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CONCEPTUAL IDEA OF DESIGN AUTOMATION FOR BUILDING ENERGY SYSTEM

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ABSTRACT

Connected construction is open communication between technologies. It is the most advanced form of technology today in the field of construction. Currently, modeling technology has been developed to help in understanding the design and building management strategies and decisions. Although it has been very advanced, it still has weaknesses in the shared system, as well as in building system products and stakeholders. Automation technology creates reliable control in connected construction processes that drive cost-efficiency. It process integrates building design, construction, and operations and also integrates developers, construction players, and building system manufacturing industries. This paper aims to present a concept of an automated support system that allows automated design decisions and management as a control of the connected construction. A Multi-Agent System (MAS) is applied to provide an appropriate decentralized approach to the characteristics of fragmentation in construction. As the result, the method covers 19 functionalities. The solution is more optimal and gives efficiency and effectiveness to deal with changing circumstances and problem-solving where data, expertise, and control are distributed.

Keywords: Building energy system, construction, conceptual idea

1. INTRODUCTION

Indonesia is one of the countries with the largest energy consumption growth rate in the world. The increase in Indonesia's energy consumption in recent years has reached 7% per year. Meeting this need requires systematic efforts. As a place for life activities, buildings are places that absorb energy use, the second largest after industry. Saving energy can be done starting with small things, including the concept of building design. Research on energy-saving buildings has been very advanced and developed (Li CZ. Et.al., 2022). The identified future research potentials include intelligent integration of energy management and control systems as well as quantitative and qualitative analysis of interactions in building energy-saving management.

Challenges and opportunities in building energy consumption are strongly influenced by changes in current world environmental conditions (M. Torabi and M. Mahdavinejad, 2021), including rapid population growth, climate change, poverty and economic vulnerability, and social problems including high migration flows which have

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implications for the provision of buildings, construction, and needs. Energy (M. Santamouris and K. Vasilakopoulou, 2021). The biggest driver of consumption patterns is global climate change (L. M. Campagna and F. Fiorito, 2022). which has an effect on decreasing heating consumption, but increasing cooling consumption, which overall drives consumption growth. Although current building design trends have benefited greatly from energy accounting tools, recent studies have shown that there is a large difference between the predicted and actual energy consumption of buildings (J. Kim et.al., 2017).

1.1. Literature Review

There are three research focuses in the field of building energy, namely consumption, efficiency, and conversion. Energy sources and developing technologies are renewable energy Its applications are various, ranging from energy-saving to the use of local materials (S.C. Capareda, 2020). Buildings as a forum for activities are a fairly large contribution to energy use after industry and transportation, greater than commercial activities. Energy savings in the building sector will have a considerable effect on the energy load, as well as form a new lifestyle (AA Pasten C. and J. C. Santamarina, 2012). Buildings in the form of various functions including residential, office commercial, retail commercial, and forms of public facilities can be in the form of single buildings or buildings with mixed functions that are connected. In the case of connected buildings, the energy and management approach is much more complex but has greater opportunities for the use of renewable energy sources (V. Olygay et.al.,2020). Buildings are the largest energy consumption sector, accounting for 40% of total global consumption and an equally important source of carbon emissions even in less developed areas, energy use in buildings represents as much as 80% of total energy use (E. Delzendeh et.al., 2017). Thus, predicting energy consumption becomes important in the design and construction of buildings, from the initial design stage to the post-occupancy, operational, and demolition phases of the building life cycle (M. Bemanian and M. Torabi, 2019).

Energy use is in the form of consumption, efficiency, and conversion in an integrated manner for the entire area, starting from the design stage to managing use with each stakeholder involved at each stage. Technology in the Architecture, Engineering, Construction, and Facility (AECF) industry is one of the keys to success (V. Pereira et.al., 2021). However, there are limitations to current technology, especially how the behavior of users of energy sources and energy systems will collaborate and be integrated automatically. Integration becomes an important role in the decision process support systems are needed for the automation relationship between building energy systems (S. Dutta, C. M. Hussain, 2020). Because it is directly related to the user, activities save not only on the choice of residential design and technology but also on user behavior (A. Paone and B. Jean-Philippe, 2018). Buildings in the form of individuals and areas are no longer seen as individuals but as groups that influence each other.

