International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Optimization Technique in Smart Home Environment: A Systematic Review

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Submitted: 11/02/2023 **Revised:** 09/04/2023 **Accepted:** 10/05/2023

Abstract: A smart home is a concept that seeks to use as little energy as possible while maximizing occupant comfort. The main difficulty encountered by power supply providers is optimising the power requirements for smart home devices in a smart grid, especially during peak times due to its significant impact on the reliability of a power grid. It gets harder for the user to manage or use each individual device in a smart home properly as the number of devices increases. Optimization models may be used to regulate smart appliances, but they must be effective and realistic To reduce power usage and increase user happiness, we describe heuristic and meta-heuristic optimization techniques in this work for home energy management systems. When faced with difficult, sophisticated optimisation challenges, such as those arising in the design of power electronics converters, metaheuristic techniques offer a practical option. An alternative strategy involves using optimisation heuristics like evolutionary algorithms, neural networks, genetic algorithms, tabu search, hybrid approaches, and many others.

Keywords: *Smart Home, Optimization, Heuristic Algorithm, Meta-Heuristic Algorithm*

1. Introduction

The idea of "smart houses" has been known since the late 1990s, and its popularity has grown since the early 2000s.The technologies for smart houses provide solutions for occupant comfort and energy efficiency. Adoption of such technologies helps assist and enable independent living among the elderly, those with dementia, and those with intellectual impairments in addition to improving occupant comfort and energy efficiency. Additionally, smart houses assist with patient monitoring and homecare [1].

The desire for smart houses and IoT (Internet of Things) gadgets is driving up household electricity usage, which is already among the top three global electricity consumers. The average family uses 90 million units of energy annually, much of it wasted, according to the US Department of Energy (DoE). The main causes of this waste are habits like forgetting to turn off lights when we leave a room or computers or televisions while not in use. Power controllers are therefore required so that users can perform activities like turning devices on and off or altering their modes of operation to achieve a goal like optimal usage[2].

Based on factors such as the room's temperature, lighting, humidity, air flow, air quality, and so on, the optimization approach is carried out. Smart homes and the optimization of their energy use are a hot topic for scientists and academics since the contentment of a building's occupants is a significant aspect. The researchers have put forth a variety of methods based on optimization algorithms to address the issues with energy management and raise the comfort level of building occupants[3].

One technology that helps inhabitants is a smart house. By boosting safety and healthcare, minimizing power consumption, and integrating smart technology into residential homes, it aims to increase user (resident) comfort levels. The home energy management system (HEMS), which offers a remote monitoring system using telecommunication technology, enables users to remotely operate and monitor smart home equipment[4].

2. Optimization

Problems involving optimization include selecting the best answer or solutions from a pool of workable ones.

1.1 Optimization Methods

Optimization methods are classified into exact and approximate methods.

1. **Exact method**

For small-scale optimization issues where they can find the ideal answer, exact methods are effective. Exact techniques, on the other hand, are inadequate for dealing with high-dimensional optimization issues.

2. **Approximate method**

Due to their effectiveness in navigating high-dimensional search spaces, approximate approaches are more effective than accurate ones [5].

