تأثير تقنية AIoT في تحسين أداء إنترنت الأشياء في أنظمة المنزل الذكي

Impact of AIoT Technology in Improving IoT Performance in Smart Home Systems

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الملخص :

قد تحاكي الآلات القدرات البشرية مثل التعلم من الأخطاء والتكيف مع المدخلات الجديدة، وذلك من خلال استخدام الذكاء الاصطناعي (IA). كما يمكن للناس استخدام إنترنت الأشياء للعيش والعمل بشكل أكثر ذكاءً والتحكم الكامل في حياتهم. ويمكن للذكاء الاصطناعي أن يعزز مزايا إنترنت الأشياء من خلال جلب الوعي البشري وصنع القرار إلى المناطق المحيطة الموجودة بالفعل، وتعزيز الكفاءة، وتحسين العمليات. يعد الذكاء الاصطناعي أحد المكونات الرئيسية للذكاء الاصطناعي للأشياء. وإنترنت الأشياء (ToIA) عبارة عن مجموعة من الأدوات المتصلة بالإنترنت التي تجمع البيانات ومن ثم يستطيع الذكاء الاصطناعي تقييم البيانات وتحويلها إلى معرفة يمكن استخدامها لإصدار أحكام أكثر ذكاءً حول أنظمة التشغيل الآلي للمنزل. يمكن للأجهزة المنزلية المزودة بقدرات الذكاء الاصطناعي للأشياء (ToIA) تغيير درجة الحرارة وتشغيل الأضواء وفتح الأبواب والمزيد. كما تتنبأ بيئة الذكاء الاصطناعي للأشياء في المستقبل بتطبيقات غير عادية ومتطورة للمشاركين في المنازل والمؤسسات والمجتمع بسبب النمو السريع للتكنولوجيا. ومع ذلك، لا يزال الذكاء الاصطناعي للأشياء في مراحله الأولى، وقد بدأ بالفعل في تغيير الطريقة التي يعيش بها الناس. تبحث هذه الدراسة في كيفية عمل إنترنت الأشياء والذكاء الاصطناعي معًا بشكل أفضل وكيف يمكن تعزيز عمليات صنع القرار في أنظمة المنزل الذكي.

الكلمات المفتاحية: الذكاء الاصطناعي (IA)، إنترنت الأشياء (ToI)، الذكاء الاصطناعي للأشياء (ToIA)، المنزل الذكي

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Abstract

Through the use of artificial intelligence (AI), machines may mimic human abilities such as learning from mistakes and adapting to new inputs. People can use IoT to live and work more intelligently and get complete control over their life. By bringing human awareness and decision-making to already-existing surroundings, boosting efficiency, and eventually improving operations, AI can enhance the advantages of IoT. Artificial intelligence is a key component of the Artificial Intelligence of Things (AIoT). The Internet of Things is a collection of internet-connected tools that collect data and then AI can evaluate the data and turn it into knowledge that can be used to make smarter judgments about home automation systems. Home appliances with AIoT capabilities can change the temperature, turn on lights, unlock doors, and more. The AIoT environment of the future predicts extraordinary and sophisticated applications for its participants in homes, enterprises, and society due to the rapid growth of technology. However, AIoT is still in its early stages, it has already begun to transform the way people live and work. This study investigates how IoT and AI can work together better and how smart home systems› decision-making processes may be enhanced.

Keywords: Artificial Intelligence (AI), Internet of Things (IoT), Artificial Intelligence of Things (AIoT), Smart Home

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I. Introduction

The goal of the smart home system is to give users access to cost-effective solutions, improved control by maximizing utilization, and one-button activation of all home appliances. Beyond simple solutions for things like lights and other chores, a smart home system's goals also include complete control over home security and the creation of a centralized home entertainment system. All smart home appliances are intended to be controlled by Internet Protocol or cloud computing through a home automation system based on the Internet of Things (IoT) [1]. IoT-based smart home systems are much more flexible than wired ones, and they also have several advantages over wired ones, including simplicity in operation and troubleshooting, ease of installation and use, and, perhaps best of all, ease of use [2]. These "smart" technologies support greater effectiveness and productivity. Data analysis is made possible by AIoT intelligence, which can then be utilized to enhance systems, gain improved performance and business insights, as well as generate data that aid systems in learning and making better decisions [3]. For three reasons, it is challenging to understand the data that smart IoT systems generate, which makes decision-making challenging. The first is the diversity of data and how it differs between different devices, the second is the volume of data received by many devices, and the third is the challenge of emphasizing the data's value. This study investigates how AIoT technology might enhance IoT and AI communication in smart homes. The remainder of this paper is organized as follows; Section 2: Theoretical background on Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML). Part 3 presents artificial intelligence for the Internet of Things (AIoT) and its implementation in smart home systems. Section 4 presents the research discussion. Finally, conclusions and future work.

