AN ARCHITECTURE FOR CLIENT-SERVER BASED CONTROL CHART PATTERNS RECOGNITION SYSTEM

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ABSTRACT

In any industrial process, regardless of how well designed or carefully maintained it is, a certain amount of process variation will always exist. One of the commonly used methods to monitor and diagnose the process variation is Statistical Process Control (SPC) chart. Some enhancements have been made by researchers to introduce the SPC chart system with patterns recognition feature. However, these SPC chart patterns recognition systems are limited to local and standalone system. There is a need to develop a client-server based system which would enable data sharing and remote access. The purpose of this study is to develop an architecture for a client-server based control chart patterns recognition (CCPR) system. Specific focus of this study is to investigate design and development aspects of the proposed client-server based CCPR system. A suitable client-server (CS) architecture and load passing procedure are investigated. Proper selection of CS architecture and load passing procedure are crucial to ensure each functional tier can be effectively integrated, system resources can be optimized and the system workload can be fairly distributed. The selection of design parameters are based on computer simulation studies using synthetic data. Candidate designs are evaluated based on calculation time, memory, processor usage and classification accuracy. The CS architecture with load passing procedure at server tier and patterns recognition at engine tier gave the best results among the investigated alternatives. This CS architecture is able to support more users and process more data. The load passing procedure with the combination of Nelson Run Rules and EWMA test resulted in better performance compared to Run Rules and CUSUM, CUSUM and EWMA and capable to prioritize the unstable processes to access the engine tier. The proposed CS architecture and load passing procedure can be used as a guideline for the development of a client-server based CCPR system.

Keywords: Control Chart Patterns Recognition, Client-Server, Load Passing.

ABSTRAK

Bagi sebarang proses industri, tidak mengambil kira bagaimana ianya direkabentuk atau dijaga dengan baik, sedikit sebanyak variasi proses akan berlaku. Salah satu cara untuk memerhatikan dan menganalisa variasi proses adalah dengan mengggunakan carta kawalan proses berstatistik. Beberapa pembaikan telah dilakukan oleh penyelidik dengan memperkenalkan carta kawalan yang mempunyai fungsi pengecam corak. Walau bagaimanapun, kebanyakan sistem pengecam corak carta kawalan masa kini hanya terhad kepada sistem setempat dan individu. Satu sistem pengecam corak carta kawalan yang berasaskan pelanggan and pelayan perlu dibangunkan. Tujuan utama kajian ini adalah membangunkan satu senibina untuk pembangunan sistem pengeram corak carta kawalan yang berasaskan pelanggan dan pelayan. Satu senibina pelanggan-pelayan dan penyimbang beban yang sesuai perlu dipilihkan. Pemilihan senibina pelanggan-pelayan yang sesuai adalah penting untuk memastikan setiap lapisan dalam sistem dapat diintegrasikan. Manakala pemilihan penyimbang beban yang sesuai dapat memastikan beban pemprosesan dapat dikongsikan ke semua lapisan sistem. Cara rekabentuk senibina ini adalah berasaskan simulasi komputer. Rekabentuk ini akan dinilai berasaskan masa pengiraan, penggunaan memori, pemproses dan ketepatan pengecaman. Senibina sistem dengan penyimbang beban berada di lapisan pelayan dan pegecam corak di lapisan enjin telah dipilih. Senibina ini dapat menyoking lebih ramai pengguna dan memproses lebih banyak data. Bagi penyimbang beban pula, teknik *Nelson Run Rules* dan EWMA telah dipilih berbanding dengan *Nelson Run Rules* dan CUSUM, CUSUM dan EWMA dan ia dapat mengutamakan proses yang tidak sihat untuk mencapai ke pengecam corak. Senibina ini boleh dijadikan sebagai panduan bagi pembangunan sistem pengecam corak carta kawalan yang berasaskan pelanggan-pelayan.

Kata Kunci : Pengecam Corak Carta Kawalan, Pelanggan-pelayan, Penyimbang Beban.

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CHAPTER 1

INTRODUCTION

1.1 Background of the problem

For the last ten years, business and manufacturing have shifted from local entities towards globalization entities. Quality has become one of the most important decision factors in making selection among worldwide competing products and service. To be a winner in this global competitive edge, the manufacturer needs to produce product with high quality within the shortest delivery time and lowest cost (Shariff, 2005).

