Intelligent Smart Home System Using Amazon Alexa Tools

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Abstract 1

The paper is devoted to developing an intelligent, innovative home system using voice assistant technologies - Amazon Alexa. This platform is designed to simplify human life and help to cope faster, more conveniently and safer with everyday tasks. The system constantly collects data and analyses user commands to create history files to generate behavioural scenarios using the neural network in the future. The system's primary purpose is to monitor, track, manage, and integrate with people's methods in their homes. The intelligent home system presented in this paper allows you to track all failures of integration systems. One of the critical factors of this information system is that the module is developed and implemented allows integration with previously incompatible hardware from Xiaomi and programmers "brains" of the voice assistant from Amazon. The first company to market a wide range of devices that can be used in the smart home of the 21st century, but unfortunately, Xiaomi does not have enough integration with voice assistants of global brands. It is one of the problems that this system is designed to solve. After all, by integrating with voice assistants, you can significantly simplify the process of controlling the house by turning on or off various appliances or systems, setting or configuring multiple means and methods of comfort, such as temperature or underfloor heating. The innovative home systems currently on the market are evolving extremely rapidly, exponentially. At present, even systems are known where, controlling the house remotely, being at the other end of the city, the user can start cooking in the kitchen, or analyse what products are missing in the refrigerator, or take a bath in advance. The main point in such a system is the convenience of the application, which is used to control a smart home. The more functions in such an application to manage the system, the more convenient it is, as practice shows. And here come the aid of voice assistants, where the user does not need to spend time flipping through the menu and looking for the correct functionality. All you need is to say the sentence clearly, the command to be executed. Then the system will trace the order into the code and, using protocols, send it to systems integrated with the house, such as security systems: cameras, motion sensors, etc. The research methods in this master's thesis are the analysis and comparison of voice assistants for integration with smart home and the study of transport protocols for data transmission between hardware devices. The primary purpose of this system was to create a "bridge" for the integration between hardware and software of two different companies from different parts of the world. This integration will open up great opportunities for a combination of devices and programs and make the process of creating an intelligent home more flexible and comfortable. The server part of the system is implemented using a development platform from Microsoft - .Net. It is the best choice because it is evolving extremely fast and provides many new features with each version. This technology is used by large business projects and small non-commercial projects. It is ideal for solving both large resource-intensive and time-consuming tasks and minor ones in which the main criterion is the speed of execution. NoSQL is chosen from the databases side because we need to store large amounts and arrays of data, and atomicity and trans-actionality are not as crucial as in systems that use relational databases. The client-side is built as simply as possible because, in this system, the critical factor is voice control, not the web interface or mobile application. The object of research is the mechanisms for creating and managing innovative home systems with the help of voice commands. The subject of study is creating, managing, and accumulating data from components and modules connected to smart home and based on them to develop

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scenarios of system behaviour. The research aims to present and analyse the functional capabilities of this system, the formation of methods, and its integration with the hardware of incompatible companies. The implemented system covers all the basic needs required to perform the functionality, as shown in the UML diagrams.

Keywords
The smart home system, voice assistants, system integration process, process optimisation, suite and software, application interface, smart house, google assistant, decision support system, smart house system, NoSQL database, compatible smart home device, personal assistant, non-relational database, video service, Amazon Alexa, digital image processing, smart assistant, software development, information system

1. Introduction

Technology plays one of the critical roles in modern society. They surround us. We face them every day, simply taking the phone in our hands. So why not make this process of interaction more profitable at the household level. In a modern house, many systems help improve human comfort. However, unfortunately, the process of maintaining and monitoring that everything is working well is still done manually, using a flashlight and a screwdriver. So why not use the technologies that are now available to humanity and not fully automate the whole process? It is one of the critical aspects of this final work. Simplify and make human life safer with smart house management solutions. In modern human reality, all home system monitoring systems can function automatically until a specific time when everything works in one working scenario. At the same time, some human resources are needed to manage and monitor such systems. Because such systems are complex in themselves, an entire administrative department must maintain the proper operation of all systems and debug them on time. That's why voice assistants come to the rescue to reduce the cost and cost of services. With the help of artificial intelligence systems, learn to appropriately interact with all sensors of lighting, ventilation, or water supply in the house or apartment. Such assistants could perform analysis and monitoring of the entire administrative department and signal if something in the home or apartment went wrong.

Moreover, they can be programmed to a scenario if something goes wrong to limit electricity or cut off the water supply, and the system does it much faster than human resources because of the stress factor and the human factor in the case of an abnormal situation for a computer system is absent. Using the term "smart home", it should be understood that it is a system that must recognise specific problems occurring in the building and respond accordingly: one of the systems can control the behaviour of others by pre-designed algorithms. One of the main features of the intellectual building is integrating individual subsystems into a single managed complex. In the American and European markets, "Smart Home" is already considered quite common, and in some states, such smart homes or their elements installation in every second house. However, about Ukraine, this technology is only gaining in popularity and has not yet reached the same level as Europe. Therefore, from my perspective, this system is relevant, especially within our country, to better demonstrate all the benefits of comfort and safety provided by this technology. Analyse the smart homes of other countries, configurations and installation tools. Investigate the methods of integration of such systems with other intelligence. It is necessary to solve the following tasks:

- Critically analyse existing models for start the processes manually and activate each device separately at the right time [1-2];
- Analysis of literature sources about control and monitor specific processes in the house, depending on the scenario and based on how they are programmed [3-4];
- Explore the activities of alternative systems, their disadvantages and advantages;
- Analyse possible ways to improve existing systems;
- Selection of tools and methods of implementation;
- System design and development.

The research object is the market for system solutions in smart homes. The research subject is ways of aggregation of device control for smart homes of different manufacturers, an adaptation of the user interface according to modern needs, automation of processes, the course of which is possible without

human intervention. The paper proposes a set of solutions for designing a smart home system with new features and integrations. It consists of developing a software tool, with possible further use in residential and office premises to increase the comfort and safety of people who are there. Enterprises can use conclusions, suggestions, and recommendations in work on the main directions of the research, firms, and developers to design better information systems.

2. Related works

Every smart home needs its voice assistant to connect to all systems and enable human-machine interaction through voice control. It isn't easy to imagine a smart home that does not have voice control in our world [5-7]. Currently, the most popular are three voice assistants, Amazon Alexa, Google Home and Siri HomePod. We will compare these three systems with each other to choose and expand the best.

Figure 1: Capabilities of a smart home

Figure 2: Currently the most popular voice assistants

If we want to create a smart home, we will need to choose a smart helper. Then, we can use it to control compatible smart home devices (such as smart lights and smart thermostats) using an app or voice commands by choosing a smart assistant. We will also be able to ask a smart assistant, play music, make phone calls and more. The three primary smart helpers are Alexa from Amazon, Google Assistant from Google and Siri from Apple. But which smart assistant is best for our research? Here are the differences between Google (Google Assistant [5]) and Alexa (Amazon Alex [6]), and Siri (Apple Siri [7]) to make the right choice for your smart home (Table 1).

Table 1
Competence of analogues [5-7]

Music service	Alexa	Google Assistant	Siri
Amazon Music	Yes	No	No
Tidal	Yes	No	No
Tuneln	Yes	No	No
Spotify	Yes	Yes	No
SiriusXM	Yes	No	No
Pandora	Yes	Yes	No
iHeart Radio	Yes	No	No
Google Play Music	No	Yes	No
Deezer	Yes	Yes	No
Apple Music	Yes	Only for iOS devices	Yes
YouTube Music	No	Yes	No

Therefore, based on the fact that the smart home system implemented with the help of a voice assistant is very relevant today and allows you to make modern life more comfortable and safer. After a critical review and analysis of the literature, Google Assistant and Alexa received the highest scores in our final calculations. Google equalled Alexa in the number of first places. Meanwhile, Siri was in

third place in both dimensions, although it was only slightly behind the total number of points [1-8]. In general, all virtual assistants were more capable than before, showing improvements in the field of voice assistants.

Figure 3: Icons that appear when calling Siri, Google and Alexa.

3. Material and methods

This chapter describes developed information systems related to IoT (Internet of Things) and voice assistants technologis [9-10]. The main point is that these technologies will become very popular and valuable in the future. Therefore, this is the reason why I have chosen this field for investigation.

Technology plays a crucial role in modern society. They surround us. We face every day, simply taking the phone in our hands. So why not make this process of interaction more profitable at the household level. In a modern house, many systems help improve human comfort. However, unfortunately, the process of maintaining and monitoring that everything is working well is still done manually, with a flashlight and a screwdriver. So why not use the technologies that are now available to humanity and not fully automate the whole process? It is one of the critical aspects of this final work. Simplify and make human life safer with innovative smart house management solutions. In modern human reality, all systems for monitoring home systems can operate automatically until a certain point, while everything works on one working scene. At the same time, some human resources are needed to manage and monitor such systems. Because such systems are complex, an entire administrative department must maintain all systems' proper operation and promptly debug them. That's why voice assistants come to the rescue to reduce the cost and cost of services. With the help of artificial intelligence systems, learn to appropriately interact with all sensors of lighting, ventilation or water supply in the house or apartment. Such assistants could perform analysis and monitoring of the entire administrative department and signal if something in the home or apartment went wrong.

