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ARTIFICIAL INTELLIGENT CAN CONTROLS SMART HOME TECHNOLOGIES

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Abstract

Internet of Things (IoT) has created new applications and environments. The Internet of Things (IoT) is making our lives a lot easier. Smart Home provides new ways of communication and service consumption. In addition, Artificial Intelligence (AI) and deep learning have increase different services and tasks by automatizing them. In this field, reinforcement learning (RL) provides an unsupervised way to learn from the environment. In this paper, a new intelligent system based on RL and deep learning is proposed for Smart Home environments to guarantee good levels of QoE, focused on multimedia services. This system is aimed to reduce the impact on user experience when the classifying system achieves a low accuracy. The Internet of Things (IoT) is making our lives a lot easier. Almost all appliances can now be monitored and, in some cases, operated remotely.

Introduction

Integrated networks are communications networks that utilize devices from multiple sensors and everyday devices, deployed in what is known as the Internet of Things. IoT is a concept that is being applied manufacturers, protocols, and service operators. Currently, using integrated networks, it is possible to interact with in multiple areas, among which we can highlight Smart Home, Smart Cities, Smart Agriculture, Smart Grid, Smart Health, and Wearables.

According to [1], in 2016 the smart home sector had a global value of $ 46 billion and they forecast a growth of 15% per year in the period 2017 to 2022. According to data from the observatory [2], the Italian market for the smart home sector in 2018 had purchase estimates of 380 million euros, which represents an increase of 52% compared to 2017. In addition, it indicated data from other European countries such as Germany (1.8 billion euros, an increase of 39%), the United Kingdom (€ 1.7 billion,

39% increase), France (€ 800 million, 47% increase) and Spain (€ 300 million, 59% increase).

We can identify Smart Home as a system that allows the monitoring and control of a home or any places easily. Its application is accomplish by both companies and individuals. In order to use it, we must have access, through an integrated network, to the devices located in the home or office. Its implementation can be very broad and located on very different devices. It can go from simple monitoring with cameras for security control, to something as complex as the use of smart refrigerators, which can place orders automatically, when they detect the lack of food. Its most common applications are the control of lighting, gas, water, air conditioning, doors and windows, security cameras, weather sensors, irrigation the home theater, etc. Some of these applications are multimedia applications. In multimedia services, the Quality of Experience (QoE) is the most important metric, since it supplies a measure of how good a service is from the user's point of view [3].

If we watch carefully, we will realize that the use of electrical energy is necessary for most of the activities that we carry out in our homes throughout the day. We must be responsible with the use of energy due both to the depletion of certain energy sources, and to the impact that occurs on the environment. On a regular basis, at home, we have a large number of appliances such as a refrigerator, freezer, dishwasher, washing machine, dryer, oven, stove, etc. that we use even several times a day. These appliances can often account for half of the energy consumption in the home. Also, it is important to control the consumption of light and the appliances used for air conditioning. In addition, the consumption of electronic devices, in general, is usually higher than it should be. In general, our televisions, multimedia players, etc have a system called standby that permits them to never be unplugged from the current, so their electricity consumption is permanent.

Artificial Intelligence can be used to enhance and optimize energy consumption in our homes. One of the biggest keys to using AI is its learning phase. The key to optimizing our energy consumption at home is data. As a smart home is an automated environment, we can monitor and get to capture the patterns of daily activities, which are provided by sensors through information technologies. The greater the amount of information available about our habits, the greater the adjustment in energy consumption savings can become. Using learning, automatic or supervised, we can make the control devices capable of selfprogramming. In addition, we can apply Deep Learning, which allows us to use logical structures very similar to those of organization of the nervous system of a mammal. By using Deep Learning on the control devices that we have at home, we will be able to optimize energy consumption in our smart home.

In this pager, we show an intelligent system in Smart Home environments that manages the set of nodes and services of the environment, enabling or disabling them based on the predictions of user's service consumption. This system is aimed to improve the results of a deep learning classification system when the algorithm is still learning from the user. Deep Learning works better with a huge number of data and our proposal, based on RL is aimed to supply better flexibility to the system.