There are several methods which can be used to improve product quality. One of the commonly used methods is the Statistical Process Control (SPC). SPC can be defined as using statistical techniques to improve and implement quality control. Since the introduction of SPC by Walter A Shewart in year 1920s, SPC have been widely adopted and applied in manufacturing industrial. It has been used for monitoring and diagnosis manufacturing process variation. SPC can be used to achieve process stability and improve process capability through the reduction of process variability.

Currently there are several computer aided SPC systems introduced by software vendors and researchers. These computer aided SPC systems can assist the manufacturers in automating the quality control functions. Nevertheless, these systems

still have some limitations. For example, the current computer aided SPC system only provides some basic functions such as automating the plotting of control charts. The most important part, the control chart data analysis still heavily relies on the operators and engineers. Usually, the operator and engineer are very busy with other production task and may not have sufficient time to perform analysis on the control chart data (Thompson *et al.*, 1998).

As noted earlier, the current computer aided SPC system are mainly based on standalone system. These standalone systems do not allow co-operation and information sharing. The accessibility of these control chart data should not be limited to the operator and engineer only. They should also be accessible to managers and customers. The control chart data can assist the manager or customer to have a better understanding on production line status and helps them in making better decision.

Beside that, the current computer aided SPC system does not allow remote access. It is only limited to one production area or factory side. The operator and engineer cannot access the status of production line remotely. Some managers and customers may not have quality engineering background. The burden of analysis the production data should not be assigned to them. The manager and customer maybe interested to know the result and status of the production line. An automated and computerized SPC system should assist them to diagnose the production line.

These are the quality control problems facing by the operator, engineer, manager and customer. So there is a need to develop a Client-Server based Control Chart Pattern Recognition (CCPR) system which would enable data sharing, remote access and intelligent diagnosis of the production line status.

1.2 Statement of the problem

Existing control chart pattern recognition systems are mainly local and standalone system. They do not provided data sharing and remote access. There is a need to enhance the standalone system towards a Client-server based control chart patterns recognition system. Several design issues need to be considered in developing such a client-server system.

The client-server based CCPR system needs to have a client-server architecture which can support multiple users simultaneously and better resource allocation. Inappropriate allocation of resources can cause certain functional tier become overloaded while the others are under loaded. An effective assignment of functional modules can enable the CCPR system to support multiple users simultaneously without additional computing resources.

Due to unique characteristics of SPC data stream, the load passing procedure as implemented in the voice and network packet system are not directly applicable in the CCPR system. A customized load passing procedure is needed for a client-server based CCPR system. Specifically, the load passing algorithm must be able to prioritize the client access based on the severity of process instability. Without a customized load passing procedure, the unstable process will have the same priority with stable process, which may result in delayed detection of unstable process data.

1.3 Purpose and Objective of the Study

The purpose of this study is to enhance the existing standalone control chart patterns recognition system towards a client-server based system which would enable efficient data sharing, remote access and intelligent diagnosis of production line.

The specific objectives of this study are:

i. To design a customized client and server architecture for a control chart patterns recognition system.
ii. To customize a load passing procedure for the client-server based control chart patterns recognition system.
iii. To provide a guideline for transforming the standalone system to a client-server based CCPR system.

1.4 Scope of the Study

Below are the scopes for this study:

i. Data stream for process variation are limited to univariate data plotted of Shewart $\bar{x}$ -chart.
ii. Design and evaluation are limited to the computer simulation studies. The published and real data are used for validation. .
iii. The simulation data arrive to the system with constant rate and speed.
iv. Different combination of computing resources are not taken into consideration. Fixed type and amount of computing resources are used.
v. Data encryption and network security issues are not included in this study.

1.5 Significance of the study

This client-server based CCPR system enables information sharing among different entities in the manufacturing system. By taking the advantageous of internet technology, this web-enabled system is accessible anytime, anywhere using a personal computer with Internet connection. Client-server based CCPR system makes the manager and customer feel easy and comfortable while interacting with the control chart system. The suitable client and server architecture ensures each functional tier can be successfully integrated. This architecture should be able to support multiple users simultaneously and ensure fair distribution of the system workload. With all these features, this client-server based control chart patterns recognition system could overcome the limitation of the standalone system. This study also provides a guideline for transformation from a standalone to the client-server based CCPR system.