Moreover, they can be programmed to the scenario if something goes wrong to limit electricity or cut off the water supply. The system does so much faster than human resources because the stress factor and the human factor in an abnormal situation for a computer system are absent. Using the term "smart home", most people still do not understand all the "greatness" of this term. The term includes the meaning of future prospects (Fig. 4), namely the opportunities that this technology will offer humanity in the future. It is expected that human life will be simplified compared to today, thanks to these pre-developed algorithms. One of the main features of the presented technology is its modularity. Namely, we have several modules that are no different from ordinary objects that surround us in the range of household tasks. For example, a "smart lamp" looks like a normal one and performs the same functions. But unlike the usual, it can not be connected to the Internet because of the wireless network and control unit. The essence of "smart home" technology is its modularity. You can take many smart gadgets and make them a composition of an intelligent system from incredible movies about the future, which is not so far away.

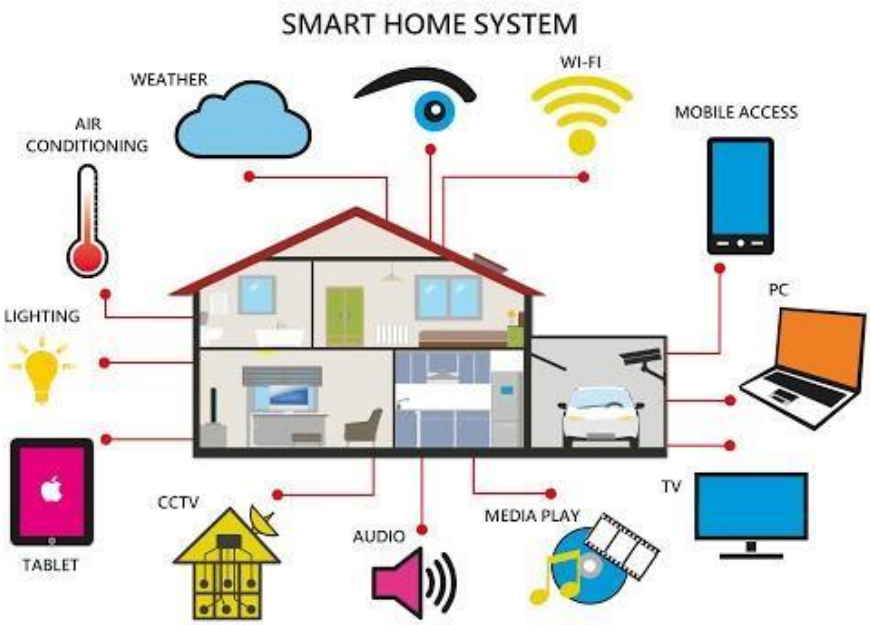

Figure 4: The systems that make up a smart home

In addition to protection and monitoring, this technology can be used for both work and leisure. For example, in the United States, 31% of the population already uses smart speakers from Amazon and Google. "Smart home" is a relatively new technology for the Ukrainian market, but thanks to a well-developed IT infrastructure in the cities of Ukraine, it will quickly gain popularity. There are already people and companies that offer to integrate smart gadgets into everyday life and make them more comfortable. In addition, as always, there is a coin on both sides. On the one hand, there is unlimited space for assembling different kinds of systems and combining different smart devices. However, on the other hand, there is a lack of software solutions to make the system integral and atomic. That is why the solution presented in this paper will be highly relevant, especially for our conditions, allowing you to integrate simple, cheap devices into the system and make the technology as flexible as possible. In the American and European markets, the "smart home" is already considered quite common, and in some states, such smart homes or their elements are installed in every second home. However, about Ukraine, this technology is only gaining in popularity and has not yet reached the same level as Europe. Therefore, from my perspective, this system is relevant, especially within our country, to better demonstrate all the benefits of comfort and safety provided by this technology.

The purpose is analyse the scope of smart homes in other countries, configurations and tools for installation. Second, investigate methods of integrating such systems with other intelligent homes based on the following tasks:

- Critically analyse existing models and methods of analysis;
- Analysis of literature sources;
- Explore the activities of alternative systems, their disadvantages and advantages;
- Analyse possible ways to improve existing systems;
- Based on the analysis to choose a method and means of realisation of the system;
- Develop a system based on the results of the tasks solved above.

The object of research: the system solutions market for smart homes. The study subject is Smart gadgets and speakers that are compatible between themselves and can form a smart home system by aggregating connected devices, system monitoring, process analysis and user interface adaptation for maximum ease of operation and configuration in the home. This work is a solution for creating a smart home with maximum flexibility, minimum resources and time, new features and integrations. It consists of developing a software tool, with possible further use in residential and office premises to increase the comfort and safety of people who are there. The results of this study can be implemented at the commercial level as a catalyst for the development of smart home technology and increasing demand for it among the population. The system consists of the minimum cost and the maximum convenience

of configurations for increased safety and comfort of human life. Other companies can also use this system for its development and the possibility of new integrations with other software products. The work presented in the paper is devoted to the development of an intelligent smart home system using voice assistant technologies - Amazon Alexa (Fig. 5) [5]. This platform is designed to simplify human life and help to cope faster, more conveniently and safer with everyday tasks. The system constantly collects data and analyses user commands to create history files to generate behavioural scenarios using the neural network in the future. The system's primary purpose is to monitor, track, manage, and integrate with people's methods in their homes.

Figure 5: Smart speakers Amazon Alexa.

The smart home system presented in this master degree work allows you to track all failures of integration systems. One of the critical factors of this information system is that the module was developed and implemented allows integration with previously incompatible hardware from Xiaomi and programmers “brains” of the voice assistant from Amazon. The first company to market a wide range of devices that can be used in the smart home of the 21st century, but unfortunately, Xiaomi does not have enough integration with voice assistants of global brands. It is one of the problems that this system is designed to solve. After all, by integrating with voice assistants, you can significantly simplify the process of controlling the house by turning on or off various appliances or systems, setting or configuring multiple means and methods of comfort, such as temperature or underfloor heating.

3.1. Systems analysis of the object of study and subject area

The smart home systems currently on the market are evolving extremely rapidly, exponentially [1-2]. At present, even systems are known where, controlling the house remotely, being at the other end of the city, the user can start cooking in the kitchen, or analyse what products are missing in the refrigerator, or take a bath in advance [3-4]. The main point in such a system is the convenience of the application, which is used to control a smart home. The more functions in such an application to manage the system, the more convenient it is, as practice shows. And here come the aid of voice assistants, where the user does not need to spend time flipping through the menu and looking for the proper functionality. All you need is to say the sentence clearly, the command to be executed. Then the system will trace the order into the code and, using protocols, will send it to systems integrated with the house, such as security systems: cameras, motion sensors, etc. The server part of the system was implemented using a development platform from Microsoft - .Net. It is the best choice because it is evolving extremely fast and provides many new features with each version. This technology is used by large business projects and small non-commercial projects [1-2]. It is ideal for solving both large resource-intensive and time-consuming tasks and small ones in which the main criterion is the speed of execution. NoSQL was chosen from the databases side because we need to store large amounts and arrays of data, and atomicity and trans-actionality are not as important as, for example, in systems that use relational databases. The client-side is built as simply as possible because, in this system, the critical factor is voice control, not the web interface or mobile application. During the master’s research work, a study of the market and the latest trends in smart homes was conducted. The implementation of this system was focused on the performance of a software product that will not be inferior to competitors, and at the same time, will be as effective and understandable in use. The first section analysed the literature and other sources and explored the most popular voice assistants and systems that can be integrated with them. We also examined the applications and applications supported by the system and determined the best voice assistant to control this smart home system and connect all possible sensors. Because voice assistants themselves are not allowed to make the interface of a smart home, all interaction with them occurs exclusively through external APIs. The second section describes the functional and non-

functional requirements that are displayed using UML diagrams. Such modelling is increasingly used to understand ways to improve the functioning of the system [5-8]. To make a product release successful, you need to analyse all possible ways to use the system, find all possible causes of system crashes and look at the application from a user's angle and provide full user experience to make the procedure enjoyable for everyday use [9-10].

The work substantiated the choice of methods as well as architectural and software solutions for system design. The main requirements were ease of implementation, good support and interaction with micro-service architecture and non-relational databases. A neural network was also used, which also has an impact on system performance. In the fourth section, the project itself was presented. A micro-service architecture was built, a database was modelled, and code was created and deployed in the cloud service for the uninterrupted operation of the application and the ability to balance the download and increase the number of service instances under heavy load. Even though the system covers all the necessary functionality, there are ways to improve it and sign to expand. It is made possible by choosing a flexible architecture and the latest software tools for creating high-quality computer products.

Therefore, we conclude that the designed and implemented system works exactly as expected at the beginning of this work, adhering to the practical and rapid implementation of all tasks set before it.

Thus, in modern management, without a clear definition of the goal, without identifying the means to achieve goals, the ratio of goals, evaluation of ways to achieve goals, and their effectiveness are not possible to correct operation of the system. Therefore, first, any goal should be specific, that is - to be expressed in both qualitative and quantitative parameters. Secondly, any goal must be accurate, i.e. achievable in particular conditions. Therefore, the construction of the goal tree is carried out "from top to bottom", i.e. in the direction from general to personal goals, through their decomposition and reduction. As foreign practice shows - properly formulated goals of the organisation - is at least 50 % of the success of its activities, because the plans are a determining factor in the strategy of the firm's behaviour in the market and much more. Thus, any organisation cannot exist without targets.

Thus, the following rules should be followed when constructing a goal tree:

- The formulated goal must have the means and resources to ensure its implementation;
- When decomposing goals, it is necessary to adhere to conditions of completeness of reduction, i.e. the number of sub-goals (lower level tasks) of each objective should be enough to achieve it;
- Vertices of the higher level of the system are, in turn, targets for vertices of lower grades;
- The development of the goal tree continues until the person who implements a task has all the means to achieve the overall goal.

