


AUTOMATED LIGHT INTENSITY CONTROLLER USING FUZZY LOGIC

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AUTOMATED LIGHT INTENSITY CONTROLLER USING FUZZY LOGIC

This thesis is presented to the Graduate School
In fulfilment of the requirements for
Master of Science (Intelligence System)
Universiti Utara Malaysia

By

Morad Ali Ambarem Saleh (89745)



**KOLEJ SASTERA DAN SAINS
(College of Arts and Sciences)
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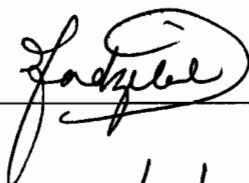
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ABSTRACT (MALAY)

Kajian ini menerangkan tentang pelaksanaan fuzzy logic dalam merekabentuk pengawal cahaya berautomatik. Pengawal cahaya fuzzy ini mengawal lampu-lampu berdasarkan kepada bilangan orang yang terdapat di dalam sesebuah bilik. Objektif utama pengawal cahaya ini adalah untuk menunjukkan bagaimana fuzzy logic boleh meminimumkan jumlah penggunaan bilangan lampu-lampu dan juga mengurangkan penggunaan tenaga elektrik. Di dalam kajian ini, pengawal fuzzy logic telah dilaksanakan dan diuji untuk meramal tingkah laku sesuatu pengawal di dalam suasana cahaya yang berbeza. Pengujian dilaksanakan dengan memantau fungsi keanggotaan parameter. Bagi pengawal lampu konvensional, perubahan lampu-lampu tersebut adalah mengikut penentuan daripada pengguna. Jika pengguna terlupa untuk memadamkan lampu, maka lampu tersebut akan kekal menyala. Walaupun adanya pengawal lampu berautomatik, namun kebanyakan sistem tersebut hanya boleh mengawal keadaan on dan off sesebuah lampu tanpa mampu untuk menerima input yang dinamik daripada pengguna. Fuzzy logic menawarkan kaedah yang lebih baik berbanding pengawal konvensional terutamanya di dalam kes pengiraan jumlah orang dan jumlah keamatan cahaya yang diperlukan. Di dalam kajian ini, fuzzy logic mempunyai keupayaan untuk membuat keputusan bagi menentukan jumlah keamatan cahaya yang diperlukan dengan mengawal bilangan lampu-lampu yang terdapat di dalam sesebuah bilik. Pengawasan ini adalah berdasarkan kepada bilangan orang yang keluar atau masuk dari bilik tersebut. Bagi pengawal lampu konvensional pula, ia tidak mempunyai keupayaan untuk menangani keadaan ini. Jika keamatan cahaya yang diperlukan berkeadaan sangat terang, adalah lebih praktikal untuk membiarkan lebih banyak lampu terpasang atau "on". Bagi kes ini, adalah sukar untuk membuat keputusan menggunakan kaedah konvensional berbanding menggunakan pengawal fuzzy logic. Pengawal fuzzy logic membantu memudahkan tugas di mana ia berupaya menentukan bilangan lampu yang diperlukan bagi kes di atas. Kajian ini telah mencapai objektifnya iaitu untuk merekabentuk sebuah sistem fuzzy logic yang disepadukan dengan litar perkakasan yang menggunakan fuzzy logic untuk mengawal keamatan cahaya di dalam sesebuah bilik. Di dalam kajian ini, kajian kes menunjukkan pengawal fuzzy logic merupakan satu kaedah alternatif yang sesuai untuk menggantikan kaedah pengawasan konvensional. Ini kerana pengawal fuzzy logic mampu mengurangkan penggunaan elektrik dan membantu membuat keputusan di dalam menentukan bilangan lampu yang perlu dinyalakan.