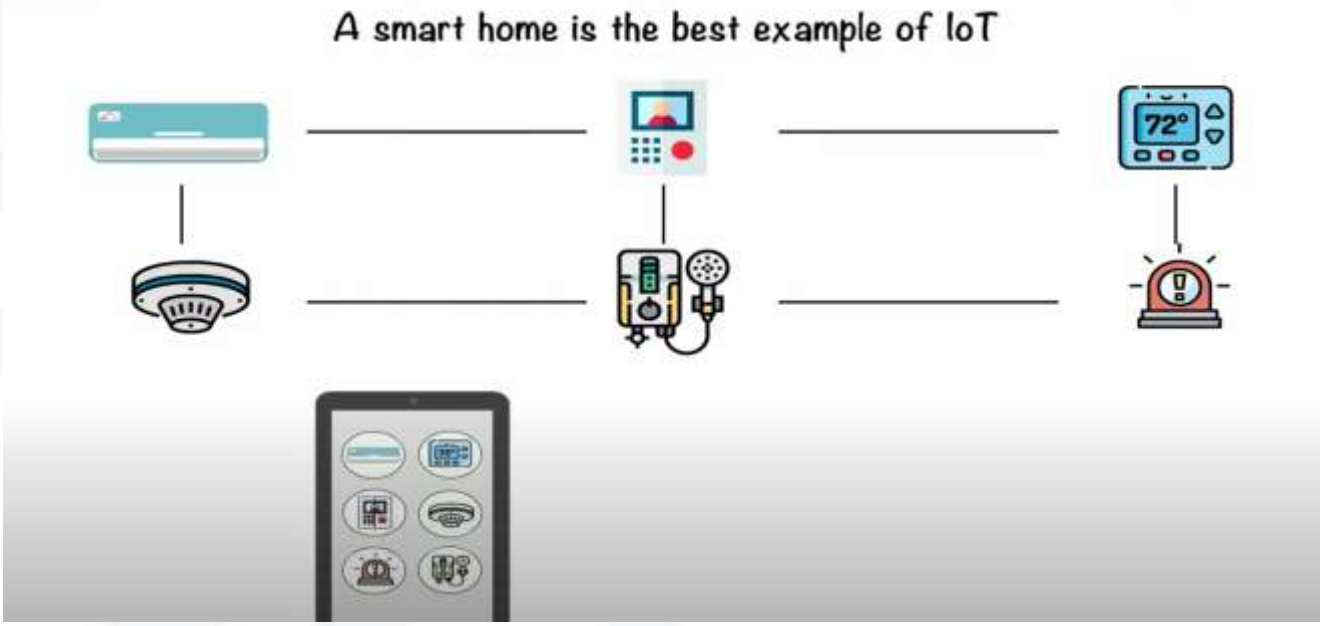
The rest of this document is constructed as follows. Section 2 presents some of the most relevant works related to our study. The network and system environment and architecture are described in Sect. 3. Section 4 briefly defines the data preprocessing and the classification model, based on deep learning. Section 5 describes the RL algorithm and all its components. Section 6 presents the evaluations of the system. Finally, Sect. 7 concludes the paper and presents some future works.

Related work

There is a large number of articles in which the authors have studied smart homes. Some authors like [4–8] present studies on IoT and Smart Home. Vasicek et al. [4] present the IoT concept in a Smart Home. They use IoT devices to create a smart home, without the need to rebuild the home. Jie et al. [5], present a highly scalable architecture, applying IoT technologies, where they can integrate many applications using a uniform interface, to develop a smart home. Khan et al. [6] present the design of an IoT Smart Home System (IoTSHS), which was designed, programmed, manufactured and tested with excellent results. The authors stress that it can benefit all parts of society by providing advanced remote control for the smart home. Malche and Maheshwary [7] analyze the functions of a smart home and its applications and introduce an architecture that they call FLIP (Frugal Labs IoT Platform), to build smart homes enabled for IoT. Yang et al. [8] present a study examining service

characteristics of smart homes in 216 samples in Korea. They also do a study of personal characteristics in the behavior of users.