This research is intended to prepare conceptual ideas for a support system that allows all project actors to evaluate alternative solutions and collaborate with other parties, and management as a control for independent building energy use. In this case, setting up a complete approach and developing a framework for automated integration. The method covers several scientific areas, namely design management, operations research, and artificial intelligence. The agent system will provide a good approach to dealing with distributed problems (J. Xie and C. C. Liu, 2017).

The solution that will be produced by the agent system will be better, more economical, safer, and optimal compared to using different software from each project actor. The obvious benefits of using agent systems are computational efficiency and effectiveness in the integration process to find the optimal solution and its ability to deal with changing circumstances and problem-solving where data, expertise, and control are distributed (A. Kumar et.al., 2020)., as well as the distribution of building energy systems, both passive and active. which requires automatic control with adaptive scenarios in the sense of exchanging and replacing each other.

1.2. Method

This conceptual idea is facilitated by the application of an agent system (A. Ghahramani et.al., 2020) that will help reduce costs and increase the value of decisions in building energy management. As an approach to increasing the value of energy use, this agent system technology will bridge the theoretical gap in automated design. It is hoped that the development of the algorithm in this research can be used as a support model for building energy system integration that is not only independent but also productive as an energy producer

The formulation of the research methodology is based on a research framework that aims to develop residential energy self-control technology that is able to meet the collaboration of all stakeholders including residential users at all stages of development from design to operation. The background of the concept of thought and the formulation of the research methodology was obtained through the synthesis of the results of a literature review and the results of an exploratory study. Based on the results of the literature study, it is found the potential for research development, so that research objectives can be formulated. To achieve the research objectives, several stages of the process and activities in this research consist of theoretical studies (literature studies), exploratory studies, confirmative studies, verification studies, and model development.

The triangulation method is formulated in the research methodology because of the use of qualitative and quantitative approaches through activities carried out simultaneously (simultaneously) and sequentially (sequential). Activities carried out simultaneously include verification studies and model development. All stages of research activities are sequentialIndonesia is one of the countries with the largest energy consumption growth rate in the world. The increase in Indonesia's energy consumption in recent years has reached 7% per year. Meeting this need requires systematic efforts. As a place for life activities, buildings are places that absorb energy use, the second largest after industry. Saving energy can be done starting with small things, including the concept of building design. Research on energy-saving buildings has been very advanced and developed (Li CZ. Et.al., 2022). The identified future research potentials include intelligent integration of energy management and control systems as well as quantitative and qualitative analysis of interactions in building energy-saving management.

Challenges and opportunities in building energy consumption are strongly influenced by changes in current world environmental conditions (M. Torabi and M. Mahdavinejad, 2021), including rapid population growth, climate change, poverty and economic vulnerability, and social problems including high migration flows which have implications for the provision of buildings, construction, and needs. energy (M. Santamouris and K. Vasilakopoulou, 2021). The biggest driver of consumption patterns is global climate change (L.M. Campagna and F. Fiorito, 2022). which has an effect on decreasing heating consumption, but increasing cooling consumption, which overall drives consumption growth. Although current building design trends have benefited greatly from energy accounting tools, recent studies have shown that there is a large difference between the predicted and actual energy consumption of buildings (J. Kim et.al., 2017).

2. RESULT AND DISCUSSION

Agent and multi-agent systems model the decentralized approach of building systems and link fragmentation in connected construction. The agent system idea in construction provides a new approach by producing higher quality and more economical solutions. An intelligent agent (IA) is an independent knowledge-based system (k-b) capable of solving certain problems and interacting with each other (G. Lai and K. Sycara, 2009). In a multi-agent autonomous system representing a building's energy system, integration is a form of interaction that allows groups of agents to reach an agreement on providing and operating the building's energy-fulfilling objectives over time. Agents are autonomous and their integration is automatic. For example, when passive energy follows the direction of the sun and when it stops being replaced by active energy.