ABSTRACT (ENGLISH)

This study describes the implementation of fuzzy logic in designing fuzzy automated light controller. The fuzzy controller controls the number of lamps lighted up based on the number of people inside the room. Its main objective is to demonstrate how fuzzy logic can minimize the number of lamps used and therefore reduce the electricity consumption. In this study, fuzzy logic controller has been implemented and tested to predict the behaviour of the controller under different light conditions by monitoring the membership function parameters. In a conventional light controller, the lamps change according to user's specification. The light will remain on if the user forgets to switch off the light. Even if an automated light controller exist, at most the system can only be controlled as on and off without being able to adapt with dynamic inputs. Fuzzy logic offers a better method than conventional control methods, especially in the case of counting the number of people and how much the light intensity is needed. In this study, fuzzy logic has the ability to make decision as to how much the light intensity is needed by controlling the number of lamps in the room according to the number of people who have entered or left the room. On the other hand, the conventional light controller does not have the ability to solve this kind of issues. It would be more practical to let more lamps "on" if the light intensity needed is very bright. A conventional method controller for this decision is difficult to find while fuzzy logic controller simplifies the task. This study has achieved its objective, which is to design a fuzzy logic system integrated with hardware circuit of automated light controller using fuzzy logic to control light intensity in a room. In this study, tests cases have illustrated that fuzzy logic control method could be a suitable alternative method to conventional control methods that could save electricity consumption and offers ease of use to human being.

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CHAPTER ONE

INTRODUCTION

This section briefly presents the background, problem statement, objective, research question, significance and scope of study. The main idea of this study is to implement Fuzzy logic in lighting control and as an alternative method of conventional lighting method.

1.0 Background

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems. A control system combinations of components (electrical, mechanical, thermal, or hydraulic) that act together to maintain actual system performance close to a desired set of performance specifications. In recent years, control system dependability has received much attention with the increase of situations where the systems that are controlled by computer such as home control systems are used (Izumikawa *et al.* 2005). Neil (2004) defines control system as an interconnection of components to form a system configuration which will be provided or (supply) the required system response. Control is automatic unless if it is not accomplished by manual (human) effect. One of the most common home control systems is lighting control.

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6. REFERENCES

- Anderson, G., Zheng, U., Wyeth, R., Johnson, A. and Bissett, J. (2000). "A rough set/fuzzy logic based decision making system for medical applications", *International Journal of General Systems*, Vol. 29 No.6, pp.879-96.
- ApronixInc.(1996).WhyUseFuzzyLogic? <http://www.aptronix.com/file/whyfuzzy.htm>
- Automatic Lighting Control for Energy Savings. Adapted from B.C. Hydro. Guides to Energy Management. *GEM No. L108. January 1990. With permission from B.C. Hydro, Vancouver, British Columbia.*
- Awad, E. M. (1999). Building Expert System. *West Publishing Company, USA.*
- Brackney. L and Shoureshi. R. (2000). Fuzzy-Based Self-Organizing Control for Buildings System, *American Control Conference.*
- Chuen. C. E. (1990). Fuzzy Logic in Control Systems: Fuzzy Logic Controller-Part I. *IEEE Transaction on System. IEEE.*
- Cristina. C, Ricardo. T, Marley. M. R., Marco. A. C. (2002). Towards Evolvable Analog Fuzzy Logic Controllers.*IEEE.*
- Cziker. A., Chindris. M., Miron. A. (2007). Implementation of Fuzzy Logic in Daylighting Control. Intelligent Engineering Systems, *11th International Conference on 195 – 200. IEEE.*
- Cziker. A, Chindris. M and Miron. A (2007). Implementation of Fuzzy Logic in Daylighting Control. *International Conference on Intelligent Engineering Systems, IEEE.*
- Daniel. S & Alan. G. (2001). Synchronous Programming of Automatic Control Applications Using OCCAD and ESTEREL. *Proceedings of the 40th IEEE Conference on Decision and Control. Orlando, Florida, USA. IEEE.*