There are writers like [9–13] who show reviews about IoT and Smart homes. Risteska Stojkoska and Trivodaliev [9] propose a holistic framework, which incorporates different components from IoT architectures/frameworks proposed in the literature. In addition to this , they identify a management model for the proposed framework, identifying the tasks to be carried out. Alaa et al. [10] present a review study, where they formalize a taxonomy focused on three areas, (1) smart homes, (2) apps, and (3) IoT in three major databases, namely, Web of Science, ScienceDirect, and IEEE Explore. Kuzlu et al. [11] present a review where they compare wireless and wired communication technologies in local area networks applied to Smart homes, taking into account the standards, protocols, data rate, coverage, and adaptation rate. Kamel and Memari [12] show a review, whose main objective is to classify the different types of Smart homes into three main groups, from the energy point of view. Groups are established at homes with energy monitoring systems, systems with control capabilities, and systems with advanced data processing capabilities. Finally, Jia Chen et al. review, in [13], the use of IoT in*home systems and applications for health monitoring. They reviewed the key factors that caused the growth of IoT monitoring at home. Then, they presented the lastest advances of the architecture of these systems.



Lastly, they discussed future outlooks and personal recommendations.

Other authors [14–18] present studies from the point of view of access security to IoT devices in smart homes. Apthorpe et al. [14] present the study of four Smart home IoT devices. They discoover that network traffic rates can show user interactions, even when the traffic is encrypted. For this reason, they indicate the need for technological solutions to protect the privacy of users. Augusto-Gonzalez et al. [15] present the GHOST framework (Safe-Guarding Home IoT Environments with Personalized Real-time Risk Control), which aims to provide cyber security to residents of smart homes. They do it through a new reference architecture, for smart home security and its users. Lin and Bergmann [16] establish key requirements to give reliability in smart homes in the future. They propose a gateway architecture, to have a high availability of the system and devices with limited resources. Meng et al. [17] present the most popular architecture for smart home platforms, detailing the functions of each of its components. They also comment on the main security and privacy challenges of the platforms and review the state of the art of the proposed countermeasures. Ammi et al. [18] propose a novel Blockchain-based solution for secure smart home systems, using a combined hyperledger fabric and hyperledger composer. Another important aspect of the proposed solution is the mapping of the attributes of a smart home to those from the hyperledger composer. This mapping allows for a customized, designed-for-purpose solution that can meet the security requirements for IoT-based smart homes.

Atat et al. [19] present the cyber-physical systems (CPS) taxonomy by providing a broad overview of data collection, storage, access, processing, and analysis. These systems are foreseen to revolutionize our world via creating new services and applications in a variety of sectors, such as environmental monitoring, mobile-health systems, intelligent transportation systems, and so on. This is the first panoramic survey on big data for CPS, where their objective is to provide a panoramic summary of different CPS aspects. Also, they provide an overview of the different security solutions proposed for CPS big data storage, access, and analytics. In addition, they discuss big data meeting green challenges in the contexts of CPS.

There are writers [20–23] who research energy management in the Smart home environment. Collotta and Pau [20] propose an energy management system for smart homes, using Bluetooth Low Energy (BLE) [21] for communications, together with a home energy management (HEM) scheme. Their results show the efficiency of the proposed system, since they reduce the peak load demand, and the charges for electricity consumption, thus increasing the comfort of its users. Al-Ali et al. [22] present an Energy Management System (EMS) for smart homes. They use Business Intelligence (BI) and Big Data analytics software to manage energy consumption,

satisfying consumer demand. Xia et al. [23]propose an edge-based energy management framework, which provides a low cost of electricity and saves on infrastructure construction. They have implemented a prototype, the results of which show a reduction in the cost of electricity of 82.3%, compared to similar cases. Celik et al [24] present a review of the antecedents in modeling of residential load, demand-side management (DSM) and demand response (DR), in the settings of a home and in a neighborhood area. The objective is to classify the structure and coordination techniques of energy management, from previous research. Authors as Wu et al. [25] discover the relations between the trend of the big data era, and that of the new generation green revolution, through a comprehensive and panoramic literature survey in big data technologies toward various green objectives and a discussion on relevant challenges and future directions.