The potential benefits of agent systems include saving time and money, computational efficiency for finding optimal results, and the ability to combine multiple strategies for changing environments. The whole provides durability and efficiency. Its capabilities enable problem-solving where there is the distribution of data, expertise, or control. The agent system that is the idea is a very complex system, involving multiple parties and technical solutions that are distributed in terms of layout and have different goals and preferences. Based on this, there are four situations that allow the agent system to play a role, namely: a. The problem domain is geographically distributed and heterogeneous; b. Sub-systems change dynamically; c. The system is complex; d. Sub-systems need to interact flexibly.

If the number of parties and technical solutions are involved, the wider the scope of the idea. The establishment of alternative use of technical solutions and the development of decision hierarchies in distributing functions to group agents will help the entire energy system perform its functions. This computer-mediated process improves comprehension, legibility, and objectivity. The system will provide additional functionality to negotiate a common problem representation of all energy system agents. All agents have the same goal (G = c0) but each has a set of activities. When there are considerations for alternative uses of new energy, the agent proposes this alternative to the appropriate agency. The need to provide a building's energy system design becomes more important throughout the connected construction stages. A way is needed to calculate energy use for the construction and operation of a building. Communication of alternative uses of energy supply from the exchange of all alternatives. The process is automation when passive energy provides, when active energy provides, and also when both go together. Figure 1 presents the product and people integration for the basic idea of building energy automation systems in connected construction.

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In this paper, the conceptual idea consists of system goals, and functionality (Table 1), and the scenario of the idea is introduced as follows:

