

The Role of Generative AI in the Future of Smart Home Configuration*

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Abstract

Since the concept of the smart home was announced, several waves of ups and downs in its adoption have been observable, but the big breakthrough promised frequently has yet to happen. There are several reasons for that, which are addressed in this paper from the perspective of configuration problems. One key reason is the overwhelming complexity and dimensionality of smart home solutions, which are not easily graspable, particularly for laypersons in their role as homeowners or dwellers. Artificial intelligence (AI), specifically conversational generative AI / Large Language Models (LLMs), could help overcome the problem and contribute to the spread of these respective technologies. In this paper, the current possibilities and future potential are exemplified.

Keywords

Smart Home, Configuration, AI

1. Introduction

Since the announcement of the concept of smart homes by the Association of Homebuilders in 1984 [1], the spread of smart homes has experienced several ups and downs, but never the big breakthrough that was frequently promised in the last five decades. In comparison, around the same time as the concept of the smart home, in 1983, IBM introduced the personal computer. The penetration of the PC and its descendants is over 100%, meaning that, statistically, all of us have more than one PC, smartphone, and/or tablet. Compared to that, the percentage of smart home penetration is poor. What we consider real smart homes are living environments where at least two smart sub-infrastructure are interconnected. Closed ecosystems or island solutions, such as a power socket with a proprietary remote control or light bulbs that can be directly operated in a smart speaker's ecosystem, do not constitute appropriate examples in our understanding. According to [2], the penetration of smart environments that fulfill the described requirements is around 30%.

There are several reasons why the adoption of smart home technology, compared to the abovementioned success story of the PC, is low. One of them is probably that, because of the dimensionality (e.g. on sensor level, on component level, on utilization level) and complexity (e.g. direct control, (conventional) remote control, cross-infrastructure control via local gateways or clouds, interoperability) of smart home systems, they are difficult to grasp, specifically for laypersons, resulting in suboptimal adaptation and utilization of the respective technologies. This reminds of the original goal of Usability (Engineering) brought to the point on the cover of IEEE Computer magazine in 1992, designed by P. Simpson: To hide the complexity of a backend system from the user.¹ The spread of AI, more concretely, conversational generative AI/large language models (LLM) such as ChatGPT could bring a revolutionary change in the field, specifically for complex tasks such as configuration in a smart home context, resulting in a situation illustrated - of course by AI - in Figure 1

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¹<https://archive.org/details/computer-magazine-1992-03>/mode/2up

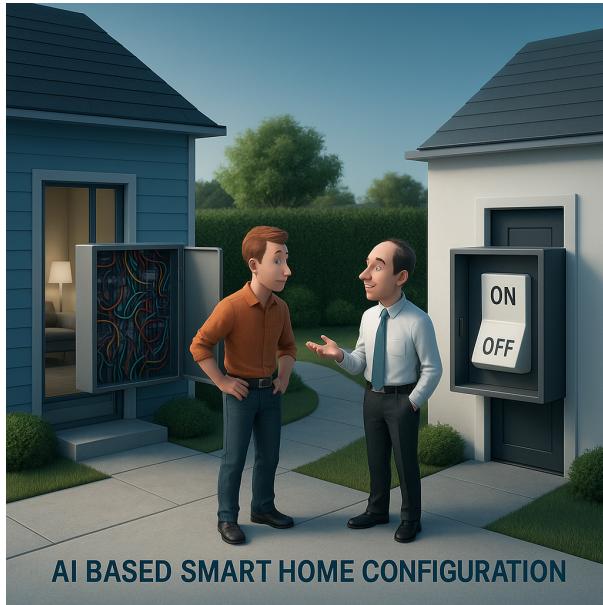


Figure 1: The ideal situation of smart home configuration, of course, also designed by AI (ChatGPT 4.0 Plus, July) - inspired by the cover design of IEEE Computer Magazine 1992/03 by P.Simpson