Therefore, the goal tree can be used to achieve the effectiveness of information support of management processes [11-18], the development, adoption, and control of management decisions.

With the skills to build a goal tree, you can look much more confidently into the future and more effectively plan both your personal and organisational actions. In the process of building the goal tree of the smart home information system, the following goals were identified [1-2]:

- The general goal is to create a ticket booking information system (Fig. 6) [1].
- Aspects of the general goal and their sub-aspects:
    a. Subject area research;
    b. Analysis of literature sources;
    c. Examination of existing systems;
    d. System description.
- System design: database design (Fig. 7) [1], component design, system analysis.
- System implementation.
    a. The home page displaying all connected devices
    b. Settings / on-page for each device,
    c. Log page to track the timestamps of system malfunctions.
    d. Create an authorization service (Fig. 8) [2].
- Criteria: Data reliability; Data completeness; Data relevance; Structure; Integrity; Hierarchy; Functionality; Performance; Reliability.

As can be seen from the diagram, the user has many different options for functionality to work with the system. These options can be Register or Authorise in the design, Call commands, add new devices, or View reports on the operation of devices saved by the service [1].

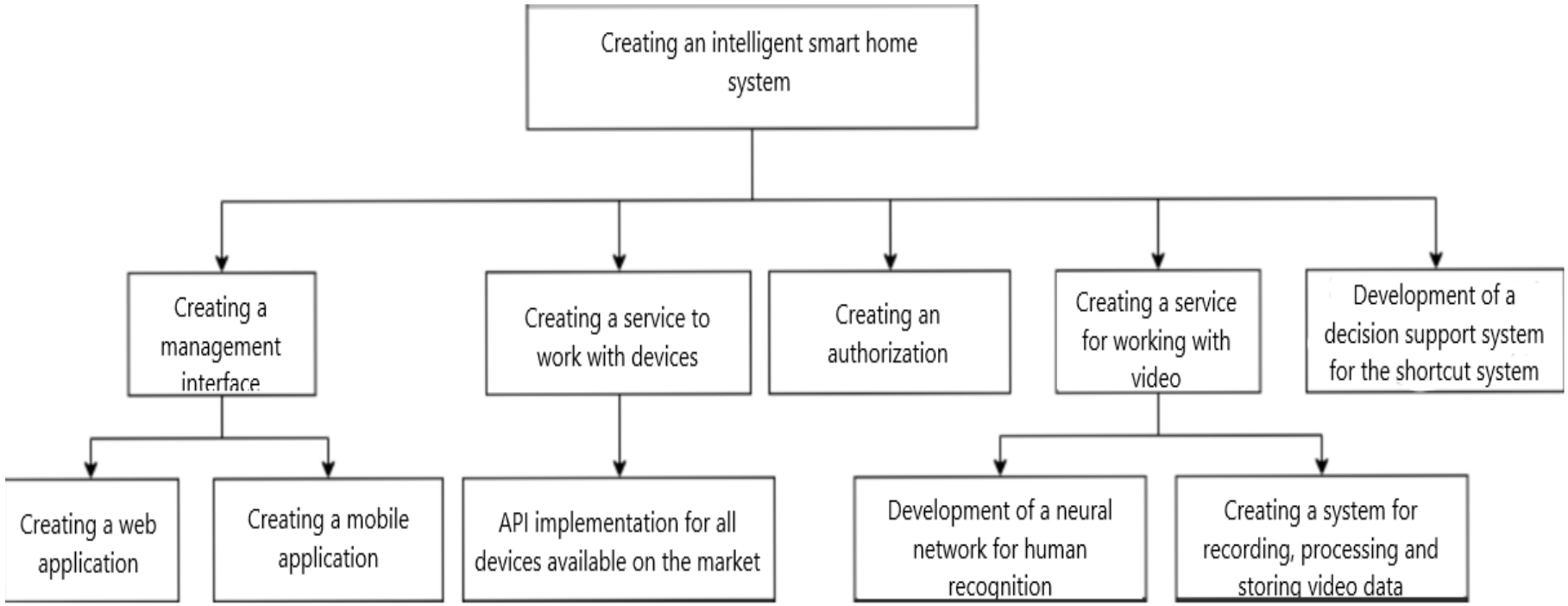

Figure 6: Goal tree

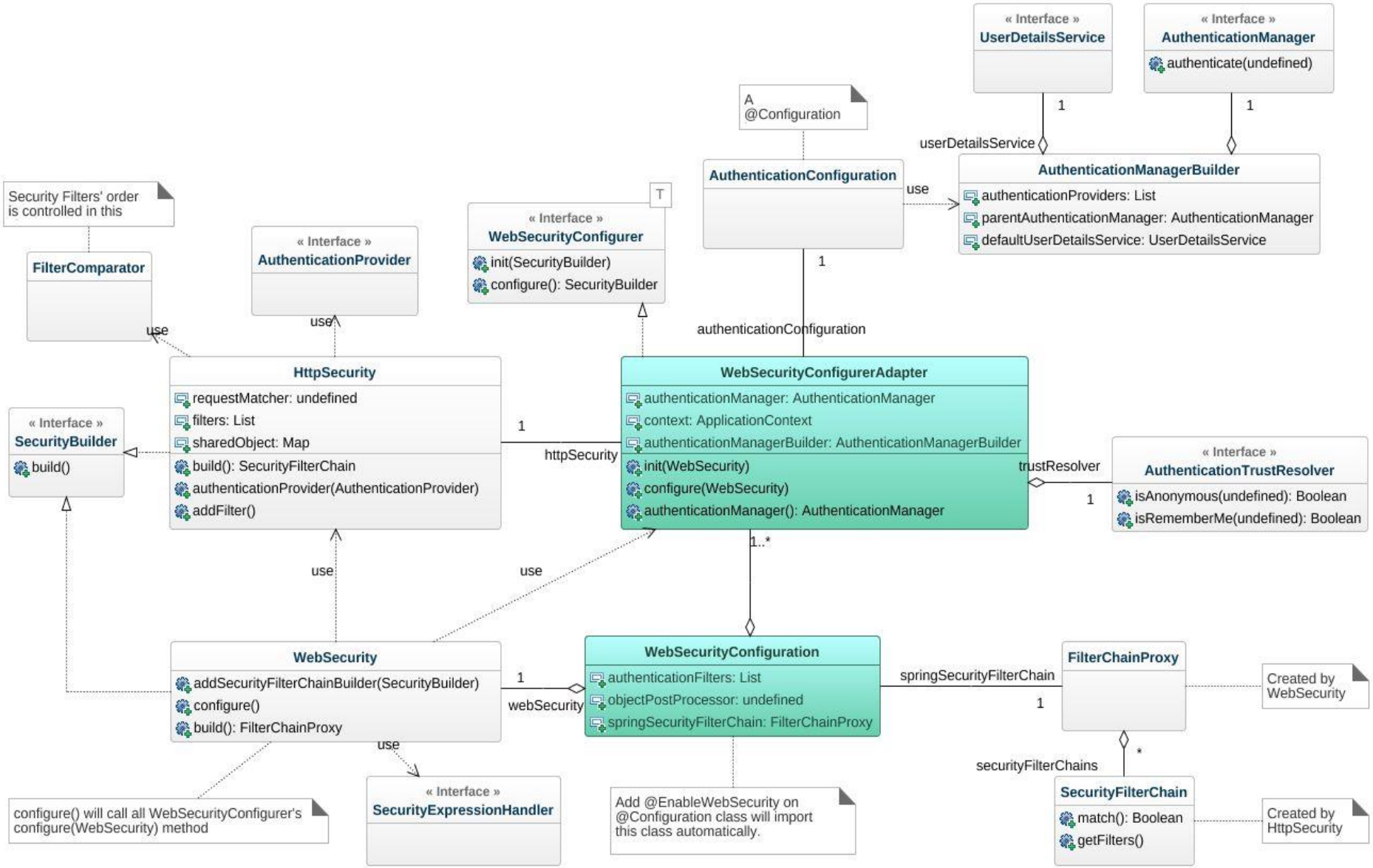

Figure 7: Diagram

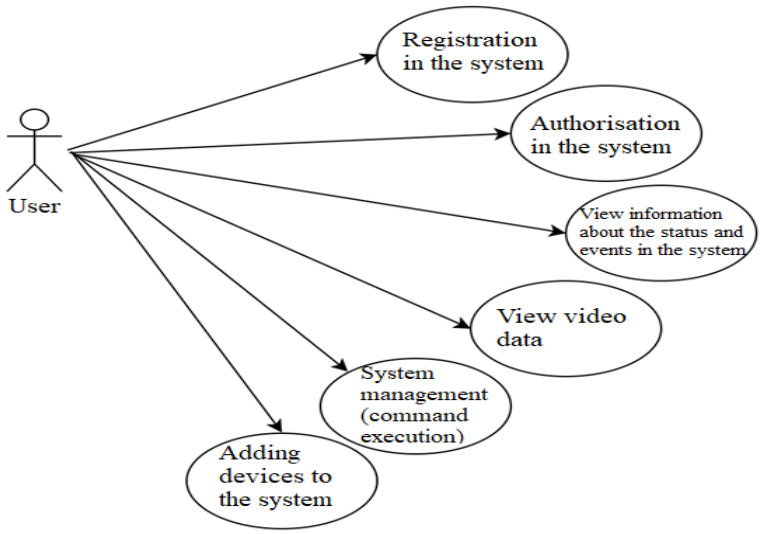

Figure 8: Diagram of use cases

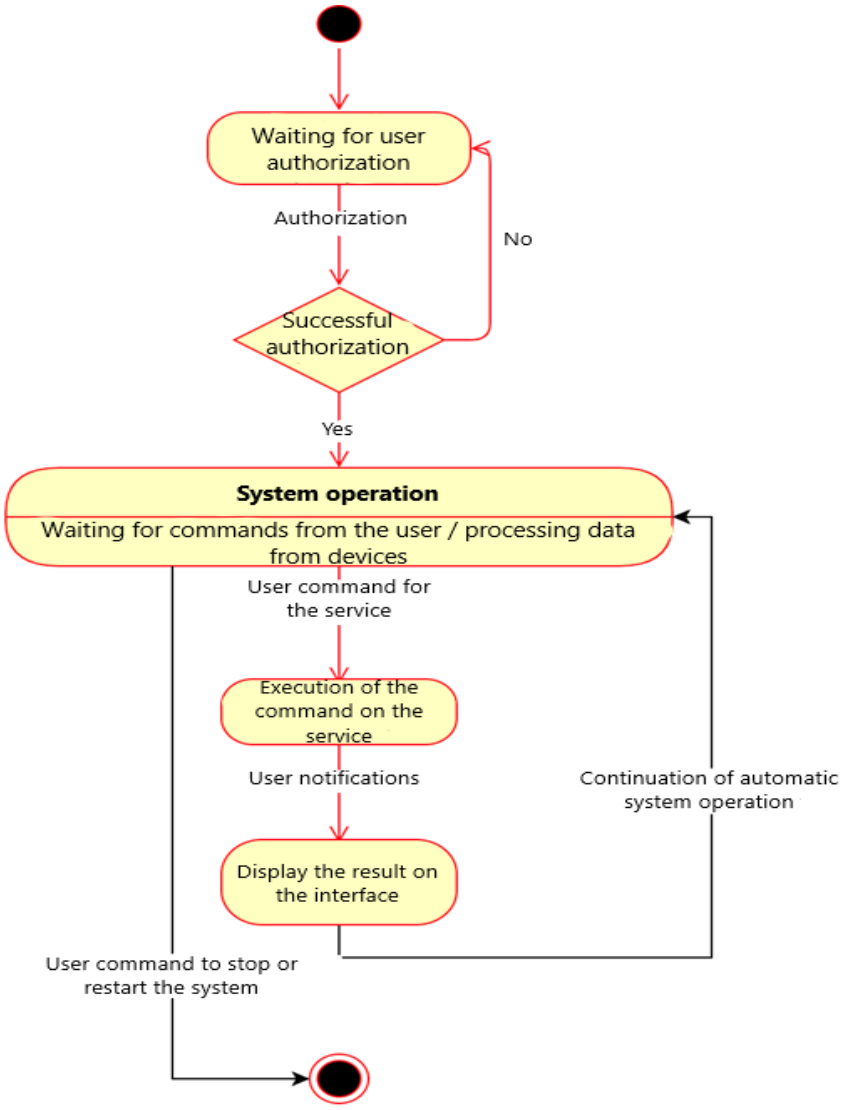

Figure 9: System state diagram

For a better understanding and debugging of the system, building a state diagram (Fig. 9) shows all the possible states in which the system may be at a certain point in time, which can significantly help test the system. The sequence diagram (Fig. 10) will allow you to see the logical sequence of all requests and processes within the system.