Amjad et al. [26] propose a cognitive edge-computingbased framework solution, to integrate the advancement of edge computing resource requirement schemes as well as the resource allocation schemes found in the literature for enterprise cloud; to attain a universal resource allocation framework for IoT. Others Authors as Jararweh et al. [27] present a novel experimental framework for IoT-based environmental monitoring applications, using concepts from Data Fusion (DF) and software defined systems (SDS). It is built on top of the software defined networking platform where the core components (the host, switch and the controller) are expanded to support other software defined systems components (such as software defined storage and security) and enable the applications of different DF techniques in IoT environments. Studies [28–32] related to the application of AI in the field of Smart Home can also be cited. Sodhro et al. [28] state that the convergence of IoT and AI promotes energyefficient communication in smart homes. Its main objective is to optimize the Quality of Service (QoS) of video transmission, which is carried out using wireless micro medical devices (WMMD), in smart healthcare homes. Guo et al. [29] make reviews of the literature and existing products to define the functions and roles of AI in Smart homes. They point out the existence of a delay between the literature and the products. Sepasgozar et al. [30] reviewed the applications of the IoT in homes, to make them intelligent, automated and digitized in many of its aspects. They have studied the literature on the use of IoT, AI and geographic information systems (GIS) in smart homes. They state that there is a considerable gap in the integration of AI and IoT and the use of geospatial data, in the field of Smart Home. Song et al. [31] present frameworks of centralized and distributed AI-enabled IoT networks. Key technical challenges are analyzed for different network architectures.

Deep reinforcement learning (DRL)-based strategies are introduced and neural networks-based approaches are utilized to efficiently realize the DRL strategies for system procedures. Different types of neural networks that could be used in IoT networks to conduct DRL are also discussed. Lloret et al. [32] proposed an intelligent system for detecting elderly problems and assist them. They proposed a communication architecture and designed a software application.

Several works have been completed about Smart Home from different points of view. However, the purpose that an automated intelligent management system can play in Smart Home environments needs to be to made clear. Consequently, we propose a new role for AI in this scenario. Our proposed system works along with the user to decrease the intrusion that an automatized service management can introduce to the user's experience. Addition , the system is oriented to especially decrease the impact of bad predictions on multimedia services, trying to guarantee a good QoE from the people's view. In order to overcome the possible difficulties that a deep learning classifying method may supply to the system, we put into use the use of an RLadapted method into the Smart Home. RL has been used in other works like in [33] due to its performance.

Proposed Architecture

In this page, the architecture of the proposal is detailed. Firstly , the network architecture is to make clear.

Then, the intelligent system is to make clear, explaining the function of each module that forms it.

Network architecture

The architecture of this proposal is an architecture with centralized management based on AI [34, 35]. This architecture is divided into five logical layers to organize and maintain divided the functions of each object connected to thenetwork.Themanagementlayer(Layer4)centralizes the information and stores the data of the features of the connected objects (dataset) and the parameters and statistics of the network. The AI uses this information to create workgroups (grouping) and routing, and other functions that keep the network operational. The multiprotocol IoT Gateway is the device in this layer in charge of doing this work and has the capacity to handle different interconnection technologies, storeinformation, host an AI, process information and control internet access.