2. Motivation

A private home is characterized by individuality/customization. Homeowners and dwellers strive to adapt their homes to their needs and preferences. Even in living contexts that are somewhat standardized (such as apartment buildings characterized by repeating floor plans and room sketches), individualization needs are obvious; see, e.g., the example of the famous LeCorbusier Building in Berlin where the inhabitants *"behaved like moles"* to undermine the structural limitations [3]. In the past, end-consumer markets have addressed related needs by offering customers a wide range of choices and possibilities across various sectors, including home equipment and furniture. Interested persons could choose from several styles, price ranges, and materials, and combine furniture and accessories in almost arbitrary combinations, as long as basic constraints, such as dimensions/measures, were appropriately considered. The possibilities of individualization were also present with conventional components of the infrastructure, such as lighting, heating, and shading, which could be combined almost arbitrarily as long as the components met certain standards. For example, light bulbs could be exchanged (e.g., for LEDs that consume less energy) as long as the correct socket type out of a few commonly used ones was correctly identified.

With the advancement of smart home systems, the situation has become more challenging (or even unmanageable) for laypersons, as devices or components that physically fit might not function automatically due to software restrictions that are not always obvious or understandable. No wonder that consumers are reluctant to let technology into their homes; they are skeptical about being able to domesticate it.

To overcome this problem on a technical level, several attempts have been made in the past to address the challenges by establishing integrative platforms. These platforms, for example, include Home Assistant [4], OpenHAB [5], Domoticz [6], and, most recently, MATTER [7]. However, due to various factors, these platforms were and still are only usable for tech-savvy users who possess a genuine interest in the technology and its adaptation. The respective problems are illustrated, for example, in an article in an Austrian newspaper [8] titled *"The Matter Debacle - When Nothing Works in a smart home as it should"*. Consumers with an average interest in or knowledge of smart technology would still either have to completely abandon the technology or invest significant amounts of money to hire professionals to do the job. The individualization and customization possibilities that consumers have been familiar with in other market segments, for example, as observed in the spread of bricolage or furniture stores

and their approach to private customers (DIY and IKEA's "*philosophy*"), are quite limited in the smart home domain. Customization would still require a high level of knowledge or expertise in different fields, specifically on a software application level². In this paper, we aim to understand/define customization needs as configuration problems, focusing on related potentials, challenges, and limitations, as well as the role Artificial Intelligence (AI) could play in the near future to address these issues. We, in a simplified manner, differentiate between two categories of configuration-related tasks/problems: 1) Configuration tasks relevant at the "*design time*" of a smart home, i.e. when a smart home is initially planned, and 2) Configuration tasks relevant at "*run time*", i.e., when the smart home is already in operation. Before delving into the specifics of AI integration, we exemplify state-of-the-art approaches to such configuration tasks from our own work.

3. Pre-AI Smart Home Configuration

The variants of smartness offered are vast; however, the possibilities for adopting the respective technology for an average end consumer are relatively limited. Related information is available, but it is heavily distributed across various websites, community forums, brochures, and other sources. The majority of the offered solutions are based on single-manufacturer systems characterized by several shortcomings. First, the solutions are presented from the supplier's perspective, emphasizing the functional range of the products and rarely taking into account the user's perspective (e.g., regarding the characteristics of their living environments and needs). A future requirement would therefore be to increase the overlap between available functionality and individualization and customization needs. A second related shortcoming is that functionality not within the supplier's portfolio or product range is neither offered nor discussed. Attempts to overcome different aspects of this problem began before the advancements in AI, and the resulting solutions can be classified as falling somewhere between conventional approaches to smart home systems and prospective AI-based tools. These solutions offered a configuration based on the integration of smart components from different manufacturers (as well as their descriptions and characteristics), i.e. on linking information and possibilities that were very scattered over different online sources before these tools became available.

3.1. Example Configuration - Design Time

To help specifically naïve users better understand the respective possibilities, the idea of the configurator solution presented below is to guide them through a configuration task on the basis of the user's own floor plan, identifying/selecting conventional equipment present in their household and smartifying it with components that support certain needs. A secondary goal of the approach is to educate users on smart home functionality by showcasing different possibilities and comparing their pros and cons (e.g., in terms of installation effort, complexity, or price). The Figure 2 shows a snippet of a configurator system developed in the course of a Master's Thesis [9], which represents a further development of our past work [10, 11].