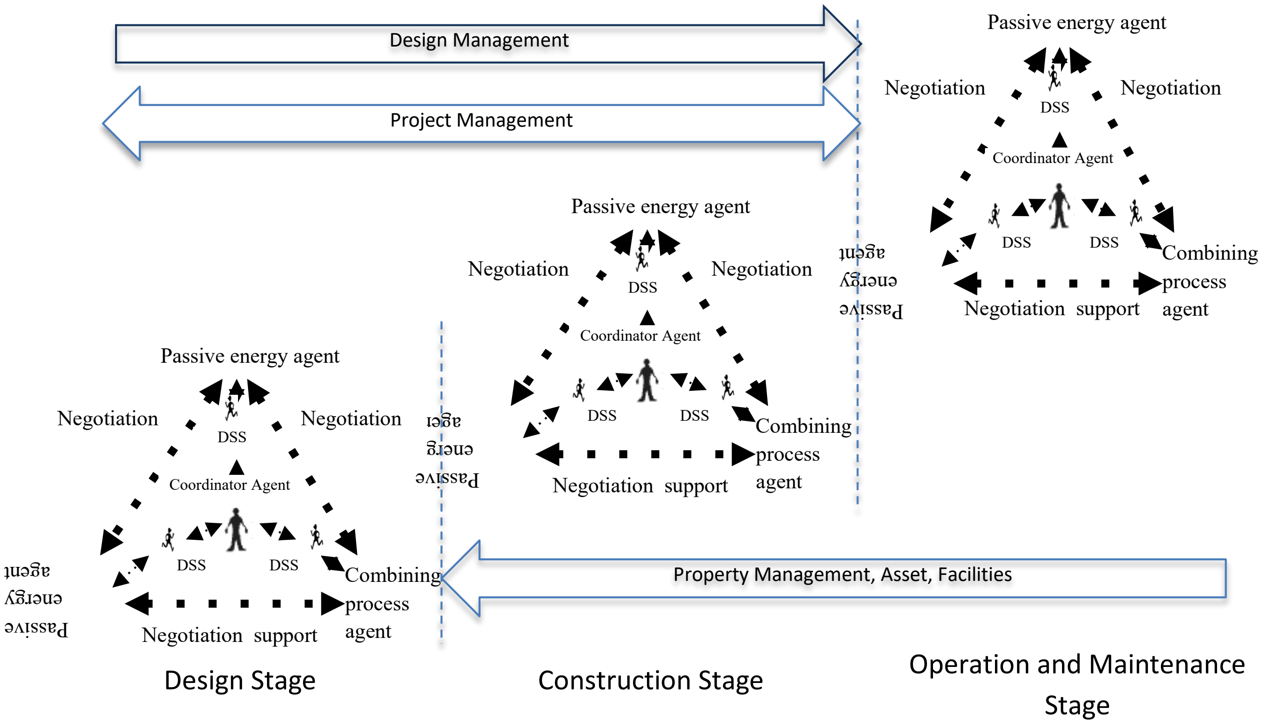

Figure1 Building energy automation system in connected construction

2.1. Goal Specification

The Goal Specification is to develop an automated system for building energy system selection. This system will offer an evaluation system for technical solutions, and elicitation preference of stakeholders, a system to analyze Pareto optimum payoff, a system to determine the best-fit technical solution option a system to accommodate trade-off analysis. Systems must facilitate personalization and are integrative, fast, and reliable at all stages of the building's energy use process every day of the week and throughout the year. The system should have valid information and be better than other methods in practice and gives better satisfaction.

2.2. System Goals and Functionalities

Table 1 The functionality of the conceptual idea

No	Functionalities	Contents	Goals
1	Online interactions	Obtains user input and presents information	Geographically distributed negotiation process

2	Individual-Group information	Receive individual stakeholder input and present group information	Receive and send individual and group information
3	Building system products information	Finds and updates product specification database and finds and updates product price database	Technical solution information online
4	Basic Value of technical solution products	Provide the basic value of product building system	Evaluation of technical solution options
5	Function database management	Provide a database of technical solution functions and find basic function	Interactive discovering function
6	Creativity in building system function	The interactive discovering function; opens diagrams and lines of communication; and why-how logic thinking	Function analysis system technique
7	Life cycle cost calculation	Calculation of life cycle cost and provides sensitivity	Life cycle cost analysis
8	Individual preferences	Provide pair-wise comparison input, and provides refining input as consistency	Elicitation Preferences of stakeholders
9	Knowledge management	Storing historical preferences from the past, and suggestions of preference from the past	Historical preferences and interactive consistency
10	Value of Pareto Payoff Optimum	Calculates Pareto payoff optimum for function; calculates Pareto payoff optimum for cost; and provides coalition formation information1	Pareto payoff optimum for each coalition
11	Best-Fit center information	Calculates best-fit options and interactive best-fit information1	Best fit of technical solution options
12	Trade-off and value change	Accommodate trade-off analysis	Accommodating trade-off analysis
13	Welcoming	Provide personalized welcome	Personalized welcoming
14	Profile monitor	Provide personalized recommendations and user option	Decisions are based on stakeholder profile
15	Negotiation process monitor	Provide building system selection options menu; provides negotiation process information; provides anonymous negotiation result	Information is available about all processes in negotiation
16	Group coordination management	Arrange supply decision result, provides an estimate for negotiation result, tracks trade-off problems; and have scenario stakeholder characteristics	Anonymous negotiation results such as opt-out, reject, accept, stop, and a new round

17	Agreement management	Provide full information on best-fit options and comparison result	Accepted best-fit option
18	Validation	Provide a similarity index and a comparison result	Similarity index information
19	Deadlock management	Options to change preference and provide deadlock anticipations	Satisfy all stakeholder

2.3. Scenario

Five scenarios will be developed, which are: opt-out scenario, group selfish scenario, group coordinator scenario, group hierarchical scenario, and scenario for deadlock. The opt-out scenario illustrates what happens when a stakeholder decides to opt-out. Information is obtained from agreement management and the trigger is opt-out options. A major decision to be made is which agent types should exist by grouping functionality into agent types (L. Padgham and M. Winikoff, 2004). One or more functions for each agent. Once a grouping is selected, each agent type is described through an agent annotation list. The process consists of two stages, namely (1) refinement of the agent in terms of its capabilities, providing agents with diagrammatic descriptions and capability descriptors, and (2) development of specifications for the function process of each building energy system agent.