In the internet layer (layer 5), the AI withinthecloudcanchoosetheIoTPlatformaccordingtothe type of parameter and the capacity to process large volumes of data. The rest of the layers are located below as

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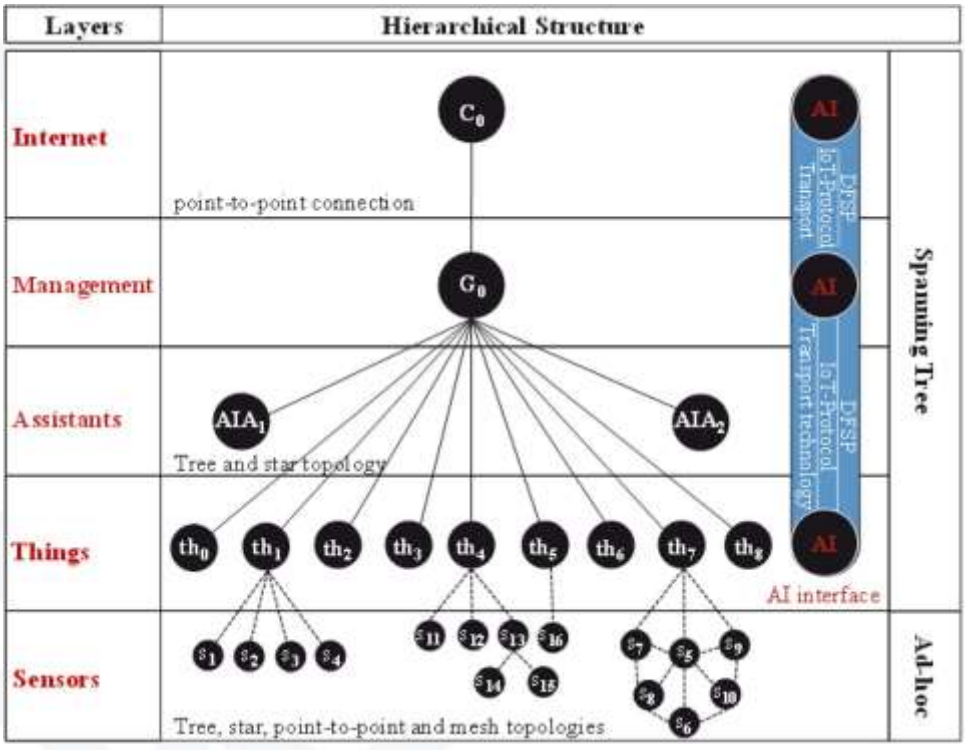
Artificial Intelligence Assistants (AIA) in layer 3, smart things (th) in layer2andsmartsensorsandactuatorsinlayer1.Inthisway, the functionalities are separated and kept as a stand-alone system. Fig. 1 shows the hierarchical distribution of the architecture with the objects represented as nodes.

This architecture is used to design Smart IoT-Networks, which contain interconnected objects with integrated AI (Smart Things). Some of these networks are Smart Home, Smart Office, Smart City, Smart Factory, among others. For this case study, the scenario is based on the connected objects in a Smart Home. The IoT Gateway's AI classifies the objects connected in the network into workgroups and roles by layer [34], and then, when an object requires resources, the IoT Gateway routes it, selecting the best node to provide them. The AI creates these groups to provide an automatic service to a user based on their features of functions, resources, and capacities. The following is a case of service within the Smart Home, e, g., when a visitor arrives at the house, the AI selects the objects



with nearby features to provide this service. The system searches inside the house if there are users or not and automatically attends the door's visit. The necessary resources for this service are multimedia such as video and sound necessary to show the image of the visit on the objects that have this resource and that are close to the user inside the house. If there are no users inside the house, it will send them to objects or mobile devices in any location. One function that would be activated would be facial recognition and identity verification and then sent to be processed in the cloud. The first object to interact in the service would be the smart main door at the front of the

