4th International Conference on
Energy, Environment and Sustainable Development 2016 (EESD 2016)

220. Graphical User Interface based Simulation Platform for Energy and Visual Comfort Management in Buildings

Ashfaque Ahmed Baloch[a,b,*], Pervez Hameed Shaikh[b], Zubair Ahmed Memon[a,b],
Shayan Ahmed[b], Muhammad Awais Arain[b], Faheemullah Shaikh[b]

[a]Institute of Information and Technologies (IICT), MUET, Jamshoro 76062, Pakistan.
[b]Department of Electrical Engineering MUET, Jamshoro 76062, Pakistan.
**Email Address: ashfaquebaloch1@yahoo.com*

Abstract

The occupant's visual comfort and energy efficiency management in the building has been offered by the intelligent automation. The energy saving and the attainment of the indoor illumination comfort index are the main challenge for the automated buildings. In this research, for the improvement of visual comfort and energy management in the buildings using simulation based platform is proposed. This provides a platform to occupants to input their preferred values using Graphical User Interface (GUI). Various fuzzy inference systems (FIS) are developed using several membership functions and rule basis. To obtain the trade-offs, resolution of conflict between the power consumption and occupant's visual comfort level has been improved that expressively achieved through implementation of multi-objective optimization algorithm (MOGA). In addition to the control design, the consumer's preference plays decisive role in achieving overall comfort. Thus, for the visual comfort and energy management in smart buildings, MOGA optimization integration with the fuzzy inferred control system is effective.

© 2016 Ashfaque Ahmed Baloch, Pervez Hameed Shaikh, Zubair Ahmed Memon, Shayan Ahmed, Muhammad Awais Arain, Faheemullah Shaikh. Selection and/or peer-review under responsibility of Energy and Environmental Engineering Research Group (EEERG), Mehran University of Engineering and Technology, Jamshoro, Pakistan.

Keywords: Optimization, Energy, Efficiency, Illumination, Visual Comfort, MOGA, GUI.

1. Introduction

With the advancement in technology the demand for occupant's indoor comfort is also growing. In most of the international energy agency countries, buildings account for the large portion of energy ingesting with 40% of primary and 32% of total energy [1]. Thus, within the building environment, energy efficiency has become the priority for the researchers. In modern building management, the two major but often conflicting subjects are human comfort and building energy consumption. In past 15 years the weightage of electrical appliances' consumption is increased by 13%, representing more than half of the energy consumption [2]. The energy outcomes can be positively or negatively affected by the occupant's behaviours and interactions with the building in a high performance buildings. In 2010, Masoso and Grobler investigated that during non-working hours the more energy (56%) was being used then the duration of working hours (44%) that rose because at the end of the working day, most of the occupants leaving equipment and lights ON [3]. Adding more to usage of renewable energy and energy efficient construction, high environmental comfort should be provided to occupants by zero energy building [4]. Actuators are employed as electrical lighting system to control the physical environment of building [5)], and to manage energy consumption and visual comfort demand, a multi-agent control system is implanted. For facilitating energy and visual comfort management in building we describe a Graphical User Interface (GUI) based simulation platform. To simulate energy and visual comfort variations in building MATLAB GUIDE is used to build a GUI platform that allows users to define their own parameters. For building control system optimization, Multi-objective Optimization Genetic Algorithm (MOGA) is used.

2. System Modeling

The power system modelling, control, operation and management are using the multi-agent system that is inspiring and fast growing technology. The agents can be software or physical entity and are fundamental components of system [6 – 8]. Figure 1 shows the proposed multi-agent intelligent controls system in this study. The control and management aim of this research is to achieve the greatest visual comfort with minimal energy consumption. Multi-agent mechanism along with evolutionary algorithm has utilized to control the indoor comfort index and to manage power dispatch for the building. The agents are classified in layers as the master coordinator agent and the peripheral agent. To optimize the set points in the master agent, the advanced multi-objective genetic algorithm (MOGA) optimizer has been embedded. The detailed block diagram of the proposed control system is shown in figure 1. Whereas, the peripheral agent is used to control the actuators that are associated with the comfort aspects, i.e., visual comfort of the occupants. The agents cause the achievement of the goal of increasing the consumers' visual comfort and reducing the consumption of energy concurrently. Generally, an agent can has definite mutual features, comprising abilities in achieving autonomy as well as the abilities to react on the variation in environment and in achieving communication [9].