The system is based on a dialogue that starts by asking users about their smartness-related needs, such as increased comfort (through remote management with a smartphone), energy savings, and safety (e.g., burglar prevention, activity deviation recognition). Based on this initial selection, a backend system pre-computes appropriate example solutions. In the example, the user has selected energy savings, and the system and user have cooperatively identified an existing radiator in the living room as equipment that should be made smarter. The system proposes connecting a compatible Shelly smart thermostat to this radiator. The process can be repeated for each room and a number of equipment items and components to generate a satisfactory solution. In most cases, however, smart components are available from different manufacturers. To ease the choice between them, the system would analyze the necessity of add-ons (e.g., gateways, adaptors) and contain explanations and ratings, which could

²In this position statement, the legal restrictions and requirements, e.g. certificates to be allowed to integrate components in electrical wiring, are not addressed explicitly but are, of course, relevant.

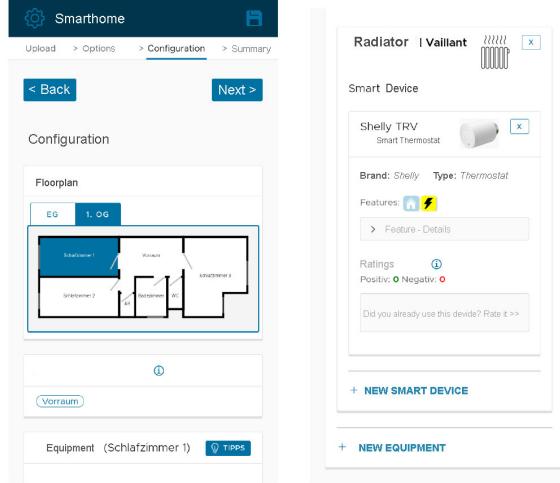


Figure 2: Example Configuration Step, adapted from Leustik, 2025

stem from other consumers or professionals who have experience with certain components. This add-on information should help in identifying the smart components that optimally meet the user's requirements.

3.2. Example configuration - Run time

When consumers are in a comfortable situation where their smart system works as needed and expected, situations may arise when functionality needs to be changed. In our view, this situation would constitute a reconfiguration problem, with the central goal of reusing existing infrastructure and, in this way, also contributing to sustainability. For example, a family member is an adult daughter who started studying abroad, resulting in significantly changed heating requirements in certain rooms. Current smart thermostats typically allow for local programming or switching between pre-programmed standard settings (e.g. weekdays, weekends, holidays). Therefore, simply selecting "holiday" for the rooms the daughter typically uses when she is absent would likely resolve the issue. Instructions for implementing these changes could be provided in the configurator shown in 2, as in the example above, provided that all components and their specifications have been integrated in the floor plan.

Another example could be that the inhabitants are not satisfied with their lighting situation; they want to exchange a light source that is already smart but only offers an "on" and an "off" status for a dimmable light source. Such a change would already initiate a configuration problem with different variants; for example, would only the light bulbs be exchanged for dimmable ones, and the lamp itself would be kept? This approach would probably require exchanging the light switch for a dimmer; if the respective light can be switched from several positions (as this is a typical case in many living rooms), the switch/dimmer components would have to be coordinated, for example, by centrally managing dimming from a device in the household's fuse box. This basic use case already involves several configuration problems, and we have not even touched on software aspects (e.g., relevant when the goal is to allow dimming from a smartphone). These kinds of problems can be not only complex and confusing but also elaborate and expensive (e.g., when hiring professionals). Moreover, in a critical view of the pre-AI configuration approach discussed above, the system would require a comprehensive knowledge base containing all alternatives (e.g., dimmers in the room, in the fuse box, or elsewhere) and would need to visualize/compare the pros and cons in an understandable manner.