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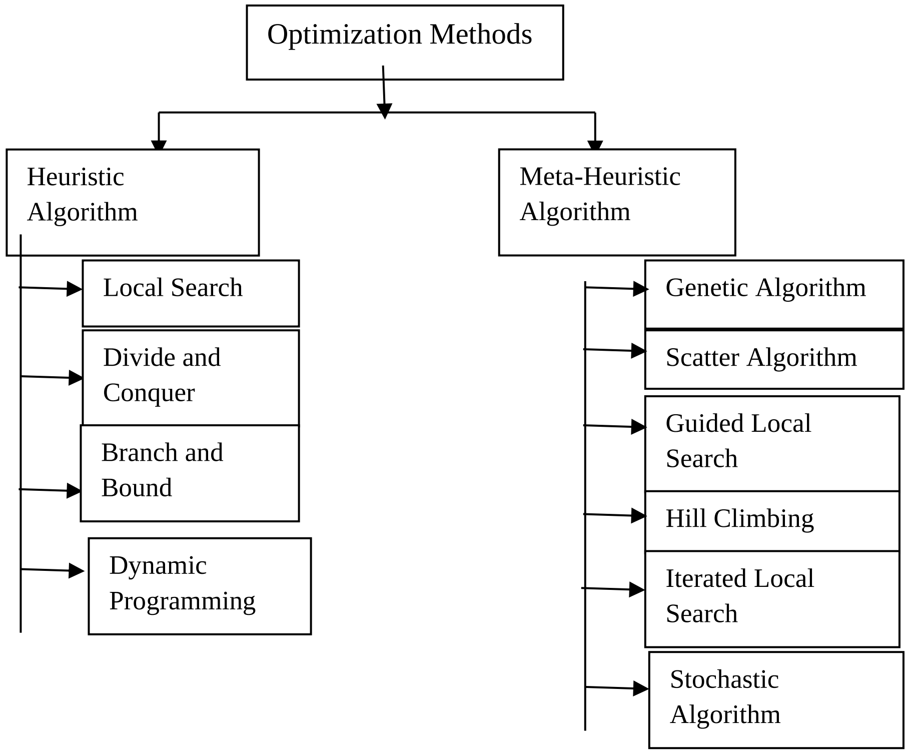

Fig 1. Optimization Methods

2.1 Heuristic Algorithm

Due to their flexibility and ability to adopt different load patterns to reduce inconvenience, heuristic algorithms produce superior results[6].

A heuristic is a method designed to solve a problem more quickly when traditional methods are inefficient or to find an approximation when traditional methods are unable to find any exact solutions. Heuristics do not ensure that the best solution will be found, so they should be viewed as approximate rather than accurate algorithms. These algorithms typically find a quick and simple answer that is near to the ideal one. [7]

2.1.1 Local Search

From one full instantiation to the next, a local search algorithm progresses starting from a complete instantiation that is selected at random. The term "local search" was coined because switching between states typically only requires a local change to the value of one variable[8].

2.1.2 Divide and Conquer

A divide-and-conquer method repeatedly divides a problem into two or more sub problems of the same or closely similar type, until these are sufficiently straightforward to be solved by themselves. After that, the sub-problems' solutions are combined to provide a solution to the main problem[9].

2.1.3 Branch and Bound

A vital part of the search space enumeration is the branch and bound technique. It lists, but strives to continually exclude areas of the search space that are unable to hold the ideal solution.

2.1.4 Dynamic Programming

Dynamic programming is a thorough search that keeps track of sub-problem solutions to prevent re-computation.

2.2 Meta-Heuristic Algorithm

Instead of providing a precise answer, meta-heuristic algorithms provide a solution that is close to optimal. Evolutionary Algorithm.

2.2.1 Genetic Algorithm

Charles Darwin's theory of evolution of living things is imitated by genetic algorithms (GA), which are direct, parallel, stochastic methods for global search and optimization.

2.2.2 Scatter Search

Hard optimization issues have been successfully solved using the evolutionary technique known as scatter search. Because each of the scatter search methodology's components can be used in a variety of ways and to varying degrees of sophistication, it is exceedingly adaptable[10].

2.2.3 Tabu Search

A solution approach in the field of metaheuristics is called tabu search (TS).

Although the approach is applicable to all optimization issues, the majority of TS applications has been and still is in discrete optimization. An initial solution serves as the starting point for a tabu search, which then moves from one solution to the next through enacting transformations. In other words, TS is a member of the single-solution search-based metaheuristic methodology family. Methodologies from this family include variable neighbourhood search and simulated annealing[11].

2.2.4 Guided Local Search

A proposed meta-heuristic method for combinatorial optimization issues is guided local search (GLS).It uses an effective penalty-based method as part of a high-level strategy to communicate with the local improvement process[12].

