*: Kluwer Academic Publishers.

Yang, J. H., and Yang, M. S. (2005). A control chart pattern recognition system using a statistical correlation coefficient method. *Computers & Industrial Engineering, 48*(2), 205-221.

Yashchin, E. (1997). Change-point models in industrial applications. *Nonlinear Analysis: Theory, Methods & Applications, 30*(7), 3997-4006.

Zacks, S. (1991). Detection and change-point problems. *Handbook of sequential analysis*, 531-562.

Zadeh, L. A. (1965). Fuzzy sets. *Information and control, 8*(3), 338-353.

Zadeh, L. A. (1978). Fuzzy sets as a basis for a theory of possibility. *Fuzzy Sets and Systems*, *1*(1), 3-28.

Zarandi, M., Alaeddini, A., Turksen, I., and Ghazanfari, M. (2007). A neuro-fuzzy multi-objective design of Shewhart control charts. *Analysis and Design of Intelligent Systems using Soft Computing Techniques*, 842-852.

Zhang, J., Li, Z., and Wang, Z. (2010). A multivariate control chart for simultaneously monitoring process mean and variability. *Computational statistics & data analysis, 54*(10), 2244-2252.

Zhang, Q., and Litchfield, J. (1991). Applying fuzzy mathematics to products development and comparison. *Food technology*, *45*(7), 108-115.

Zhang, Q., Litchfield, J., and Bentsman, J. (1990). *Fuzzy predictive control system for corn quality control during drying.* Paper presented at the Food processing automation. Proceedings of the 1990 conference, Lexington, Kentucky, USA, 6-8 May 1990.

Zimmermann, H. J. (1996). *Fuzzy set theory--and its applications*: Kluwer Academic Publishers.

Zou, C., Zhang, Y., and Wang, Z. (2006). A control chart based on a change-point model for monitoring linear profiles. *IIE Transactions, 38*(12), 1093-1103.