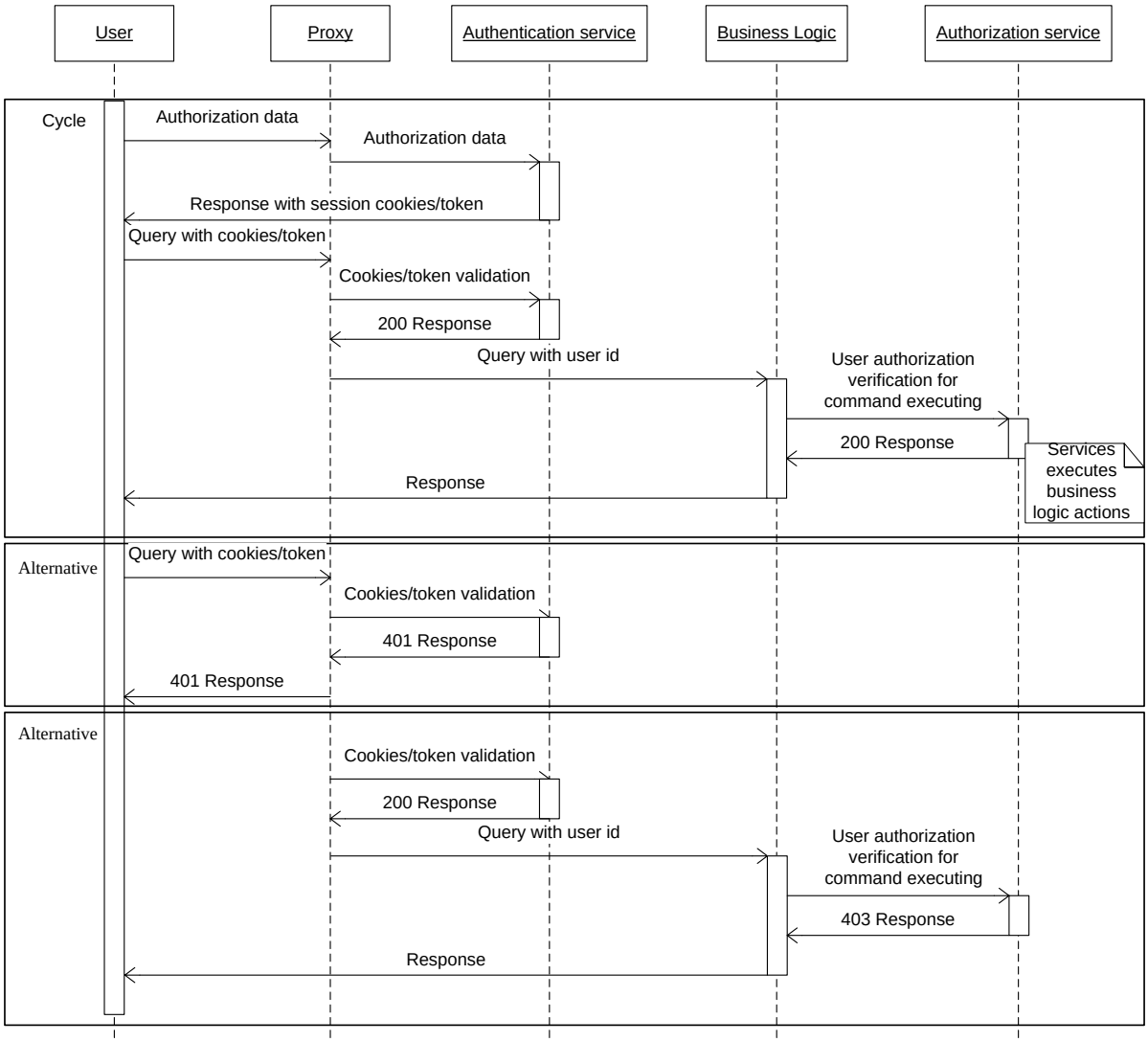

Figure 10: Authentication service sequence diagram

A state machine is any device that stores the status of an object at a specific time and can change the situation or cause other actions based on the received input data. States refer to different combinations of information that an object may contain rather than how it behaves. To understand the various forms of an object, you can visualise all possible states and show how the object enters each state, which can be done with a UML state diagram. Each state diagram usually begins with a dark circle indicating the initial state and ending with a boundary circle indicating the final state. However, state diagrams are not necessarily the best tool for recording overall progress despite clear starting and ending points. Instead, they illustrate specific types of behaviour, such as the transition from one state to another. Therefore, state diagrams mostly depict states and changes.

Rectangles represent states with rounded corners, which are marked with the name of the state. Transitions are indicated by arrows that move from one state to another, showing how conditions change. Below you can see both of these elements at work on a basic chart for student life. Our UML charting tool can help you develop any custom machine state chart.

Like most UML charts, state charts have several uses. The main applications are:

- Images of event-driven objects in a jet system [19-34].
- Illustrations of use scenarios in a business context.

- Description of how an object moves through different states
- Display the general behaviour of the state machine or the behaviour of the corresponding set of state machines.

To better understand the necessary infrastructure, and in the case of micro-services, it is essential, you need to build a deployment diagram (Fig. 11).