1.6 Organization of the Thesis

This report is organized into seven chapters. Chapter 1 gives explanation on the background, statement of problem, objective, scope and significance of study. Chapter 2 presents literature review on board and focus area of the study. Techniques and technologies for the client-server based system development are presented here. Chapter 3 discusses the research methodology for this study. It begins with discussion on the problem situation, solution concept followed by the researches planning, source of data, equipment used and performance measurement methods. Chapter 4 describes the experiments and statistical analysis carried out to select a suitable client and server architecture. Chapter 5 describes the experiment and statistical analysis carried out for selecting a customized load passing procedure for the client-server based CCPR system. Chapter 6 presents the techniques and methods used for the prototype system implementation and validation. Lastly, Chapter 7 summarizes the research finding and concludes the study.

REFERENCES

Adnan Hassan (2002). *On-Line Recognition of Developing Control Chart Patterns* Universiti Teknologi Malaysia : Ph.D. Thesis.

Adnan Hassan, Mohd Shariff Nabi Baksh , Awaluddin Mohd Shaharoun and Hishamuddin Jamaluddin (2003). Improved SPC chart pattern recognition using statistical features. *International Journal of Production Research.* 41(7): 1587 – 1603.

Ahmad Tarmizi Idris (2005), " Penggunaan Run Rules dan Zone Test Untuk Mengesan Perubahan Anjakan Process Min", UTM Undergraduate Project.

Ahn, S. H. and Bharadwaj, B. (2002). Web-based design and manufacturing systems for automobile components: Architectures and usability studies. *International Journal of Computer Integrated Manufacturing*. 15(6): 555-563.

Alan, D. S. (2004). Empirical Exploration for a Product Data Management (PDM) System at a Major Telecommunications Firm. *Journal of Industrial Management & Data Systems*. 104 (6): 513-525.

Al-Assaf, Yusof. (2004). Recognition of control chart patterns using multi-resolution wavelets analysis and neural network. *Journal of Computers & Industrial Engineering*. 47: 17-29.

Alfredo, I. H., Fernando M., Guillermo, V., Gianfranco, P. and Guy C. ,(2001). Real-Time ECG Transmission Via Internet for Nonclinical Applications. *IEEE Transaction on Information Technology in BioMedicine*. 5: 253-257.

Andrew S. T. (2003). *Computer Networks.* New Jersey : Prentice Hall PTR.

Anon (2005). On-line support for engines. *Elsevier Engineering Information.* 206: 45-50

Anosike, A. and Zhang, Z. W. (2004). Dynamic integration of manufacturing systems' operations using intelligent agents, *Proceedings of the IASTED International Conference on Robotics and Applications.* 23-25 August 2004. CA : Acta Press. 107-112

Ashaab Ahmed (2007). Knowledge web-based system to support e-manufacturing of injection moulded products, *International Journal of Manufacturing Technology and Management*. 10 (4) : 400-418.

Azrina Lazim. (2008), "An Optimization of Plating Process Using DOE", UTM Thesis.

Bunthit, W. and Jonathan H (2007). Neural network classification of extended control chart patterns, *WSEAS Transactions on Computers.* 6(1): 160-166.

Bhavin V. M. and Zhou, Y. J. (2003). Middleware for Web-Based Manufacturing. *10th International Conference on High Performance Computing* 17-20 December 2003, India: Hyderabad. 80-90

Biehl, M., Prater E. and McIntyre J. R. (2004). Remote repair, diagnostics and maintenance. *Journal of Communications ACM*. 47(11): 100-106.

Carey, M.J., Kiernan, J., Shanmugasundaram J., Shekita,E.J. and Subramanian, S.N. (2000). Middleware for publishing object-relational data as XML documents. *Journal of Computer Data Modelling.* 15: 646–648.

Chad R. and Stephens J. (2004). *Beginning MySQL Database Design and Optimization: From Novice to Professional.* C.A.: Apress Inc.

Chatterjee, D., Tari, Z.and Zomaya,A. (2005). A Task-Based Adaptive TTL Approach for Web Server Load Balancing. *10th IEEE Symposium on Computers and Communications* : 877 - 884

Choudhury, A., Ramrattan, S. and Butt, S.(2003). Remote data collection and transfer as a teaching tool for process monitoring and control. *ASEE Annual Conference Proceedings* : 12843-12850

Claudio, G. A. (2003). Flexibility configurations for the supply chain management. *International Journal of Production Economics.* 85(2): 141–153.