- Demiroren. A & Yesil. E. (2003). Automatic generation control with fuzzy logic controllers in the power system including SMES units. *ScienceDirect*. doi:10.1016/j.ijepes.10.016.
- Donna L. Hudson, Maurice and E. Cohen. (2007). Weighing Evidence in Decision Support Systems. Computers and Their Applications : 95-100.
- Francis Rubinstein, Michael Siminovitch, and Rudolph Verderber. (1993). Fifty Percent Energy Savings with Automatic Lighting Controls, *IEEE TRANSACTIONS*.
- Friedlob. G. T and Schleifer. L. L, (1999), Fuzzy Logic Application for Audit Risk and Uncertain. *Managing Auditing Journal*, 14(3), 127-135.
- Froschauer. R, Auinger. F & Grabmair. G. (2006). Automatic control application recovery in distributed IEC 61499 based automation and control systems. *Proceedings of the IEEE Workshop on Distributed Intelligent Systems: Collective Intelligence and Its Applications (DIS'06).IEEE* .
- Garibadi. J.M, (1997). Intelligent techniques for handling uncertainty in the assessment of neonatal outcome. *PHD Thesis, university of Plymouth*. UK.
- Garibaldi. J. M, and IFeachor. E. C. (1999). Application of simulated Annealing Fuzzy Model Tuning to UmbilicalCord Acid-base Interpretation, *IEEE Transaction on Fuzzy Systems*, Vol.7, NO.1.
- Godo, Ramon. L, Josep Puyol-Gruart, Carles. S, (2000). Renoir, Pneumon- IA and Terap- IA: three medical applications based on fuzzy logic. *Artificial Intelligence Research Institute (IIIA), Spanish Scientific Research Council (CSIC), Campus UAB, 08193 Bellaterra, Spain*.

Godo. L, Lopes de Mantaras. R, Payol-Gruart. J, and Siera. C, (2000), Renoir, Pneumom-IA and Terap-IA : three medicakapplications based on fuzzy logic. *Journal of Artificial Intelligence in Medical*, 21.pp.153-162.

Goonatilake and Khebbal(1995). *Intelligent Hybrid* (Editors). New York: John Wiley & Sons.

Gradojevic. N, Jing. Y and Garvelle. T. (2001). Neuro-Fuzzy Decision-making in Foreign Exchange Tradding and Other Application. *UBC Economics Depeartment*, Canada.

Hasilogu. A. S, Yavuz. U, Rezos. S, and Kaya. M. D. (2003). A Fuzzy Expert System for Produce Life Cycle Mnagement. *International XII, Turkish Symposium on Artificail Intelligence and Neural Networks*.

Heemin. P, Jeff. B & Mani. B. S. (2007). Design and Implementation of a Wireless Sensor Network for Intelligent Light Control. *Cambridge, Massachusetts, USA. ACM*.

Herrmann. C. S. (1995). A Hybrid Fuzzy-Neural Expert System for Diagnosis, In *proceedins of the International Joint Conference on Artificail intelligence (IJCAI)*. Montreal, Canada. Morgan Kaufman.

Microcontroller Datasheet. <http://cxem.net/doc/mc/at89c52.pdf>

Ilyas. E & Yunis. T. (2005). Fuzzy logic control to be conventional method. *ScienceDirect* .

Jason H. T. & Michael P. Y. (2003). Applying Fuzzy Logic to Medical Decision Making in the Intensive Care Unit, *American Journal of Respiratory and Critical Care Medicine*.

Jee. S., Koren. Y. (2004). Adaptive fuzzy logic controller for feed drives of a CNC machine tool. *Mechatronics* 14(3):299–326.

Joseph. B. (2006). Paradigm shift— an introduction to fuzzy logic. *IEEE*.

Kuo. K., and Lin. J. (2002). Fuzzy logic control for flexible link robot arm by singular perturbation approach. *Appl Soft Comput*.

Lefteri. H. T., Robert. E., Uhrig. (1997). Fuzzy Neural Approaches in Engineering. *Professional Reference and Trade Group*. 605 Third Avenue, New York, N.Y. 10158-0012

Liang. M., Yeap. T., Rahmati. S., and Han. Z. (2002). Fuzzy control of spindle power in end milling processes. *Int J Mach Tools Manufact* 42:1487–96.

Lin. J. C, and Shiffman. R. N, (1996), Operationalization of Clinical practice Guidelines Using Fuzzy Logic. *Center for Medical Informatics, Yale University School of Medicine, New Haven, Connecticut, USA*.

Lin F., Yang. S.c(2003). Adaptive fuzzy-logic velocity observer for servo motor drives. *Mechatronics* 13:229–41.