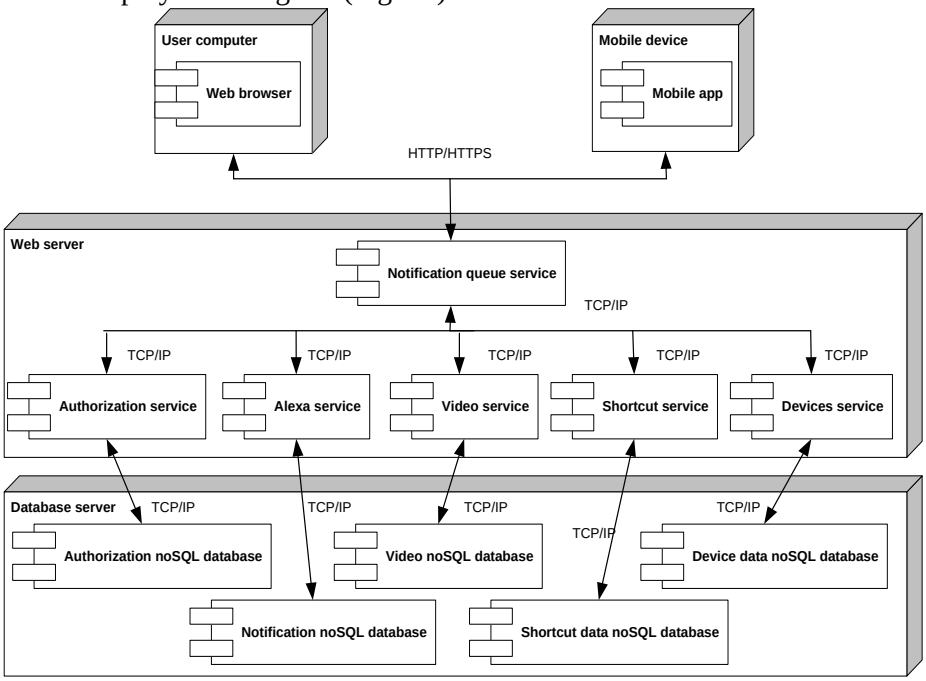

Figure 11: System deployment diagram

Data Flow Diagram is a visual representation of any process or information flow in the system. By displaying the data flow of a procedure or method, DFD helps to understand the process or system under study better, explore its flows, and improve them. In addition, such a diagram is designed to help implement a new strategy or technique. DFD can range from simple overviews to complex granular mappings of a process or system (Fig. 12).

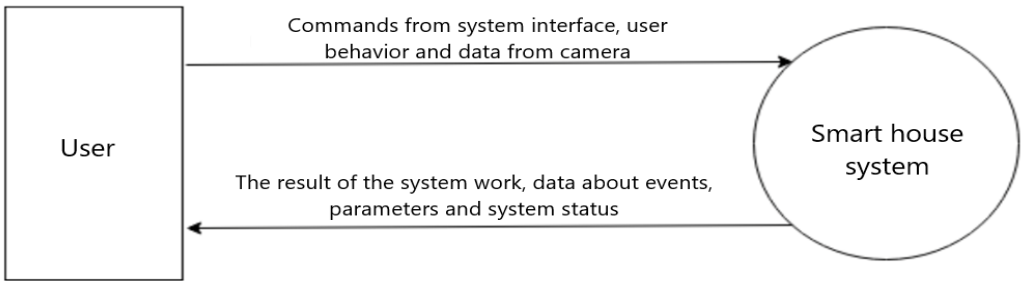

Figure 12: Context diagram of a smart home system

Based on the diagram, the system receives user commands using video cameras and collects user data for further processing. The user, through the devices' graphical interface and direct operation, returns information about events, system status, and process. The next step is to build a first-level diagram - decomposition, which is still a general overview, but they invest in more detail than a context diagram [2]. It will give more detailed information about the methods and flows within the system (Fig. 13). In this diagram, you can observe the transmission flows and data processing processes that connect the main functional parts of the system. The next step will be to decompose each of these processes separately (Fig. 14 - 16). This diagram shows that all messages within the system are stored in a database and also sent for analysis to the shortcut system. From the flow decomposition diagram inside the video service, it is clear that the service is connected to a neural network to search for and recognise faces on video [35-44]. The service also saves video data and allows the user to view it in the future.

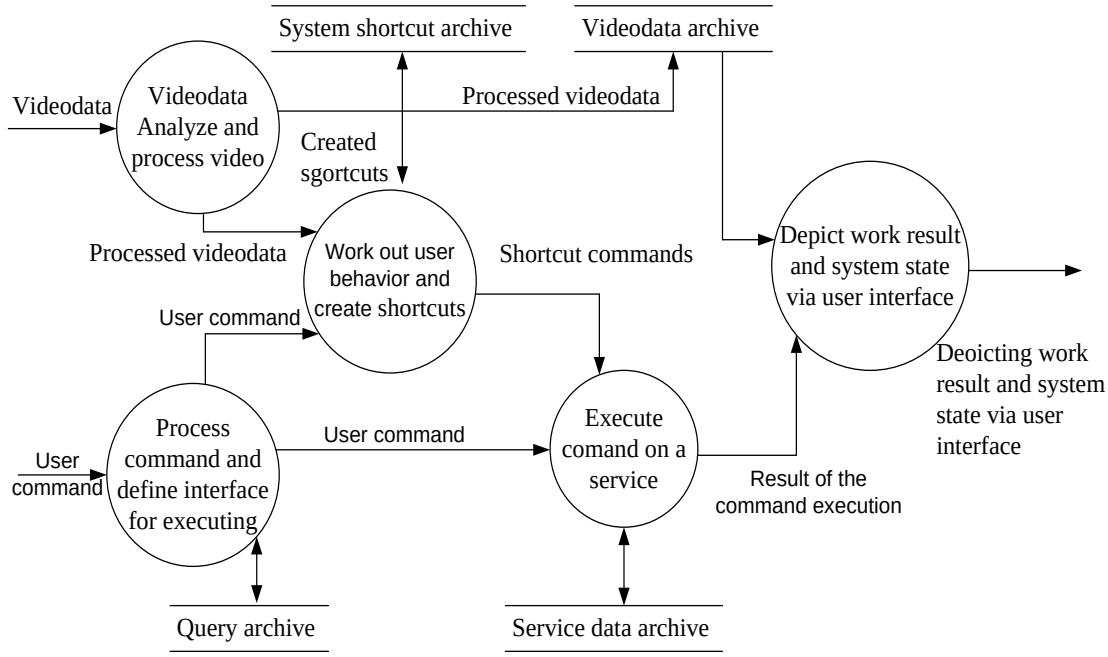

Figure 13: Diagram of the first level of decomposition

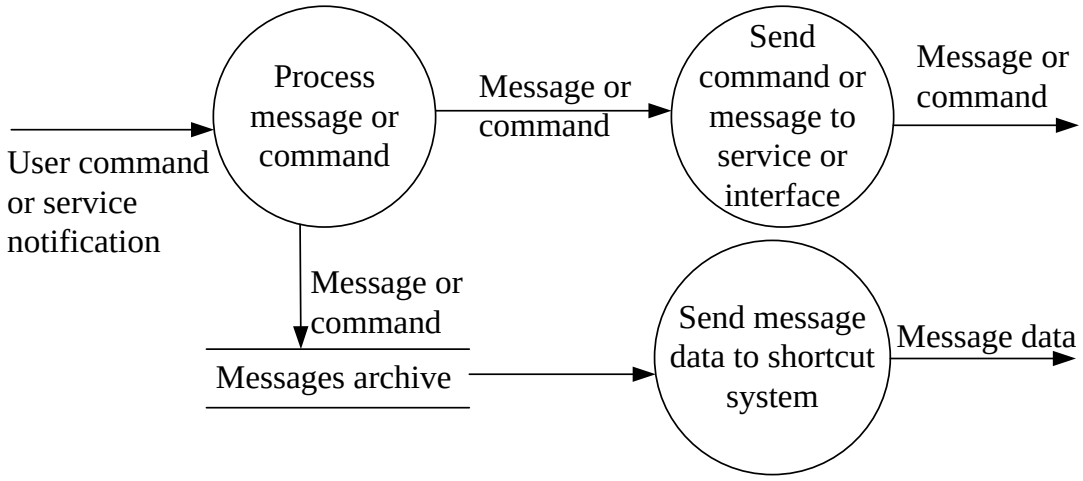

Figure 14: Decomposition of the message queue process

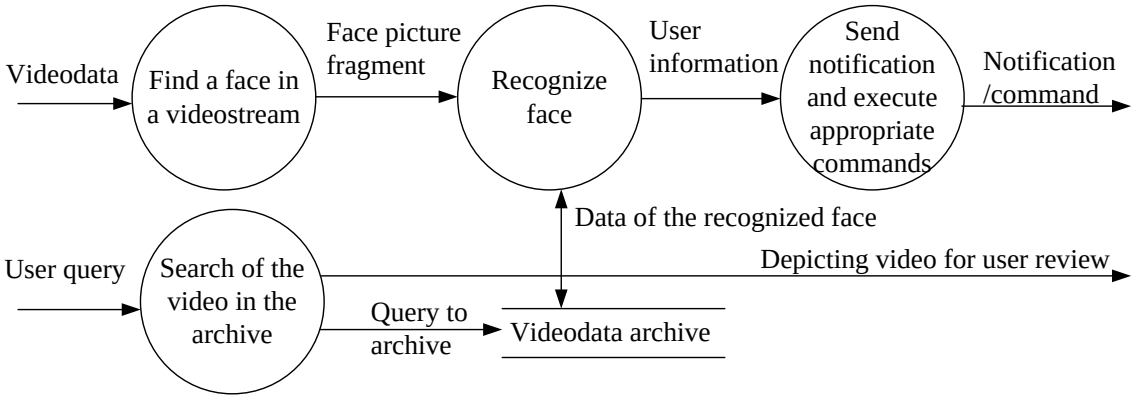

Figure 15: Decomposition of the video analysis process

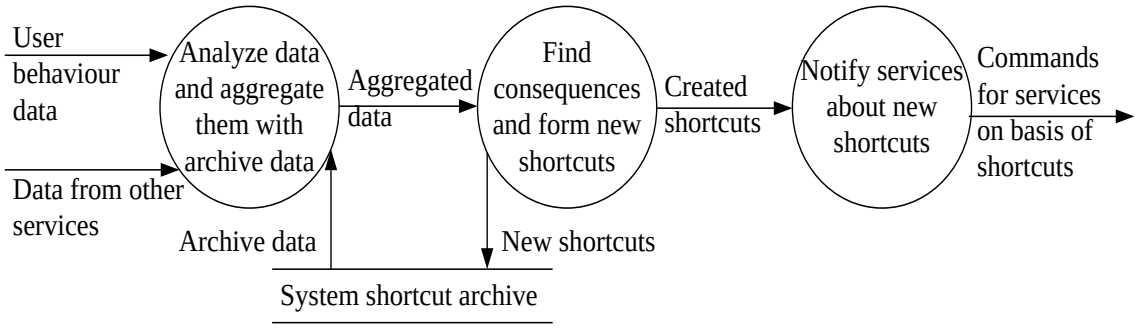

Figure 16: Decomposition of the shortcut system operation process

These diagrams simply break down the processes into more detailed sub-processes. Theoretically, DFDs can go beyond level 3, but this is rare [2]. Level 3 data flow diagrams are pretty complex, which usually does not make sense to break them into detail [2].