Das, S.K., Sen, S.K. and Jayaram, R.(1997). A structured channel borrowing scheme for dynamic load balancing in cellular networks. *Proceedings of the 17th International Conference onDistributed Computing Systems.* 27-30 May 1997, 116 -123.

David A. and Michael (2005). *MySQL Reference Manual.* MySQL AB Group.

Deependra M. and Ganesh J. (2005). Web services and flexible business processes: towards the adaptive enterprise. *Journal of Information & Management*. 42: 921-933.

Dong, H.Z. and Liu, D.X. (2004). Fractal-agent based information security policies of Web-based collaborative manufacturing system. *Journal of Computer Integrated Manufacturing Systems*. 10: 166-171.

Doty, L.A. (1996). *Statistical Process Control.* 2nd ed. Industrial Press Inc.

Edmond C. and Yu K.M. (2007). A concurrency control model for PDM systems. *Journal of Computers in Industry* 58(8): 823-831.

Eugene L. G. and Richard S. L. (1996). *Statistical Process Control*. Seven Edition. McGraw-Hill Companies,Inc.

Fabisiak B. and Boleslaw T. (2003). Threats, vulnerabilities and exposures to networked manufacturing systems. *International Conference on Security and Management.* 2: 461-466.

Gauri, S. K. and Chakraborty, S. (2006). Feature-based recognition of control chart patterns. J*ournal of Computers and Industrial Engineering*. 51(4): 726-742.

Gillespie W. and Gordon M. (2003). Securing your process control networks. *Journal Advanstar Communications*. 20(7) : 14-23

Guh, R.S. and Tannock J.D.T. (1999). A neural network approach to characterize pattern parameters in process control charts. *Journal of Intelligent Manufacturing*. 10(5): 449-462

Guh , R.S. (2003). Integrating artificial intelligence into on-line statistical process control. *Journal of Quality and Reliability Engineering*. 19(1): 1 – 20

Guh, R. S. (2005). A hybrid learning-based model for on-line detection and analysis of control chart patterns. *Journal of Computers and Industrial Engineering.* 49(1): 35-62

Hartmut, E. and George, F.P. (2003). Client- Server and Gateway Systems for Remote Control. *Conference on Instrumentation and Measurement Techology*, 20-22 May 2003: 1428-1430

Hamada A. and Eric H. (2004). Emerging Client-Server and Ad-hoc approach Inter-vehicle communication Platform. *Vehicular Technology Conference*. 26-29 September 2004: 3955-3959

Han, S. and Oh, K.(2001). Web based rSPC(realtime Statistical Process Control) system supporting XML protocol. *IEEE International Symposium on Industrial Electronics Proceedings*, 12-16 June 2001 : 399-403

Hawkin, D. (1993). Cummulative Sum Control Charting : An Underutilized SPC Tool. *Journal of Quality Engineering*, 5(3): 463-477.

He, J.S. (2000). An architecture for wide area network load balancing. *IEEE International Conference on Communication*. 12-16 June 2001: 1169 – 1173

Helen L., Peter B. and Julian G. (2004).The Management of Product Data in an Integrated Aircraft Analysis Environment. *Journal of Computing and Information Science in Engineering* 4(4):359-364

Hui, C.C and Samuel, T.C(1997). Efficient Load Balancing in Interconnected LANs Using Group Communication. *Proceedings of the 17th International Conference on Distributed Computing Systems*. 27-30 May 1997:141 – 148

Hunter, J.S. (1986). The Exponentially Weighted Moving Average. *Journal of Quality Technologies*, 18 : 203-210.

Huang, G.Q. (2003). Collaborative Product Definition on The Internet : A Case Study. *Journal of Materials Processing Technology* 139(3): 51-57.

Huang, M.Y., Lin, Y, J, and Hu Xu (2004). A Framework for Web-based Product Data Management Using J2EE. *International Journal Advanced Manufacturing Technologies*, 24(12): 847-852.

Hwarng, H. B. (1997).Neural network approach to identifying cyclic behaviors on control charts: a comparative study. *International Journal of Systems Science.* 28(1): 99-112.

