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A COMPARISON OF VARIOUS RESIDUAL-BASED CONTROL CHARTS FOR DETECTING AND MONITORING ABNORMAL RIVER WATER LEVELS

(Perbandingan Pelbagai Carta Kawalan Berasaskan Residual untuk Mengesan dan Memantau Paras Air Sungai yang Tidak Normal)

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ABSTRACT

Malaysia experiences recurring floods with numerous issues that have surfaced annually. The rapid overflow of river water necessitates monitoring abnormal levels with a visualization tool as an alarm system. This study utilized a control chart approach to monitor the Klang River's water level in Taman Sri Muda for a signal of potential flood occurrence. Aiming to identify a suitable method, this study compares several residual-based control charts to achieve the purpose. Due to the autocorrelation issue that might cause false alarms, this study emphasizes the implementation of control charts based on residuals. The control chats were developed based on the residual observations obtained from the best time series model, ARIMA (1,1,1), involving the Mean Shewhart (I-Shewhart), Moving Average (MA), and Exponential Weighted Moving Average (EWMA). The results show that EWMA Residual with λ=0.05 is found to have the best performance compared to other control charts; followed by EWMA Residual with λ=0.1 and the I-Shewhart Residual with a detection score of 7.1, 3.84, and 3.56 percent respectively. The results revealed that the detected water level anomalies occurred dominantly in April, October, and November. The study emphasizes the efficiency of early signals produced by the control charts in detecting abnormal water levels by visualizing their occurrence and behaviour in the Klang River at the study location.

Keywords: anomaly; autocorrelation; control chart; floods; river water level

ABSTRAK

Malaysia mengalami banjir berulang dengan pelbagai isu yang timbul pada setiap tahun. Limpahan air sungai yang cepat memerlukan pemantauan tahap yang tidak normal dengan alat visualisasi sebagai sistem amaran. Kajian ini menggunakan pendekatan carta kawalan untuk memantau aras air Sungai Klang di Taman Sri Muda terhadap kemungkinan berlakunya banjir. Dengan matlamat untuk menghasilkan kaedah pengesanan yang sesuai, kajian ini membandingkan beberapa carta kawalan berasaskan data reja untuk mencapai tujuan ini. Disebabkan isu autokorelasi yang mungkin menyebabkan amaran palsu, kajian ini menekankan aplikasi carta kawalan yang berasaskan data reja sebagai teknik untuk membina carta kawalan kualiti. Carta kawalan dibangunkan berdasarkan data reja yang diperoleh daripada model siri masa terbaik iaitu ARIMA (1,1,1), meliputi Mean Shewhart (I-Shewhart), Moving Average (MA), dan Exponential Weighted Moving Average (EWMA). Hasil kajian menunjukkan carta kawalan reja EWMA dengan λ=0.05 didapati memberikan prestasi terbaik berbanding carta kawalan yang lain; diikuti oleh carta kawalan reja EWMA dengan λ=0.05 dan carta kawalan I-Shewhart dengan peratus skor pengenalpastian 7.1, 3.84 dan 3.56 masing-masing. Keputusan analisis mendapati anomali paras air sungai berlaku secara dominan dalam bulan April, Oktober, dan November. Kajian ini menekankan kecekapan isyarat awal yang dihasilkan oleh carta kawalan melalui visualisasi dan tingkahlaku paras air yang tidak normal di Sungai Klang di lokasi kajian.

Kata kunci: anomali; autokorelasi; carta kawalan; banjir; aras air Sungai

References

Ahmed A.N., Yafouz A., Birima A.H., Kisi O., Huang Y.F., Sherif M., Sefelnasr A. & El-Shafie A. 2022. Water level prediction using various machine learning algorithms: a case study of Durian Tunggal river, Malaysia. *Engineering Applications of Computational Fluid Mechanics* **16**(1): 422-440.

Asmat A., Wahid S.N.S. & Deni S.M. 2021. Identifying rainfall patterns using Fourier series: A case of daily rainfall data in Sarawak, Malaysia. *Journal of Physics: Conference Series* **1988**(1): 012086.

Bjelonja A. 2021. Comparative analysis of process control charts in order to define most efficient sampling frequency. Master Thesis. Lappeenranta–Lahti University of Technology.

Chen S. & Yu J. 2019. Deep recurrent neural network-based residual control chart for autocorrelated processes. *Quality and Reliability Engineering International* **35**(8): 2687-2708.

da Cunha Alves C., Konrath A.C., Henning E., Walter O.M.F.C., Paladini E.P., Oliveira T.A. & Oliveira A. 2019. The Mixed CUSUM-EWMA (MCE) control chart as a new alternative in the monitoring of a manufacturing process. *Brazilian Journal of Operations & Production Management* **16**(1): 1-13.