This service is designed to analyse all processes and events in the system and create based on the obtained data of specific patterns of system behaviour without user intervention (shortcuts) or offer the possible user options depending on previous use [1]. Other services are relatively simple and do not require additional analysis of the data streams that pass through them [1]. You created it not just to keep it - whether it's team members, your boss, or stakeholders [2], it's likely to be seen by someone else. Charts can be sent directly to development teams, managers, or other parties interested in developing the product, giving the recipient access to the document. Depending on the recipient's role, you can provide them with permission to edit or send the schema only [2]. So, due to the decomposition of all major processes in the system, it became possible to perform a more detailed review and analysis of sub-processes of this system. Data used to establish communication between all processes and sub-processes, both inside and outside the system [1].

3.2. Building a hierarchy of tasks. Analytical hierarchy method

The next step is to determine the type of information system being designed. To do this, use the method of the Analytic Hierarchy Process (AHP). The Analytic Hierarchy Process (AHP) is a method of organising and analysing complex solutions using mathematics and psychology. It was developed by Thomas L. Saaty in the 1980s and has been improved since then.

Information is needed to build management models and make decisions. But the available statistical quantitative information, as a rule, is scarce. There is never too much experience either. The primary source of information is people (users, experts, decision-makers). It is usually easier for a person to provide the necessary data informally or verbally, at the qualitative description and evaluation (so-called soft information). These requirements are best met, in particular, developed by the Saaty method of Analytic Hierarchy Process (AHP) [45-55]. Its purpose is to support the adoption of multi-purpose multi-criteria decisions when selecting one of many objects (solutions, strategies, etc.).

To solve several practical issues, when it is necessary to consider the qualitative characteristics of alternatives when making decisions, it is essential to formalise the problem and feel the weight influence of attributes on the optimal choice of solution. For example, a small business decides to use one of the three outsourcing firms (A1, A2, A3, respectively). On the other hand, it is possible to choose a company considering the criteria of benefits, such as the state of technical support, qualifications and experience of staff, the company's image and more. Thus, choosing an alternative is based on evaluating criteria and analysis of many options (Fig. 17). Solving the economic problem of choosing a multi-purpose multi-criteria solution (strategy) is seen as a step-by-step prioritisation of goals and criteria. Note that a person has two characteristics of analytical thinking: the first - the ability to observe and analyse the results of observations, the second - the ability to establish relationships between words, assessing the density of these relationships, and then synthesise these relationships in the general perception of the observer. It gives an idea of the principle of identity and decomposition, the principles of discrimination, comparative judgment and synthesis, on which AHP is based. Since the use of micro-service architecture, one of the biggest problems is communication between services. This problem will be solved with AHP. Let's select 4 of the possible transport layer protocols to create optimal

communication between system services. These will be TCP, UDP, SOAD and HTTP. These protocols are the most popular and best suited for data transfer tasks, while their popularity guarantees a high level of stability and support. They selected four protocols. Each alternative will have one criterion, which will mean using a specific protocol for all communications, and one will be responsible for building contacts using different protocols. We present the efficiency data of other protocols in the a Table 2, in percentage (maximum is 100%) (Fig. 18) [2].

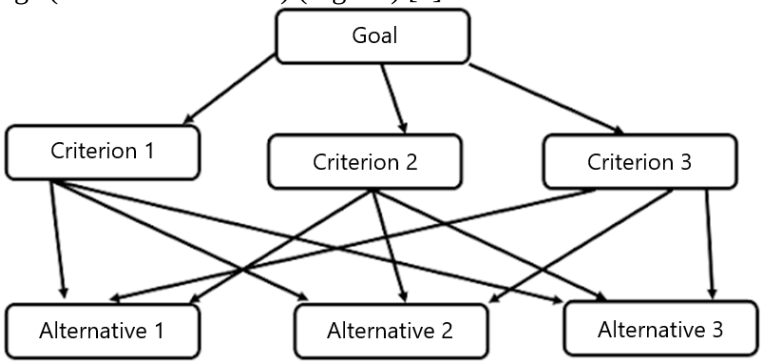

Figure 17: The main stages of the method of analysis of hierarchies

Table 2
Indicators of alternatives

Alternatives	HTTP	UDP	TCP	SOAD
A	50	30	40	100
B	60	100	60	30
C	45	55	100	70
D	100	40	60	65
E	70	70	70	70

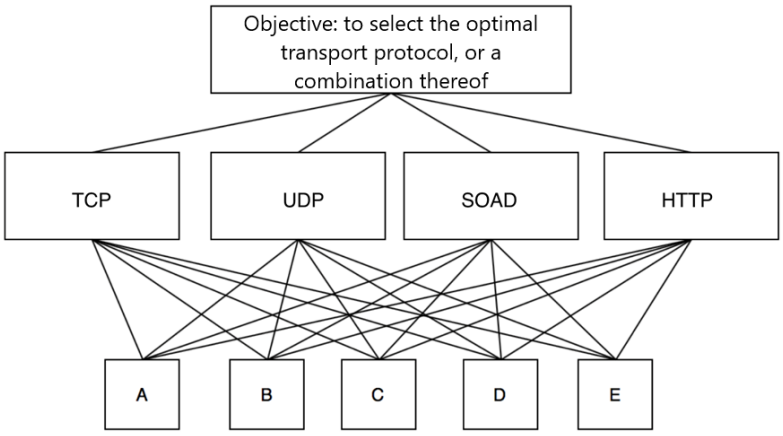

Figure 18: Structuring the problem

It is necessary to implement pairwise comparisons of criteria with each other and then alternatives. First, construct a matrix of pairwise comparison of measures. Then, depending on the importance of each process, fill in the table of criteria (Table 3) [2].

Table 3
Determining the weights of the criteria

Criteria	Accuracy of analysis	Speed of analysis	Optimisation speed	Quality optimisation	Own vector	Weight criterion
Accuracy of analysis	1	3	5	9	3.41	0.56

Speed of analysis	1/3	1	3	7	1.63	0.27
Optimization speed	1/5	1/3	1	5	0.76	0.13
Quality optimization	1/9	1/7	1/5	1	0.24	0.04

Now you need to find your vector and normalise it to determine the "weight" of each of the criteria. To do this, see the geometric mean for each row of the matrix. Then, in the column "Weight of the criterion", write the result of the normalisation operation for the elements of the previous column (Table 3) as we see the criterion, which is not surprising, since this is the system's primary process, after it in descending order are the speed of analysis, optimisation speed, and quality of optimisation.

But this is not the end of the criteria. It would help if you determined the consistency index (IP) λ_{max}. Then, multiply the matrix of pairwise comparisons by the normalised eigenvector column.

$$\begin{pmatrix} 1 & 3 & 5 & 9 \\ 1/3 & 1 & 3 & 7 \\ 1/5 & 1/3 & 1 & 5 \\ 1/9 & 1/7 & 1/5 & 1 \end{pmatrix} \times \begin{pmatrix} 0{,}56 \\ 0{,}27 \\ 0{,}13 \\ 0{,}04 \end{pmatrix} = \begin{pmatrix} 2{,}36 \\ 1{,}11 \\ 0{,}53 \\ 0{,}17 \end{pmatrix}$$

Now we find the corresponding relations (y_i / x_i), which give an approximation to λ_{max}

1) 2.36/0.57 = 4.17
2) 1.11/0.27 = 4.12
3) 0.53/0.13 = 4.17
4) 0.17/0.04 = 4.21

Based on the obtained numbers, we find λ_{max} (arithmetic mean of these relations):

$$\lambda_{max} = \frac{4{,}17+4{,}12+4{,}17+4{,}21}{4} = 4{,}17$$

It remains to determine the consistency index:

$$CI = \frac{\lambda\,max - n}{n-1} = \frac{4{,}17-4}{3} = 0{,}06$$

The obtained SP characterises the allowable consistency of judgments because the necessary condition of the SP <0.1 is fulfilled (Table 4) [2].

Table 4

Pairwise comparison of alternatives by the criterion of "accuracy of analysis" [2]

	A	B	C	D	E	Vector	Weight
A	1	3	1/3	3	5	1.72	0.26
B	1/3	1	1/5	1	3	0.72	0.11
C	3	5	1	3	7	3.16	0.48
D	1/3	1	1/5	1	3	0.72	0.11
E	1/5	1/3	1/7	1/3	1	0.32	0.05

You can see that alternative C dominates this indicator. Its weight is 48%. Alternative E has the lowest value for this criterion - 5%. The formula for determining the final indicator looks like this: $V_X=w_1*V_{X1} + w_2*V_{X2} + w_3*V_{X3} + w_4*V_{X4}$, where w_i is the weight of the criterion, and V_{Xj} is the value of the importance of alternative X according to the criterion.