Hwarng, H.B. (2005). Simultaneous identification of mean shift and correlation change in AR(1) processes. *International Journal of Production Research.* 43(9): 1761 – 1783

Jay L. (2003). E-manufacturing – Fundamental, tools and transformation. J*ournal of Robotics and Computer-Integrated Manufacturing*. 19(6): 501-507

Jon, E., Warner G. and Rupert J. (2003). *Apache Tomcat Bible*. Wiley Publishing Inc.

Jun, S.H., Park, S.S., Ju, C.J. and Hyunbo C. (2003). CORBA-based integration framework for distributed shop floor control.*Journal of Computers & Industrial Engineering.* 45(3): 457-474

Lee, S.Y., Jang, J.S., Jung, K.H.and Choi, K.H. (2003). Web based SPC based on SNMP. *International Journal of Industrial Engineering*. 10(4): 497-503.

Li, W.D., Lu. W.F., Fuh, Y.H. and Wong, Y.S. (2004). Collaborative Computer Aided Design - Research and Development Status. *Computer Aided Design Journal.* 37(9): 931-940.

Liu, D., Du, J.H., Zhao, Y. and Song, N.L. (2004). Study on the time-delay of Internet-based industry process control system. *Proceedings of the World Congress on Intelligent Control and Automation*. 15-19 June 2004: 1376-1380.

Marin, G.A. (2006). Network security basics. *IEEE Journal of Security & Privacy*. 3(6) : 68-72.

Martin Z. (2006).eLearning in manufacturing processes: Implementation by integrated Web services and streaming services.*Proceedings - Advanced Industrial Conference on Telecommunications/Service Assurance* : 492-497

Marty H. and Larry B. (2004). *Core Servlets and Java Server Pages*. Second Edition. Prentice Hall PTR Book.

Michlin, Y., Sedan, B. and Ingman (2004). Reliability improvement of internet web servers through statistical process control. *IEEE Transactions on Reliability*. 53(4): 551-556

Ming R., Zhou J.M. and Yang H.M. (1998), Architecture of Integrated Distributed Intelligent Multimedia System for On-line Real-time Process Monitoring. *IEEE International Conference on Systems, Man, and Cybernetics*. 11-14 Oct. 1998. San Diego:IEEE, 1411 - 1416.

Ming X.Y., Yan J.Q., Lu W.F. and Song B. (2007), Mass production of tooling product families via modular feature-based design to manufacturing collaboration in PLM. *Journal of Intelligent Manufacturing*. 18 (1): 185-195.

Mohd Shariff Nabi Baksh. (2005). E-Manufacturing Addressing The Global Imperative. Syarahan Perdana Professor 20, Universiti Teknologi Malaysia.

Mohd. Soperi Mohd. Zahid, Jafri Mohd Rohani and Suraj Govindan (2000). Web-based Statistical Process Control (SPC): A Proposal. *Proceedings of the Second International Conference on Advanced Manufacturing Technology*. Johor Bahru .16-17 August 2000: 243-251.

Montgomery, D.C.(2004). *Introduction to Statistical Quality Control*. 5th Edition New York: Wiley.

Morita, T. and Hidaka T. (2004). Visual customer relationship management system that supports broadband network E-commerce. *IEICE Transactions on Communications*. 87(7): 1789-1796

Nelson, L.S. (1984). The Shewhart Control Chart Tests for Special Causes. *Journal of Quality Technology*. 16(4): 237-239

Nurmilaakso, J.M., Kettunen, J. and Seilonen, I. (2002). XML-based supply chain integration: a case study. *Journal of Integrated Manufacturing Systems* , 13(8): 586 - 595

Olaf K, Matthias O. B. and Roland S.(1998). Client - Server Based Mobile Robot Control. *IEEE/ASME Transactions on Mechatronics*. 3(2): 82-90

Ott, E.R. Schilling, E.G. and Neubauer, D.V. (2000). Process Quality Control, Trouble Shooting and Interpretation of Data. 3rd USA: McGraw-Hill.

Park, N.S. and Lee G.H (2006). Agent-based web services gateway. *Proceedings of SPIE - The International Society for Optical Engineering*. 6387 : 63870

Peter, M.R and Henry S. R. (2003). XML for scientific publishing. *Journal of OCLC Systems & Services.* 19: 162-169.