3. CONCLUSION

The conceptual idea is based on the need to integrate the building's energy system automation to carry out its functions. Multi-agent systems provide opportunities for coordination, communication, and collaboration between agents of building energy technology solutions. Goal specifications, functionality, and scenarios of a multi-agent system are presented as an initial idea that allows an agent system to be built.

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5. REFERENCES

Li CZ., L. Zhang, X. Liang, B. Xiao, V.W.Y. Tam, X. Lai, and Z. Chen. 2022. "Advance in the research of building energy saving". Energy and Buildings, 254

Torabi, M., and M. Mahdavinejad. 2021. "Past and future trends on the effects of occupant behavior on building energy consumption". J. of Sustainable Architecture and Civil Eng. 2(29): 88-101

Santamouris, M., and K. Vasilakopoulou. 2021. "Present and future energy consumption of buildings: challenges and opportunities towards decarbonization". e-Prime – Advance in Electrical Engineering, Electronics and Energy 1: 100002

Campagna, L.M. and F. Fiorito. 2022. "On the impact of climate change on building energy consumptions: a meta-analysis". Energies, 15: 354

Kim, J., T. Hong, J. Jeong, M. Lee, K. Jeong, and J. Jeong. 2017. "Establishment of an optimal occupant behavior considering the energy consumption and indoor environmental quality by region". Applied Energy, 204: 1431-1443

Capareda, S.C. 2020. Introduction to Renewable Energy Conversions, 1st Ed. Routledge.

AA Pasten, C. And J.C. Santamarina. 2012. "Energy and quality of life". Energy Policy, 49: 468-476.

Olgyay, V., S. Coan, B. Webster, and W. Livingood. 2020. Connected Communities: A Multi Building Energy Management Approach. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75528

Delzendeh, E., S. Wu, A. Lee and Y. Zhou. 2017. "The impact of occupants' behaviors on building energy analysis: A research review". Renewable and Sustainable Energy Reviews 80(May): 1061-1071.

Bemanian, M. and M. Torabi. 2019. "Determining theoretical origins of recycling in Iranian-Islamic architecture; with grounded theory approach". Naqshejahan, 9(3): 167-175.

Pereira, V., J. Santos, F. Leite, and P. Escorcio. 2021. "Using BIM to improve building energy efficiency – A scientometric and systematic review". Energy and Buildings, 250: 111292

Dutta, S., C.M. Hussain. 2020. Sustainable Fuel Technologies Handbook. Elsevier.

Paone, A. and B. Jean-Philippe. 2018. "The impact of building occupant behavior on energy efficiency and methods to influence it: a review of the state of the art". Energies 11(4): 953

Xie, J., and C.C. Liu. 2017. "Multi-agent systems and their applications". J. of International Council on Electrical Engineering, 7(1): 188-197

Kumar, A., A. Verma, and S. Prakash. 2020. "AI-based building management and information system with multi-agent topology for an energy-efficient building: towards occupants comfort". IETE J. of Research 3:1-12.

Ghahramani, A., P. Galicia, D. Lehrer, Z. Varghese, Z. Wang, and Y. Pandit. 2020 "Artificial intelligence for efficient thermal comfort systems: requirements, current applications and future directions". Frontier in Built Environment, 6(49).

Lai, G. and Sycara, K. 2009 A generic framework for automated multi-attribute negotiation. Group Decision and Negotiation 18(2): 169-187

Padgham, L. and Winikoff, M. 2004 Developing Intelligent Agent System a Practical Guide. John Wiley&Sons, New Jersey