4. AI-based smart home configuration

4.1. Related work

Already before the current hype of generative AI / LLMs, AI was thematized in the context of smart homes. For example, Kastner et al. [12] emphasized the potential of AI-based automation (in the domain of energy efficiency) based on Artificial Neural Networks (ANN) in 2010. In 2020, Bicakci [13] highlighted the relevance of AI-generated algorithms used for automating smart home functionality in simulated environments, while also pointing out the potential limitations of such algorithms in real-world environments (e.g., in terms of errors).

Kopytko et al.[14] considered the connection between smart homes and AI as a promising area for new implementations/applications in 2018, for example, to overcome problems related to the variety/diversity/incompatibility of offered solutions. Jahanbakhsh et al. [15] propose retrieval-augmented generation of LLM for the automation of daily routines, or as they put it, "*smart-home orchestration*". Adaptive automation is exemplified on the basis of OSGi-based³ smart home platforms in combination with LLMs. Anik et al. [16] show the possibilities and limitations of automated configuration/programming of smart home functions in the context of YAML("a *human-readable data serialization language*"/Home Assistant. Although not explicitly addressed, the work can be considered relevant for deriving use cases for the utilization of AI (specifically in the context of platforms such as Home Assistant).

The explicit utilization of conversational generative AI, to our knowledge, is not addressed in the related literature in the context of Smart Home Configuration. However, there are a few works from related fields. One example from the field of CSP (Constraint satisfaction problems) by [17] analyzes the application of LLMs for constraint modelling. Another example from the field of conceptual modelling is provided by Fill et al. [18], who used ChatGPT to generate ER (entity relationship) diagrams.

4.2. AI at Smart Home Design Time

We took the example use case presented in section 3 and asked different AI engines for solutions based on the following prompt:

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I have a Vaillant radiator in my living room and I want to make it smart. What possibilities do I have?
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Listing 1: Prompt "Smart Heating"

The answers of Google Gemini (Chrome Browser Integration) and Chatgpt 4.0 Dialogue Interface are as follows:

The provided answers differentiate themselves by several characteristics. Gemini directly focuses on advanced smartness, concretely, an integration in MyVaillant. The benefits are motivated, but not the disadvantages (e.g. being a closed system). In this regard, ChatGPT provides a broader variety of solutions, starting by proposing simple and independently working smart thermostats from different manufacturers, also mentioning the manufacturer platform MyVaillant (this part was exchanged in the figure by "...", because it is comparable to the information provided by Gemini), and finally discussing the possibility of integration in cross-platform solutions (e.g. Alexa, Homekit, etc.). What can also be considered positive is showing the pros and cons of the proposed solutions in an overview table.

4.3. AI at Smart home Run Time

A suitable example, in a way similar to the dimmer problem described above, was brought to the author's attention and evaluated in the context of this paper. A homeowner who already utilizes a smart home environment (Alexa) wants to integrate another smart lighting system in a new living room wall unit

³OSGi Alliance (formerly Open Service Gateway Initiative) - a Java-based component platform that eases the development of complex systems, such as smart homes

To make your Vaillant radiator smart, you can either [upgrade to a smart thermostat](#) like Vaillant's **sensoCOMFORT**, **sensoHOME**, or **sensoROOM**, or [install smart radiator valves](#). These options allow you to control your heating remotely via a smartphone app or voice assistant like Alexa or Apple HomeKit. 

Here's a more detailed look at the possibilities:

1. Smart Thermostats:

Vaillant's senso range:

These thermostats (sensoCOMFORT, sensoHOME, sensoROOM) connect to the myVAILLANT connect internet gateway and the myVAILLANT app, allowing you to control your heating from anywhere. 

Compatibility:

Vaillant smart thermostats are designed to work with most Vaillant heating systems manufactured from 2006 onwards. 

Integration:

You can integrate them with other smart home devices like Amazon Alexa or Apple HomeKit for voice control. 

2. Smart Radiator Valves:

Functionality:

These valves replace your existing thermostatic radiator valves (TRVs) and allow you to control the temperature of individual radiators.

Control:

You can adjust the temperature of each radiator remotely via a smartphone app.