Pham, D.T. and Wani, M.A. (1997). Feature-based control chart pattern recognition. *International Journal of Production Research*. 35(7): 1975-1890.

Pham, D.T. and Wani, M.A. (1999). Efficient Control Chart Pattern Recognitino through Synergisticand Distributed Artificial Neural Network. *Proceedings of the Institution of Mechanical Engineer.* Part B, 213:157-169.

Rainer A. and Schahram D. (2005), Modeling and implementing medical Web services. *Journal of Data & Knowledge Engineering.* Vol. 55(2): 203-236

Rand Dixon (1996). *Client / Server and Open Systems: A Guide to the Technologies and the Tools that Make Them Work*, John Wiley & Sons, Inc.

Renaud and Paul, E. (1996). *Introduction to Client / Server System.* 2nd Edition. New York:Wiley Inc.

Robert, K. and Gordan, G. (2000). Balancing Web Server Workload. Conference on Knowledgebase-Based Intelligent System. 30 Aug 2000: 683-686

Rodolfo, E. H., Karina, C., Jose, E. and Jim, E. (2005). Networked sensing for high-speed machining processes based on CORBA. Journal of Sensors and Actuators. 119(2): 418-426.

Saygin C. (2004). A manufacturing laboratory for integrated hands-on applications. *ASEE 2004 Annual Conference and Exposition.* 20-23 Jun 2004: 9335-9349

Schubert Foo , Siu, C. H. and Peng, C. L. (2002). Web-based intelligent helpdesk-support environment. *International Journal of Systems Science*. 33(6): 389-402

Schmidt D.C, Levine, S. and Mungee, (2003). The design of the TAO real time object request broker. Journal of Computer Communication. 21(4): 294-324.

Sreenivas, G. and Zhang, A. D. (1996). NetMedia: A Client-Server Distributed Multimedia Environment. *International Workshop on Multimedia Database Management Systems*. 4-16 August 1996: 160-167

Sean S. and Teresa F. (2002). Virtual onsite support: using internet chat and remote control to improve customer service. Proceedings ACM SIGUCCS User Services Conference, US. 20-23 Nov 2002: 143 – 147

Silverston, L. (2001), *The Data Model Resource Book : A Library of Universal Data Models for All Enterprises*. 1st Edition. Wiley Publisher.

Shen, W.M., Wang, L.H. and Sherman, L. (2003).Distributed management, monitoring and control of manufacturing shop floors. *Proceedings of the ASME Design Engineering Technical Conference.* Chicago United States. 2-6 September 2003: 927-936

Sheremetov L. and Rocha, M. L. (2004). Collective Intelligence as Framework for Supply Chain Management. *International IEEE Conference Intellegent Systems*. Varna, Bulgaria. 22-24 Jun 2004: 417-422

Shi D. F. (2007). Development of an online machining process monitoring system: Application in hard turning. *Journal of Sensors and Actuators Physical*. 135 (2): 405-414.

Stavros Goutsos and Nikos Karacapilidis (2004). Enhanced supply chain management for e-business transactions. *Int. J. Production Economics.* 89(2): 141–152.

Stephen L. A. and Bruce R. (2003). XML for e-journal archiving. *Journal of OCLC Systems & Services.* 19: 155-161.

Subu M.P., Waerstad, H., and Cortvriendt L. (2003). From sensor to web using PLC with embedded web server for remote monitoring of processes. *Proceedings of IEEE Sensors 2003*. 22-24 Oct. 2003. IEEE, 966 – 969.

Swift, J. A. (1987). “Development of a Knowledge Based Expert System for Control Chart Pattern Recognition and Analysis.” Oklahoma State University: Ph.D. Dissertation.

Szabados, B., Hodaie, P., Lu, J. and Ahluwalia, K. (2003). Application of remote instrumentation to manufacturing. Instrumentation and Measurement Technology Conference 2003. IEEE, 1370 – 1375.

Tan W. F. (2004), “A Characterization of Solder Paste Printing Process Using DOE”, UTM Thesis.

Tserng, H. P., Dzeng, R.J., Lin, Y.C. and Lin, S.T. (2005). Mobile Construction Supply Chain Management Using PDA and Bar Codes. Blackwell Publishing Inc. 20: 242-264.