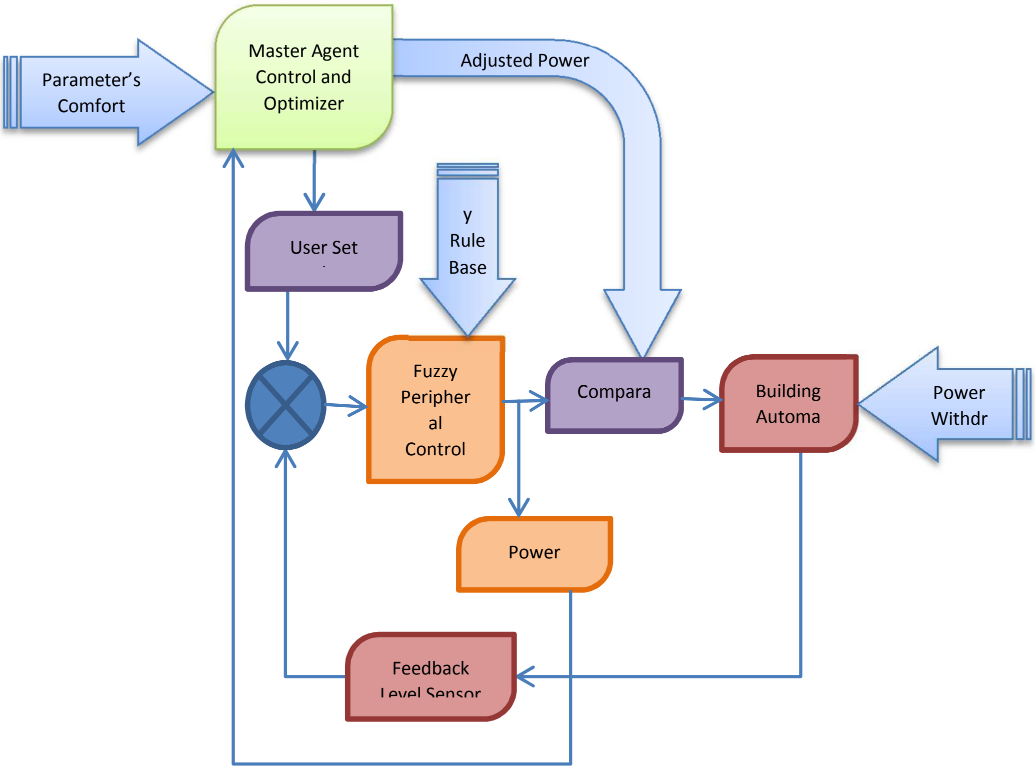


Fig. 1. Building Automation System Flow Structure

2.1. Multi-objective Genetic Algorithm (MOGA)

Evolutionary GA is capable of resolving the multi-objective optimization problems as exploiting a population-based approach. However, modified solitary objective GA can be employed to search non-dominated multiple group of solutions in a one run. Simultaneous searching capability of various solution spaces of GA is promising for challenging problems of discontinuous, non-convex and multi-modal solution sets.

Rather than the required derivative and additional assisting data, it just work with the objective functions. Using genetic operators, it examines in population and employs possible rules that proceeds towards optimal solutions [10]. Consequently, crossover exploits best solution structures of dissimilar objectives to produce new uncontrolled solutions in unmapped area of Pareto Front. Mostly, MOGA doesn't demand weigh, scales or prioritize objects from the user. This makes GA, widely held experiential methodology for multi objective strategy and for optimization problems also. Typically, the GA that reserved best solutions execute better than those don't reserve [11]. Thus being widely held experiential methodology for multi objective design and optimization problems [12].