Lotfi A. Z. (1997). Toward a theory of fuzzy information granulation and its centrality in human reasoning and fuzzy logic. *Research supported in part by NASA Grant NCC 2-275, ONR Grant N00014-96-1-0556, LLNL Grant 442427-26449, ARO Grant DAAH 04-961-0341, and the BISC Program of UC Berkeley. ScienceDirect. Elsevier Science*.

Lotfi A. Z. (1984). "Making computers think like people," *I.E.E.E. Spectrum*.

Lotfi A. Z. (2004). Fuzzy Logic System: Origin, Concept, and Trends, *UC/Berkeley, University of California*.

- Mamdani EH.(1974). Application of fuzzy algorithms for control of simple dynamic plant. *Proc IEEE* 121(12):1585–8.
- Marks. L.A, Dunn. E.G, Keller. J.M & Godsey. L.D. (1995). Multiple criteria decision making (MCDM) using fuzzy logic: an innovative approach to sustainable agriculture, *Proceedings of ISUMA-NAFIPS, IEEE*.
- Mendel. J, (1995). Fuzzy Logic Systems for Engineering: *A Tutorial, In, Proc, of the IEEE, 38(3)*.
- Metin. A, Maurice. C, Donna. H. (1997). Fuzzy sets in life sciences, *Fuzzy Sets and Systems, Elsevier Science*.
- Metin , Ciresi, Gregory. (1997). Fuzzy logic in medical control applications. *Biomedical Engineering Applications, Basis Communications*. Vol 8. No 6 (1996) 471-487 [issn:10162356].
- Mohd. K. H., MohdAmraliah. M., and Ikmal. A. Jalal. (2003). Lighting Management System. *Student Conference on Research and Development (SCORED) Proceedings, Putrajaya, Malaysia*.
- Neil. A. D. (2004). Introduction to Control Systems. *University of Wisconsin-Madison*.
- Ojala. T, (1999), Neurofuzzy System in Control. *Master Science Thesis, Tampere University of Technology*.
- Philip. B. (2007). Fuzzy Logic Control of the Syrup Mixing Process in Beverage Production. *Leonardo Journal of Sciences. ISSN 1*.
- Radakovic. Z., Milosevic. V., and Radakovic. S. (2002). Application of temperature fuzzy controller in an indirect resistance furnace. *Appl Energy* 73:167–81.

- Roberto. S, Oscar. C, Patricia. M, Antonio. R & Oscar. M. (2006). Experimental study of intelligent controllers under uncertainty using type-1 and type-2 fuzzy logic. *ScienceDirect*.
- Shoureshi. R., Brackney. L, Kubota. N, and Batta. G. (2000). A modern control approach to active noise control,” *ASME J. Dynamic Syst., Measurement, Contr.*, vol. 115, pp. 673–678.
- Sulaiman. F, Ahmad. A & Kamarulzaman. M.S. (2006). Automated Fuzzy Logic Light Balanced Control Algorithm Implemented in Passive Optical Fiber Daylighting System. *AIML 06 International Conference, Sharm El Sheikh, Egypt*.
- Wang LX. (1994). Adaptive fuzzy systems and control: design and stability analysis. Englewood Cliffs, NJ: Prentice-Hall.
- Watson. I, (1998). CBR is a methodology not a technology. In, Research & Development in Expert Systems XV. Miles. R, Moulton. M, & Bramer. M, (Eds), pp. 213-223. *Springer, London. ISBN 1-85233-086-4*.
- Woo. Z., Chung. H., and Lin. J. (2000). A PID type fuzzy controller with self-tuning scaling factors. *Fuzzy Sets Syst* 115:321–6.
- Yager.R.R and Zadeh. L. A. (1992), An Introduction to Fuzzy Logic Application in Intelligent System. *Kluwer Academic Publisher: UAS*.
- Yu. I., Kazuhiro. Y., and Junji. H. (2005). Fault-Tolerant Control System of Flexible Arm for Sensor Fault by Using Reaction Force Observer. *IEEE/ASME TRANSACTIONS ON MECHATRONICS*, VOL. 10, NO.