2.2.5 Hill Climbing

The HC local search method works by iteratively improving existing answers. It begins with a solution that is thought of as the current solution in the search space, which could be produced randomly or computed on the spot. The algorithm looks at its surrounding solutions and, if one of them is superior to the current one, it may replace it. The algorithm then moves from one solution to the next in the search space until no more advancements are possible[13].

2.2.6 Iterated Local Search

Iterated local search (ILS) is a straightforward and widely used stochastic local search technique that generates a randomized walk over the space of local optima by iteratively applying local search to perturbations of the current search location[14].

2.2.7 Stochastic algorithm

Stochastic search techniques are intended to solve deterministic issues or problems with embedded random noise[15].

3. Literature Review

Butt et al.,2019 [16] The proposed concept refers to the residential component as "Smart Homes" (SHs).The major objectives of the SG are to control the load of SHs during peak hours, conserve energy, reduce costs, and minimize delays.SG efficiently completes work by utilizing smart appliances, renewable energy sources, and the Smart Meter (SM).Demand Response (DR), which balances the load from peak to off-peak hours without impacting the users' comfort level, aids in managing a load of consumers and utility.

Albuquerque et al., 2018 [17] The suggested model uses a weighted aggregation function to determine the ideal times to turn on actual household appliances based on energy usage statistics, load-limiting constraints, and user preferences.

Jiang and Wu, 2020 [18] A novel home load scheduling algorithm that takes cost effectiveness into account is suggested. Analyzing users' usage patterns allows for the creation of the ideal energy consumption curve.

Haider et al., 2016 [19] Based on consumer purchasing patterns, the author presented an ideal dynamic dispatching system for residential power equipment that would motivate users to control their energy consumption within reasonable bounds and meet lower energy consumption targets. A novel home load scheduling algorithm that takes cost effectiveness into account is suggested. Analyzing users' usage patterns allows for the creation of the ideal energy consumption curve.

Khan et al., 2018 [20] To manage the load in smart homes and ensure the highest level of satisfaction for users.

Mohsenian-Rad and Leon-Garcia, 2010 [21] In a situation where electricity prices are being determined in real time, suggest residential load control optimization with price prediction. By timing the activities of each appliance, subject to the unique requirements of the user, it reduces the householder's electricity costs. The scheduling problem models the user perspective as a waiting parameter with an escalating cost. As a result, the price of power and the waiting parameter value are used to schedule each appliance's operation.

Khan et al., 2019 [22] proposes a residential load control addresses the trade-off between electricity costs, waiting times, and load peak.

Research Gap

Technique(s)	Achievement(s)	Pricing Schemes	Limitation(s)
Fuzzy controller [23]	Load reduction, optimal user comfort, and minimal electricity costs	Dynamic price	Required high computational time
HEMS [24]	Both throughout the week and on the weekends, energy is used, costs for power, and energy savings are produced.	ToU CPP	renewable and sustainable energy resources and RES are not considered
MILP, Dijkstra [25]	The overall cost and trades off performance for computational complexity.	ToU	Inconsideration of consumer comfort, PAR and RES
IoT [26]	Encourages users to operate and monitor gadgets locally	-	Ignored load scheduling, consumer comfort and electricity cost reduction
MOA [27]	Reduces electricity cost	RTP-IBR	Inconsideration of RES, ESS and consumer comfort
Pareto-optimal front [28]	Reduced electricity costs and longer operational delays	Day-ahead RTP	Ignored user comfort and RES
Informatics solution and ANN[29]	Forecasts consumption, reduces peak consumption, improves the efficiency of everyday appliances, and reduces the strain on the main grid.	ToU	Inconsideration of RES

4. Conclusion

In this paper, we present optimization technique for minimizing power consumption and maximizing user satisfaction. We study demonstrates that the offered strategy can offer many ideal solutions in a variety of scenarios based on sensor costs and the asked-for coverage precision. Multiple techniques have been modified to achieve optimal scheduling (1) Heuristic Algorithm (2) Meta-heuristic Algorithm. Future directions could include enhancing algorithm behavior, external power resources, and objective function quality.

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