Benefits:

Smart radiator valves help you optimize heating in specific rooms, potentially saving energy and money. 

3. Internet Gateway:

- myVAILLANT connect:** This gateway connects your Vaillant heating system to the internet, enabling smart control and remote access. 

- Integration:** It works with Vaillant boilers, heat pumps, and hybrid systems. 

- Benefits:** It allows you to monitor your heating system's performance, receive energy usage insights, and optimize your heating for efficiency. 

4. Smart Home Subscription:

Vaillant's Smart Home Subscription:

This subscription provides access to expert support, remote diagnostics, and helpful tips for maintaining your heating system.

Benefits:

It helps ensure your heating system runs smoothly and efficiently, potentially saving you money on energy bills. 

2. Whether you're already using a **Vaillant boiler with controls**, and
3. Your desired level of **smart integration** (voice control, app scheduling, room-level control, etc.).

SCENARIO 1: Traditional Radiator with Thermostat Valve (Most Common)

If your Vaillant radiator has a standard thermostatic radiator valve (TRV), you can simply replace it with a smart radiator thermostat.

Option A: Smart TRV Replacement

Replace the manual TRV with a smart one. Works standalone or with a hub.

Features:

- Room-by-room temperature control
- App control and scheduling
- Can work with existing heating system

💡 Popular Products:

- tado° Smart Radiator Thermostat
- Netatmo Smart Radiator Valve
- Eve Thermo (HomeKit only)
- Bosch Smart Radiator Thermostat

⚠️ These fit most M30x1.5 TRV valves. Adapters are often included.

SCENARIO 3: Full Smart Heating System (Zone Control)

For advanced setups or multiple zones, you can combine a **smart thermostat** system with multiple smart TRVs.

Option C: Complete Smart Heating System

E.g., tado°, Netatmo, or Honeywell evohome

Features:

- Central control of heating schedule
- Room-by-room TRV control
- Open window detection, geofencing, etc.

Integration:

- Works with Alexa, Google Assistant, Apple HomeKit, IFTTT
- Some systems (like tado°) can connect to eBUS-compatible boilers using an extension kit

Power & Installation Notes

- Most smart TRVs are battery powered and replace the existing manual head
- No plumbing work needed—only mechanical replacement
- Some systems may need an **Internet bridge or hub**

Summary Table

Solution Type	Room Control	Boiler Control	Smart Home Compatible	Install Difficulty
Smart TRVs only	Yes	No	Yes	Easy
Vaillant vSMART / myVaillant	No (unless paired)	Yes	Limited	Medium
Smart thermostat + Smart TRVs	Yes	Yes (modulating if eBUS-compatible)	Yes	Medium

Recommendation

If you're just starting:

- Start with **smart TRVs** (like tado° or Netatmo) to control individual rooms.

If you already use a **Vaillant boiler**:

- Consider **myVAILLANT connect** or **vSMART** for boiler integration.
- Pair with smart TRVs for full control.

Would you like me to help pick a solution based on your exact boiler model or what ecosystem you already use (HomeKit, Alexa, etc.)?

Figure 3: Side-by-side comparison of results provided by Google Gemini and ChatGPT 4.0

to be purchased. Following the improved performance in the previous example, ChatGPT was asked to provide a proposal. The results look similar to the ones presented in Figure 3 and can be summarized as follows:

- The light source in question is named Mittled, but cannot be made smart directly. ChatGPT explains that a controller (Tradfri) is required.
- The system could then be controlled via a proprietary remote control or connected to a smart gateway, which exists in two versions.
- The gateway has to be allowed to access the Alexa ecosystem, ChatGPT describes the procedure to be performed in the Alexa app.
- Examples of possible Voice commands are provided to show how the new components could be controlled in the context of the existing environment
- Finally, a video showing the necessary steps and a summarizing list are provided.

The example underlines the potential of AI and also gives an idea of sustainability in the context of smart homes (by combining existing with new smart components).

5. Discussion and Conclusion

In this paper, we tried to exemplify the potential of conversational generative AI platforms in supporting smart home configuration tasks. The preliminary conclusions to be drawn are mixed in several aspects.