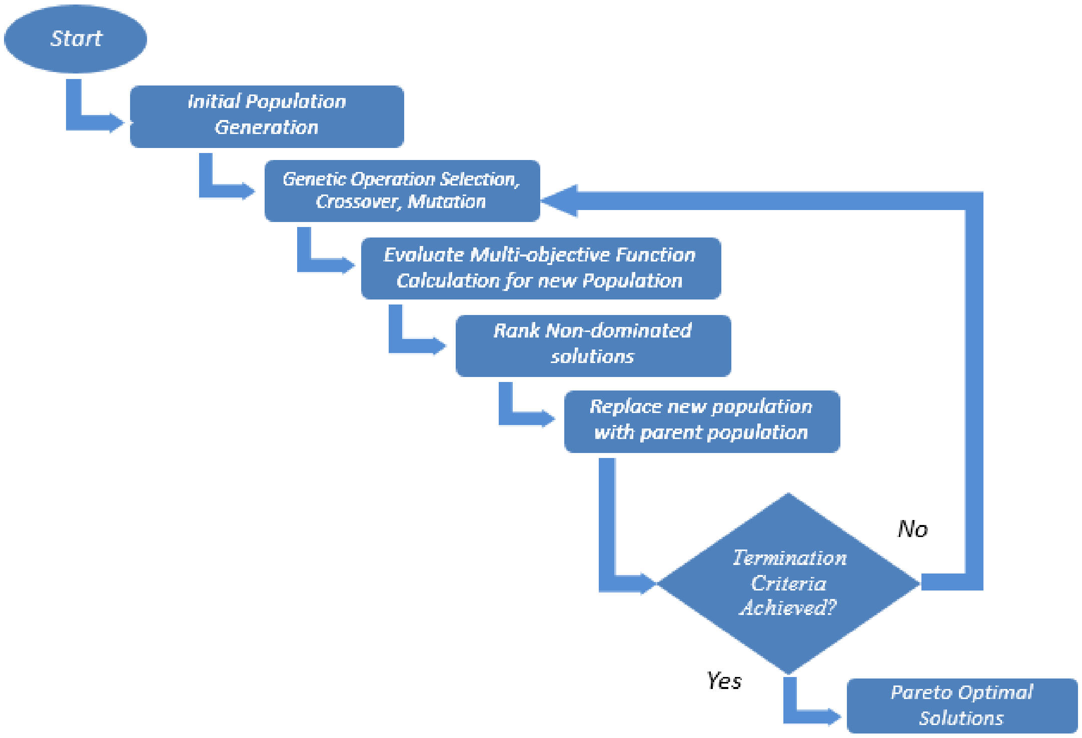
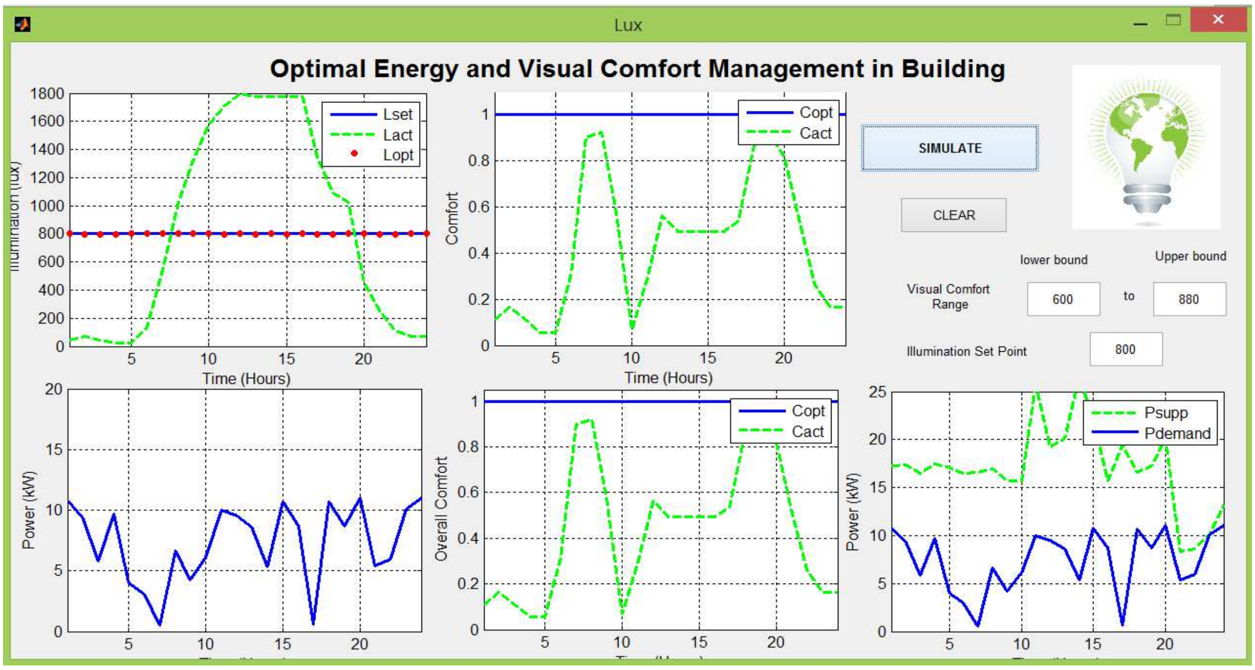


Fig. 2. Flowchart of Multi-objective Optimization Genetic Algorithm

2.2. Graphical User Interface (GUI)

For energy and visual comfort management in building, a MATLAB GUI is designed in this study. GUI is basically a graphical display platform in which occupants can interact with programs through one or more windows. The tasks can be achieved through graphical interface by the occupants deprived of knowing that how the program is coded or how the task is being performed. To create graphical user interface GUI, the development environment is provided by MATLAB called GUIDE. There are two steps of create a GUI; first is, laying out the GUI and another one is its programming. GUI components can be dragged and dropped into the layout area in GUIDE layout editor by the programmers to create a GUI. The MATLAB program file will be automatically generated by GUIDE that controls the GUI operations and their codes can be edited to complete desired functions [3]. Furthermore, using Simulink, GUIDE can be integrated to display results. To observe system performance and allow users to manipulate the parameters conveniently, the GUI-based simulation platform can be used. The main GUI is shown in figure 2.