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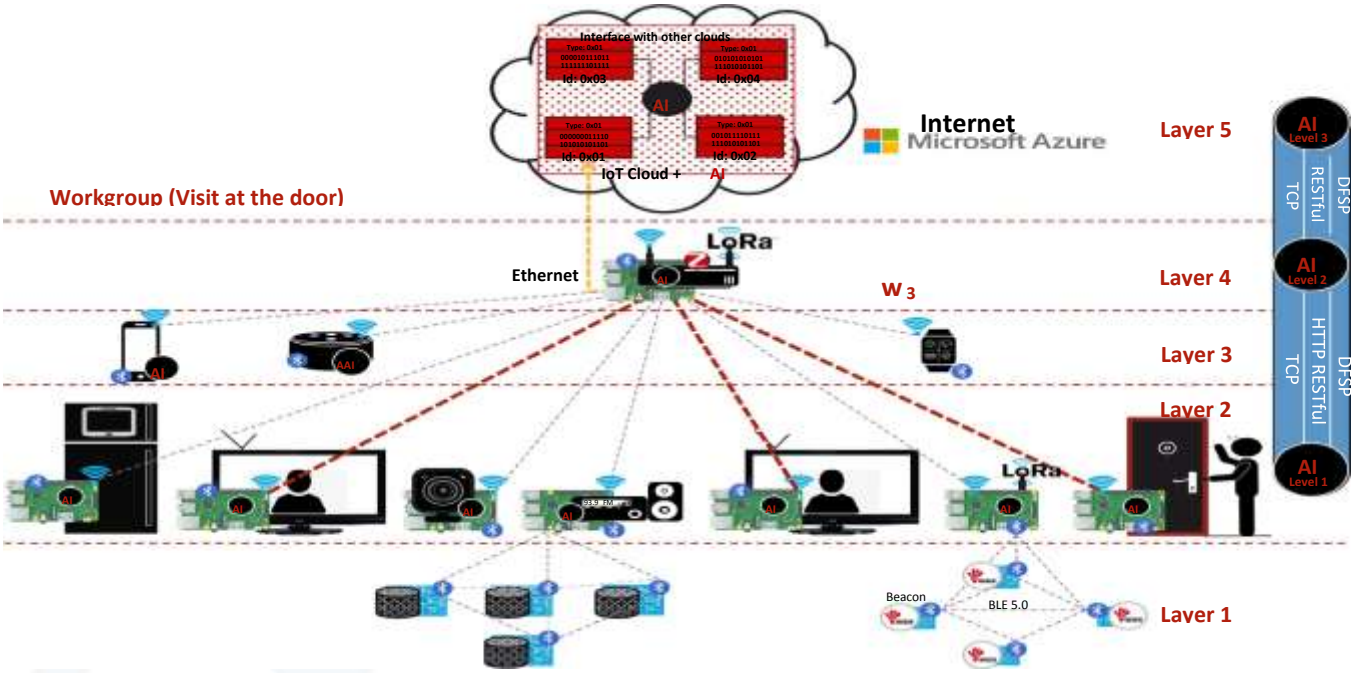
house. This would be the requesting node for the resource and would execute the recognition and verification function. The IoT Gateway's AI would be in charge of distributing and transmitting the video and voice to the objective objects that have this resource



and that meet the condition of being close to a user and with the capacity to reproduce it. Fig. 2 shows a case study for a workgroup that attends the door's visit service in a Smart Home through this architecture. This workgroup is organized according to the layers of the architecture in Fig. 1. When the smart door attends a
visit, it activates a request to send video and image processing data. The image processing data (facial recognition) is sent through the AI interfaces until the visitor's identification is obtained. The video is sent to each connected object with multimedia playback functions that is close to the user and routed through the IoT Gateway. Therefore, the smart home announces a visit and the identification of a person located in the main door. If the user is away from home, the IoT Gateway will send the information through the cloud to the closest objects with multimedia functions to the user (E.g., Smart Car, Smartphone, Tablet

In Smart Home, in this architecture, the IoT Gateway, the IoT Gateway, either by voice commands or either by a through the IoT nodes, can supply multimedia services. smartphone application, the user can play their favorite Through user requests given to the smart assistant placed in music in the audio system on the distributed speakers in the house, watch movies-on-demand, music in the audio

system on the distributed speakers in the Fig. 1 IoT Smart architecture house, watch movies-on-demand, or automatic record surveillance videos of the house.

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