The solutions provided by AI platforms are impressive in terms of combining almost all information that is distributed over different online sources, and, in many cases, tedious to find and difficult to mentally connect in the past. We tried out several problem prompts (which are not completely presented in the paper due to space constraints), for example, asking for the possibilities of connecting/integrating smart home systems of different suppliers. One of them is based on OAuth⁴, allowing the reciprocal exchange of data between different cloud platforms. The solution, which took us several days in the past, was provided by AI within seconds, including information on how to register with the two platforms to be connected, how OAuth works, etc.

As mentioned in the context of the work by [9], we initiated our efforts at a time when generative AI was not widely available, with the goal of integrating related information distributed across multiple sources and storing it locally. Due to the easy accessibility of LLMs, this problem, meanwhile, appears to be obsolete or solved. The educational aspect, which we tried to cover in our approaches, is also covered by AI tools appropriately, at least by some of them. In the examples shown, specifically ChatGPT adequately explains the pros and cons of proposed solutions. Because of the quantity and variety of sources the different AI platforms can access, it is probable that even solutions for exotic combinations of smart and conventional devices can be made possible with the help of AI, and in this way contribute to sustainability, because devices considered as old or outdated would still not have to be thrown away. Such a problem occurred in our past work, in a field study within the context of active and assisted living (AAL)[19]. We had to manually find a solution to connect 380V-operated kitchen stoves (which are more or less standard in Austria) to a smart home system. The benefits of this approach are sustainability (because still-working devices do not have to be exchanged) and, even more important, usability and user experience; because of allowing people to keep their familiar devices while still benefiting from smartness. Not surprisingly, AI already offers a solution for such problems as well.

However, some weaknesses/gaps of AI-based results can be identified and will probably inspire future research. The proposed alternatives still require a certain level of knowledge in the field to be able to evaluate their usefulness. For example, alternative switching components that are principally equivalent might require different backend infrastructures with significantly different complexity. One component could be able to directly communicate via Bluetooth/Wifi/ Zigbee, while the other is based on a proprietary local gateway and/or the cooperation of separate cloud systems. This is something that laypersons might not be able to fully evaluate, but would require the consultation of experts. This is another aspect that should be investigated in future work, based on the following aspect. The majority of solutions in the context of smart homes are based on electric devices, the installation of which requires qualification and certification. This task is (also in conventional settings) covered by local SMEs. These SMEs are in a difficult role in several aspects: They are the first address for the end consumers because of their reachability and expertise and, probably existing customer relationship. However, they are - as in the pre-smart eras - responsible for the correct installation of components, their function, and - in case of problems - their adjustment or repair. At present, they have to deal with the problem that smart components not only require knowledge in their core expertise (e.g. electrical engineering, electronics) but also a certain level of knowledge, if not even expertise, in the field of informatics (software development, parametrization and maintenance), which they are (on average) only limitedly trained in. This presents a specific challenge when customers request solutions that require functionality or components not included in the SME's standard portfolio. On a non-representative and scientifically sound level, the authors have observed that SMEs advise their customers against smart solutions due to the expectation that they will be held responsible for problems by the customer, for which they may not expect support from the supplier's side. The target group of SME would probably

⁴(short for Open Authorization), a standard for granting access and data exchange between different web-based systems as an alternative to user/password-based access

have to be involved in future solutions based on AI, to sort of "moderate" the proposed solutions.

A final aspect is the representation of results. Our past approaches were, as this seems to be the state of the art in the field, based on floor plan representations of smart home solutions. Suppliers such as Gira, Bosch, Feelsmart (for a comparison see [9]) also base their configuration solutions on this approach. In future work, we will investigate how well AI performs based on pictorial representations of homes and how this influences the results.

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Declaration on Generative AI

During the preparation of this work, the author used Google Gemini Chrome Plug-In and ChatGPT 4.x Prompt System for deriving the AI-related examples presented in this paper. Further, the author used Grammarly for typo and grammar correction and text adaptation. After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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