Therefore, for options A, B, C, D, E of the choice of methods of distribution of system resources, we will receive the following values of their priority:

$V_A = 0{,}56 \cdot 0{,}26 + 0{,}27 \cdot 0{,}11 + 0{,}13 \cdot 0{,}17 + 0{,}04 \cdot 0{,}11 = 0{,}21$

$V_B = 0{,}56 \cdot 0{,}11 + 0{,}27 \cdot 0{,}28 + 0{,}13 \cdot 0{,}17 + 0{,}04 \cdot 0{,}33 = 0{,}17$

$V_C = 0{,}56 \cdot 0{,}48 + 0{,}27 \cdot 0{,}03 + 0{,}13 \cdot 0{,}06 + 0{,}04 \cdot 0{,}33 = 0{,}29$

$V_D = 0{,}56 \cdot 0{,}11 + 0{,}27 \cdot 0{,}11 + 0{,}13 \cdot 0{,}44 + 0{,}04 \cdot 0{,}11 = 0{,}15$

$V_E = 0{,}56 \cdot 0{,}05 + 0{,}27 \cdot 0{,}47 + 0{,}13 \cdot 0{,}17 + 0{,}04 \cdot 0{,}11 = 0{,}18$

As you can see, the priority of alternative C is the highest (it is 29%). Respectively, this alternative solution is the best in the method of analytical hierarchy, which was applied to this problem with these

criteria [2]. It means that the best solution to communication between services is to use TCP data transfer protocol. Thus, with the help of three different methods of analysis, namely - the tree of goals, context diagrams and the technique of analytical hierarchy, this system was considered and analysed. The section described all the processes and possible scenarios of the projected design, development, and deployment on the server-side. Analytics were also carried out with the help of AHP (analytical hierarchy process), and the highest priorities and alternatives were identified and to determine the optimal way of allocating software and hardware resources between them. In performing the work, a tree of goals was built, a conceptual model was developed, as a result of which the following types of diagrams were made: use cases, classes, sequences, state transitions, activity. Each of them is described and as detailed as possible. The system is now fully documented, and its processes are described.

3.3. Methods of solving the problem

The main tasks in the design and development of the system will be to choose the exemplary system architecture, definition. Then, the leading intelligent solutions of the developed system will be:

- Service of integration of new devices and creation of scripts of the system;
- System of support of decision-making based on the received commands.

To successfully choose methods using solving the problem, it is necessary to specify the requirements for each of the services and the infrastructure and business logic of the developed system. First of all, it is essential to define the requirements for system architecture. Once development begins, changing the architecture will be a challenging and labour-intensive and resource-intensive task. Every wrong decision in the next stage of system implementation will have a huge impact and will be extremely difficult and expensive to change. Time and resources will grow exponentially in the future. The main requirement for the architecture will be the independence of individual tasks. In addition to complex software resources and intelligent solutions, there will be services for other components.

Therefore, the chosen system must work with images from such a perspective and be high-precision because this system will also be part of the home security system [56-64], i.e. will provide access to many control functions of the product. Since smart home systems do not offer many users (usually 5-7 people), the main parameter will be the recognition accuracy, not speed (allowable recognition time 1-2 seconds). The next step will be to define the requirements for the decision support system. The system is designed to help the user to use and will be an intelligent hint that will create specific rules of conduct based on previous user actions. The next step is to choose methods to solve these problems.

Table 5
Comparison of architectural approaches

MSA	Monolith
Partial deployment	Simplicity
Fault tolerance	Consistency
No state	Intermodular refactoring
Heterogeneity	

Regarding the development methods used, special attention should be paid to the intelligent components of the system - neural network for face recognition and shortcut decision support system [11-18]. AlexNet was based on the convolutional neural network (CNN), a specialised artificial neural network that roughly mimics the human visual system. In recent years, CNN has become key to many computer vision programs. Here's what you need to know about the history and work of CNN. Its weight determines the behaviour of each neuron. When feeding pixel values, artificial CNN neurons highlight different visual features. When you enter an image into ConvNet, each of its layers generates multiple activation maps. Activation cards highlight the corresponding elements of the picture. Each neuron takes a portion of the pixels as an input signal, multiplies their colour values by their weight, sums them up, and triggers them through the activation function diagonal ribs. The output of the first layer is presented as the input of the next layer, which pulls out more complex processes, such as angles and combinations of edges. As they penetrate the convolutional neural network, the layers begin to

exhibit higher-level functions, such as objects, faces, and so on. The operation of multiplying pixel values by weights and summing them is called "convolution" (hence the name of the convolutional neural network). CNN usually consists of several convolutional layers, but it also contains other components. The final CNN layer is a classification layer that takes the final convolution level output as input (remember, higher convolution levels reveal complex objects). Reliability (values from 0 to 1) determines how likely it is that the image belongs to the "class". For example, if you have ConvNet that detects cats, dogs, and horses, the result of the final layer is the possibility that the input image contains any of these animals. Convolutional neural networks and their modifications are considered the best in accuracy and speed algorithms for finding objects on the stage [35-44]. The backpropagation method was used for training. This method allows you to select the repetition rate of specific commands or operations and then create a regular rule for smart home [56-64].

3.4. Technical characteristics of the selected software development tools

To develop an intelligent system, you need to choose the most appropriate method, software and utilities. There is a use for each service of those technologies, allowing to carry out the appointed tasks as effectively as possible. To select these, it is necessary to analyse the available technologies.

After analysing the above programming languages, different languages were selected to develop additional services. To create the message queue service, the C # language was chosen because it showed higher performance than other languages when working with forwarding messages. Python technology was selected for the video service, device service and shortcut service. These services will work with intelligent systems (face recognition, shortcut system), and the chosen language is best suited for these tasks. The C # language was selected for the authorisation service because it is fast and reliable, which is very important for the authorisation process. New versions of the framework allow you to make this service cross-platform, allowing you to deploy the system on any device. The .Net Core web framework will be used. HTML mark-up language and CSS for stylistic design were chosen to develop the front-end. The Angular6 framework was selected to create business logic, which facilitates work with the Typescript language, which describes the logic front-end. When choosing tools for creating databases, it was decided to focus on NoSQL solutions because the system does not involve transactions but will often write and read data from databases, which SQL does poorly, forcing services to wait.

So, several different technologies have been chosen to develop an intelligent system, including Typescript, Angular6, HTML \ CSS (user interface), C # (authorization service) and Python (device service, shortcut service, video service), each of which has been used to perform their tasks best. Because the system was developed as a web application, the Angular6 framework was used to create the front-end. The database service was NoSQL because the system does not involve transactions but requires many simultaneous operations and scalability. Face recognition service uses a deep convolutional neural network to analyse and recognise people who fall. Software methods and tools have been selected that meet today's challenges and standards. These tools will help you develop software that will meet the requirements.

4. Experiments, results and discussion

The developed system is called "Alexa Skill + Edition". The functional limitations of system are:

- Lack of open API in old devices designed for smart home systems;
- Need for a 24-hour server (for local system deployment).

The smart home system is designed to solve the following tasks:

- Control of "smart" devices within the smart home;
- Ensuring the security of the smart home;
- Face recognition and related response to authorised users or others;
- Intelligent user support (creating new rules based on user behaviour);
- Providing a user-friendly system management interface.

Because the system was developed cross-platform, it can be run on any operating system. The system has the following hardware requirements: processor frequency not less than 2.4 GHz, RAM capacity -

2 GB or more, hard disk memory capacity, solid-state drive - 60 GB or more, network connection Internet with a supported speed of at least 10 MB/s.

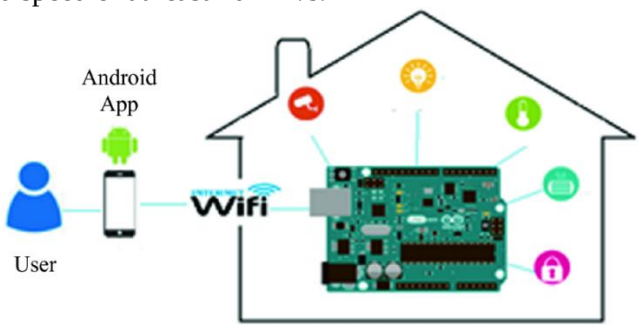

Figure 19: User interaction with the system

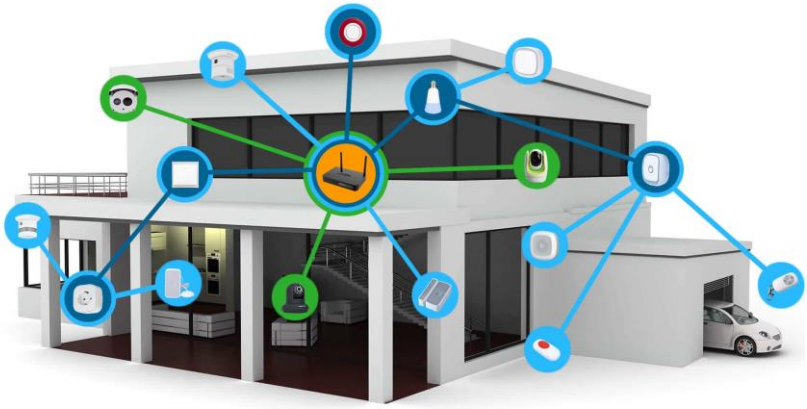

Figure 20: Model of placement of connected devices in the system

Therefore, the architecture of the system and databases is chosen to use system resources as efficiently as possible. In addition, the processes occurring in the system are made as independent as possible, which avoids hangs due to oversaturation of dependencies between different services. After completing the design and development of the system (Fig. 21-22), it is necessary to analyse the resulting system and make sure that it meets the requirements and criteria [1-2].