Referring to the first part of interface, data sets are entered by the user, here the preferred illumination comfort range are supposed to set by the user. MOGA will be used to tune the set points for visual comfort demand. Once all the user-defined parameters have been set, simulate button can be pushed to launch simulations. The simulation results for power consumption and visual comfort values are shown in second part of the interface.



Visual Comfort Range: lower bound 600 to Upper bound 880

Illumination Set Point: 800

Fig. 3. GUI-based simulation for Energy and Visual Comfort Management in Building

3. Simulation and Results

Fig. 3 shows the model framework build using the MATLAB GUI, the values of visual comfort range for lower bound and upper bound are set as 600 and 880 respectively, with the illumination set point at 800. As we press the simulate button the GUI will present the results as shown in the fig. 3.

The first graph in the above figure represents the illumination versus time with the set illumination, actual illumination and optimum illumination. As we can see that the set illumination and optimum illuminations are up to the value of illumination set point 800 (set by the occupant) and can be seen that the illumination level is maintained according to the occupant's comfort. In the second graph, the occupant's comfort versus time graph is shown, as it is shown that the actual comfort level is varying according to the occupant's comfort. The third graph is Power (i.e. in kW) versus time, which shows the consumption of power to maintain the occupant's desired visual comfort. Fourth graph is representing the overall comfort of the occupant versus time, it can be seen that the actual comfort is well maintained with respect to the optimal comfort. Last graph is representing power demand versus actual power supplied and can be seen during maintaining the occupant's desired visual comfort.

4. Conclusion

It is clear from above results that the suggested GUI-based simulation platform is user friendly and results can be conveniently observed. Through the spontaneous GUI, the preferred weights and comfort zones can be defined by the occupants. Furthermore, the platform displays complete information including the, total power consumption, power supplied and power demand, set, actual and optimum illumination level and overall occupant's visual comfort demand. Conferring to actual data, the maximum overall comfort level can be reached by adjusting the set points online.

Acknowledgment

This research work was done during the Erasmus Mundus Exchange programme at Politechnika Wroclawska, Poland. I would like to acknowledge Prof. Dr. Przemyslaw Janik of Politechnika Wroclawska, Poland, Dr. Pervez Hameed Shaikh and Prof. Dr. Zubair Ahmed Memon of Mehran University of Engineering & Technology, Jamshoro, Pakistan for their continuous encouragement and support for this research.

References

[1] L. Martirano et al. A fuzzy-based building automation control system. IEEE industry applications magazine 2016: 10 – 17.

[2] Dounis, Anastasios I., and Christos Caraiscos. "Advanced control systems engineering for energy and comfort management in a building environment—A review." *Renewable and Sustainable Energy Reviews* 13.6 (2009): 1246-1261.

[3] Raziei SA, Mohsenian-Rad H. Optimal demand response capacity of automatic lighting control. In: Proceedings of the innovative smart grid technologies (ISGT); 2013. p. 1–6.

[4] Yang, Rui, Zhu Wang, and Lingfeng Wang. "A GUI-based simulation platform for energy and comfort management in Zero-Energy Buildings." *North American Power Symposium (NAPS), 2011*. IEEE, 2011.

[5] A.I. Dounis and C. Caraiscos, “Advanced control systems engineering for energy and comfort management in a building environment—A review,” Renewable and Sustainable Energy Reviews, vol.13, issue 67, pp. 1246–1261, August – September 2009.

[6] Julia K. Day, David E. Gunderson. Understanding high performance buildings: The link between occupant knowledge of passive design systems, corresponding behaviors, occupant comfort and environmental satisfaction. Building and Environment 2015: 84: 114-124.

[7] Salvatore Carlucci, Francesco Causone, Francesco De Rosa, Lorenzo Pagliano. A review of indices for assissing visual comfort with a view to their use in optimization processes to support building integrated design. Renewable and sustainable energy reviews 2015; 47: 1016-1033.

[8] Shaikh PH, Mohd.Nor NB, Nallagownden P, Elamvazuthi I. Building energy management through a distributed fuzzy inference system. Int J Eng Technol (IJET) 2013;5(4):3236–42.

[9] F. Rahimi and A. Ipakchi, "Demand Response as a Market Resource Under the Smart Grid Paradigm," Smart Grid, IEEE Transactions on, vol. 1, pp. 82-88, 2010.

[10] Schneider Electric, <http://www.schneider-electric.com/solutions/ww/en/ seg/27947930-smart-cities/27957983-smart-buildings-homes> [accessed on 17.11.2013].

[11] C. A. Coello, "An updated survey of GA-based multiobjective optimization techniques," ACM Comput. Surv., vol. 32, pp. 109-143, 2000.

[12] C. M. Fonseca and P. J. Fleming, "Multiobjective optimization and multiple constraint handling with evolutionary algorithms. I. A unified formulation," Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, vol. 28, pp. 26-37, 1998.