Gove A.D., Sadler R., Matsuki M., Archibald R., Pearse S. & Garkaklis M. 2013. Control charts for improved decisions in environmental management: a case study of catchment water supply in south-west Western Australia. *Ecological Management & Restoration* **14**(2): 127-134.

Grimshaw S.D. 2023. Constructing control charts for autocorrelated data using an exhaustive systematic samples pooled variance estimator. *Journal of Quality Technology* **55**(3): 349-365.

Horng Shiau J.J. & Ya-Chen H. 2005. Robustness of the EWMA control chart to non-normality for autocorrelated processes. *Quality Technology & Quantitative Management* **2**(2): 125-146.

Jafarian-Namin S., Fallahnezhad M.S., Tavakkoli-Moghaddam R., Salmasnia A. & Fatemi Ghomi S.M.T. 2021. An integrated quality, maintenance and production model based on the delayed monitoring under the ARMA control chart. *Journal of Statistical Computation and Simulation* **91**(13): 2645-2669.

Kadri F., Harrou F., Chaabane S., Sun Y. & Tahon C. 2016. Seasonal ARMA-based SPC charts for anomaly detection: Application to emergency department systems. *Neurocomputing* **173**: 2102-2114.

Lee K. & McGreevey C. 2002. Using control charts to assess performance measurement data. *The Joint Commission Journal on Quality Improvement* **28**(2): 90-101.

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

Lu C.W. & Reynolds Jr M.R. 1999. EWMA control charts for monitoring the mean of autocorrelated processes. *Journal of Quality Technology* **31**(2): 166-188.

Magaji A.A., Yahaya A. & Asiribo O.E. 2015. Assessing the effects of autocorrelation on the performance of statistical process control charts. *International Journal of mathematics and statistics invention* **3**(6): 15-23.

Mehmood R., Lee M.H., Baqar M. & Riaz M. 2020. Application of quality control charts for early detection of flood hazards. *Polish Journal of Environmental Studies* **29**(6): 4241-4248.

Montgomery D.C. 2019. *Introduction to Statistical Quality Control*. 8th Ed. Hoboken, NJ: John Wiley & Sons, Inc.

Nguyen H.D., Nadi A.A., Tran K.D., Castagliola P., Celano G. & Tran K.P. 2023. The Shewhart-type RZ control chart for monitoring the ratio of autocorrelated variables. *International Journal of Production Research* **61**(20): 6746-6771.

Ozilgen S., Bucak S. & Ozilgen M. 2013. Improvement of the safety of the red pepper spice with FMEA and post processing EWMA quality control charts. *Journal of Food Science and Technology* **50**(3): 466-476.

Riaz M., Abbas N. & Does R.J. 2011. Improving the performance of CUSUM charts. *Quality and Reliability Engineering International* **27**(4): 415-424.

Sabahno H. & Celano G. 2023. Monitoring the multivariate coefficient of variation in presence of autocorrelation with variable parameters control charts. *Quality Technology & Quantitative Management* **20**(2): 184-210.

Shaadan N., Jemain A.A., Latif M.T. & Deni S.M. 2015. Anomaly detection and assessment of PM10 functional data at several locations in the Klang Valley, Malaysia. *Atmospheric Pollution Research* **6**(2): 365-375.

Sharifuddin A.N., Ali H. & Rahman A.A. 2019. Exponential Weighted Moving Average (EWMA) control chart for air pollution index at SK Batu Muda, WP Kuala Lumpur. *Test Engineering and Management* **81**: 3944-3953.

Sheu W.T., Lu S.H. & Hsu Y.L. 2023. The generally weighted moving average control chart for monitoring the process mean of autocorrelated observations. *Annals of Operations Research* 1-29.

Shmueli, G. & Cohen, A. 2003. Run-length distribution for control charts with runs and scan rules. *Communication in Statistics-Theory and Methods* **32**(2): 475-495.

Silpakob K., Areepong Y., Sukparungsee S. & Sunthornwat R. 2023. A new modified EWMA control chart for monitoring processes involving autocorrelated data. *Intelligent Automation and Soft Computing* **36**(1): 281-298.

Yusuf N.M., Saudi A.S., Shafii N. & Roespinoedji D. 2020. Flood risk pattern recognition in Kinabatangan River, Sabah. *PalArch's Journal of Archaeology of Egypt/Egyptology* **17**(10): 4018-4025.

Zaidi F.S., Dai H.L., Imran M. & Tran K.P. 2023. Monitoring autocorrelated compositional data vectors using an enhanced residuals hotelling T2 control chart. *Computers & Industrial Engineering* **181**: 109280.

Zhou Z.G. & Tang P. 2016. Improving time series anomaly detection based on exponentially weighted moving average (EWMA) of season-trend model residuals. *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, pp. 3414-3417.

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