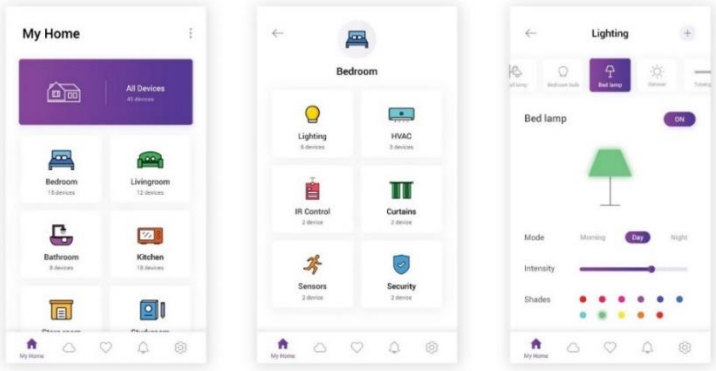

Figure 21: Main pages of the system

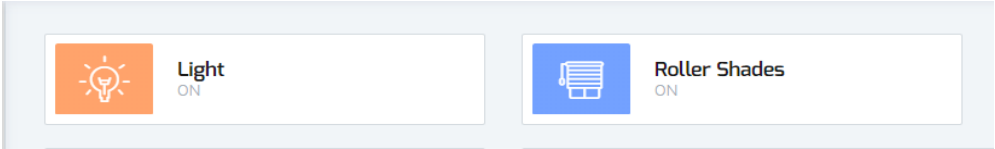

Figure 22: Device Control Panel as the main page of the user interface

The user can turn devices on and off and view their status, change, and availability of all connected devices (Fig. 23). The interface allows you to view indicators and set the desired parameters using the same slide bar. A house plan is available in the system (Fig. 24), with which you can divide the devices in the house into rooms and control them not separately but within the space [1-2].

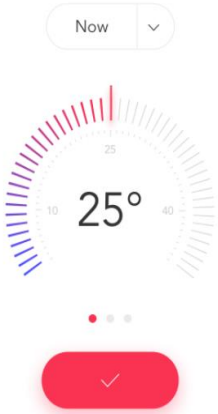

Figure 23: Humidity and temperature control panel for parameters of different sensors

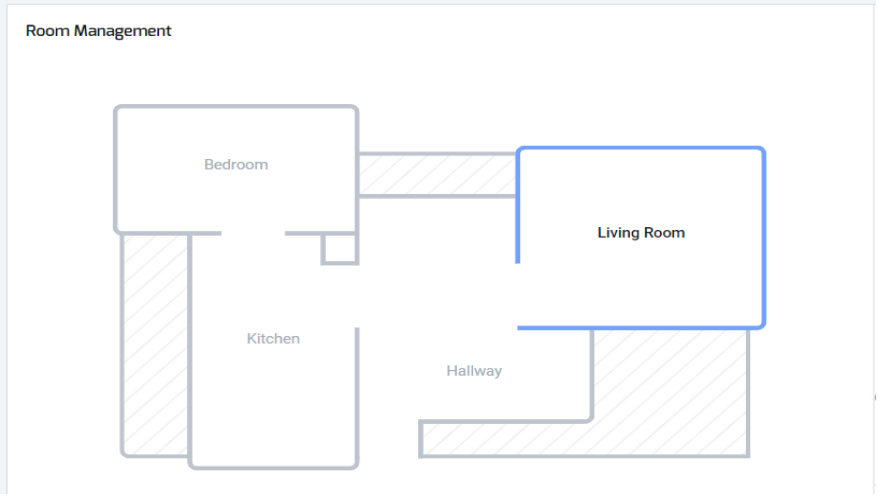

Figure 24: Smart home plan on the control interface (for example, all lights on or off)

The system also allows you to connect to and receive data from smart meters from many manufacturers. For user convenience, these data are displayed in the form of a diagram (Fig. 25).

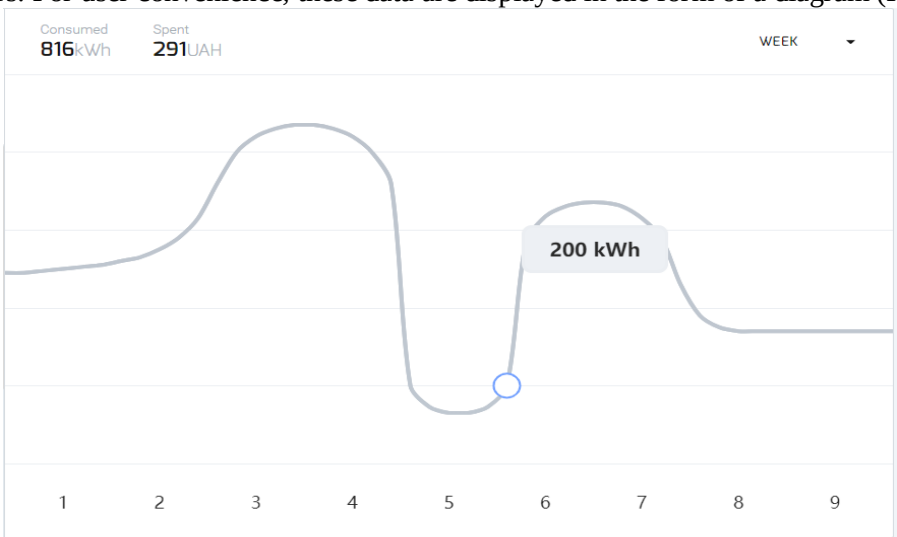

Figure 25: Diagram of service consumption volume and period of a particular service type

The application duplicates the essential control functions present on the web interface and adds the ability to create specific shortcuts based on the mobile device's geolocation on which it is installed. After all the basic processes are connected with work in real-time, to be revealed using images, such systems will be in great demand in the future. Comparing their relevance now and three years ago, we can conclude that such techniques will gain popularity every year, especially regarding the security and safety of their own homes.

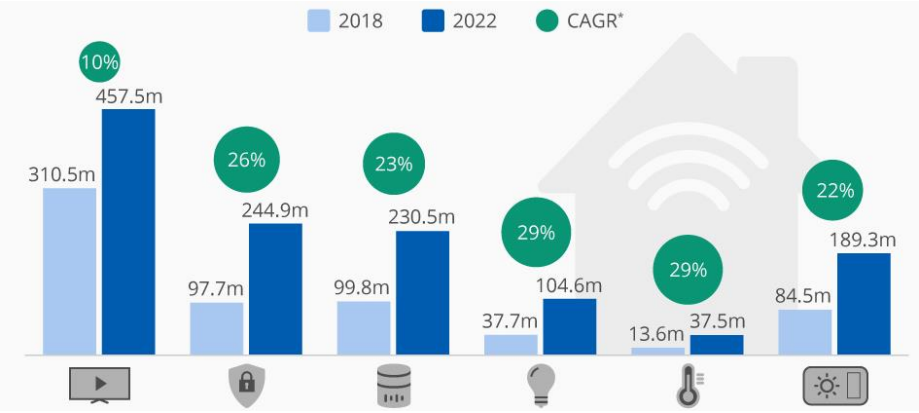

Figure 26: Ratio of popularity among smart home devices compared to 2018 -2021

Thus, a software product was designed and created in work, namely an intelligent smart home system. Its architecture has been designed, the infrastructure and the interconnections between the services have been developed. All the services that make up the system and their communication system were created and tested. During the development and testing of the system, the necessary hardware and software were identified, the basic requirements were determined [1-2]. After the result was completed, a control example was analysed, which showed that the system is fully functional and performs all the tasks set before it.

5. Conclusions

In writing the work, the latest trends in the market of systems for smart homes were studied. The work focused on developing a system that is not inferior to existing counterparts and, at the same time, will be an effective tool to meet user needs. The paper analysed the literature and other sources and explored the most popular voice assistants and systems that can be integrated. We also examined the applications and applications supported by the system and determined the best voice assistant to control this smart home system and connect all possible sensors. Because voice assistants by themselves do not allow you to make a smart home interface and all interaction with them takes place exclusively through external APIs. The article describes the functional and non-functional requirements using the methodology and its display in UML diagrams. To better understand ways to improve the functioning of the system, such modelling is increasingly used. To make a product release successful, you need to analyse all possible ways to use the system, find all possible causes of system crashes and look at the application from a user's angle and provide the full user experience to make the system enjoyable for everyday use. The choice of methods and also the architectural and software decision of designing of the system was substantiated. The main requirements were ease of implementation, good support and interaction with microservice architecture and non-relational databases. A neural network was also used, which also has an impact on system performance. The fourth section presented the project itself. A microservice architecture was built, a database was modelled, and code was created and deployed in the cloud service for the uninterrupted operation of the application and the ability to balance the download and increase the number of service instances under heavy load. Although the system performs all the planned functions, it is necessary to improve it further because new solutions will soon appear in competitors. Thus, it is essential to consider possible options for enhancing and expanding the system. So, we can conclude that the designed and implemented system operates as intended and performs all its tasks while doing so stably and quickly.

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