Thompson D.M., Homer, G.R. and Thelwall, M. (1998). An examination of the potential role of the Internet in distributed SPC and quality systems. Conference on the Control of Industrial Processes. 9-11 Feb 2004**:** 51 – 57.

Tony B. (2001). *Server Load Balancing*. First Edition. O’ Really

Toussaint, J. and Cheng, K. (2002). Design Agility and Manufacturing Responsiveness on the Web. *Journal of Integrated Manufacturing Systems*. 13(5): 328-339.

Vera d. C. , Luis F. D. , Adriano M. S. (2004). Comparative Study of The Performance of The CuSum and EWMA control charts. *Journal of Computers and Industrial Engineering*. 46(4): 707-724.

Vivek C., Bakore, A. and Eaves J. (2004). *Professional Apache Tomcat 5*. John Wiley & Sons, Inc.

Wang, M.D., Zhao, L.P. and Zhu, H.J. (2003). An application system of intelligent SPC based on the web. *Proceedings of the International Conference on Agile Manufacturing*. 4-6 Dec 2003:535-539

Wang, L.H., Samsa, R., Vernera, M. and Xib, F.F. (2003). Integrating Java 3D Model and Sensor Data for Remote Monitoring and Control. Journal of Robotics and Computer-Integrated Manufacturing. 19(2): 13-19

Wusteman J. (2003). XML and e-journals. *Journal of OCLC Systems & Services*. 19(1): 125 – 127.

Wu, Y. Z. and Yi, M.H.(2003). Efficient, Proximity-Aware Load Balancing for Structured P2P Systems. *Conference on Peer-to-Peer Computing*. 1-3 Sept. 2003: 105-106

Wetherill, G.B. and Brown, W.D. (1990). *Statistical Process Control: theory and practice*. First Edition. T.J.Pewaa (Padstow) Ltd.

William, S.E. and Jeffrey G.K. (2004). Improved Design Review Through Web Collaboration. *Journal of Management in Engineering*. 20(2): 55-60.

William Xu and, Tony Liu (2003). A Web-enabled PDM system in a Collaborative Design Environment. *Robotics and Computer-Integrated Manufacturing Journal*, 19(4): 315-328.

Yang, C.G. and Zhang, C.N.(2003). An XML-based administration method on role-based access control in the enterprise environment. *Journal of Information Management and Computer Security*. 11(5): 249-257.

Yang, H. and Xue, D. (2003). Recent Research on Developing Web-based Manufacturing System: A Review. *Int. J. Prod. Res*. 41(5) 3601-3629,

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

Yanmaz, E. and Tonguz, O.K. (2004), Dynamic load balancing performance in cellular networks with multiple traffic types. *IEEE 60th Vehicular Technology Conference*. 26-29 Sept. 2004 : 3491 – 3495

Zan, T, Fei, R.Y. and Wang, M. (2006). Research on abnormal pattern recognition for control chart based on neural network. *Journal of Beijing University of Technology*. 32 (8) :673-676.

Zahir Tari, Broberga, J., Albert,Y.Z. and Baldonic, R. (2005). A least flow-time first load sharing approach for distributed server farm. *Journal of Patallel Distribution Computer*, 65(7): 832-842.

Zeng, F. F. and Liu, Z. F. (2004). Model of Product Data Management and Its Application in PDM System. Journal of Huazhong University of Science. 32(10): 94-96.

Zhao, L.P. and Wang, M.D. (2004). Quality control system model based on web workflow. *Journal of Computer Integrated Manufacturing Systems*. 10(5): 502-507.

Zhao W.D., Hong Y., Ni, Z.H. and Xing Y. (2003). Research on remote monitoring and control of CNC system based on Web and field bus. *Journal of Southeast University (Natural Science Edition)*. 33(1): 45-48

Zheng, H. X. and Wan, Y. C. (2004). Distributed manufacturing system based on whole resource integration. *Journal of Computer Integrated Manufacturing Systems*. 10(4): 415-421.

Zheng, X.L., Deren, C. and Wu, Z.G. (2004). Secure strategy for networked manufacturing system. *IEEE International Conference on Systems, Man and Cyberneticz*. 10-13 Oct. 2004 : 4232-4237

Zhong, X., Rong, H. and Bhu, Y. (2004). Load balancing of DNS-based distributed Web server systems with page caching. *International Conference parallel and Distributed Systems*. 7-9 Jul 2004: 587 – 594.