II. Theoretical Background

A. Internet of Things (IoT)

The Internet of Things, or IoT, is a network of connected computing devices, mechanical and digital machinery, items, animals, or people that may send data over a network without the assistance of a human or a human computer [3]. A person with a heart monitor implant, a farm animal with a biochip transponder, a car with built-in sensors that alert the driver when tire pressure is low, or any other animal or human being might all be considered things in the Internet of Things. a manufactured item capable of receiving an IP address and transmitting data over a network [4]. IoT is being used by businesses across all sectors to boost productivity, better understand customers, deliver better customer service, enhance decision-making, and boost corporate value [5]. A person with a heart monitor implant, a farm animal with a biochip transponder, a car with built-in sensors that alert the driver when tire pressure is low, or any other animal or human being might all be considered things in the Internet of Things. a manufactured item with the ability to receive an IP address and send data over a network. IoT is being used by businesses across all sectors to boost productivity, better understand customers, deliver better customer service, enhance decision-making, and boost corporate value [6].

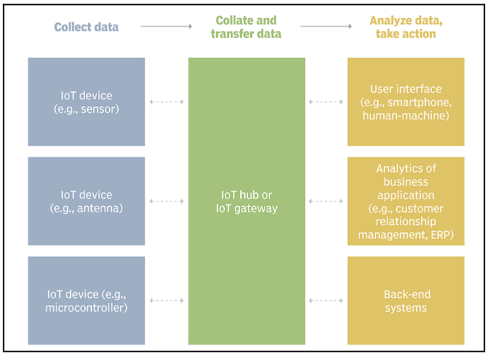


Figure 1: An example of how an IoT system works from collecting data to taking action

The IoT ecosystem, as seen in Figure 1, is made up of network-capable smart devices that use embedded systems like processors, sensors, and communication gear to gather, send, and process environmental data. Connected to IoT gateways or other edge devices, IoT devices exchange sensor data that is either routed to the cloud for analysis or examined locally. These gadgets occasionally interact with other similar devices and respond to information shared between them. Although people can engage with these gadgets to set them up, give them commands, or access data, much of their work is done by them without their help. These network-enabled devices' connectivity, networking, and communication protocols are heavily influenced by the particular IoT application being used. IoT can also make use of machine learning and artificial intelligence (AI) to streamline and enhance the data collection process [7].

B. *Artificial Intelligence (AI)*

Artificial intelligence & Decision making

The simulation of human intelligence by machines, particularly computer systems, is known as artificial intelligence. Expert systems, natural language processing, speech recognition, and computer vision are some specific uses of AI [8]. A choice is made through the processes of decision-making, information collection, and alternative solution evaluation. By collecting pertinent information and identifying options, a step-by-step decision-making process can assist you in making more deliberate and thought-out decisions [9].

Machine learning (ML)

Without being explicitly coded, software systems can predict events more accurately because of machine learning (ML), a subset of artificial intelligence (AI). Machine learning systems estimate new output values using historical data as input [10]. Machine learning comes in various forms. Supervised learning: in this type of machine learning, a data scientist determines the factors that the algorithm should consider while determining their relevance and gives the algorithm labeled training data. Indicate the algorithm's input and output. Unsupervised learning is a different subset of machine learning. Algorithms learned on unlabeled data are used in this sort of machine learning. The algorithm searches the dataset for significant relationships. Both the predictions or suggestions the algorithms make and the data on which they are trained are predefined. Semi-supervised learning is a different kind of machine learning. This method of machine learning combines the first two kinds. The algorithm's training data can frequently be provided by data scientists, but the model can evaluate the data on its own and gain an understanding of the dataset. Reinforcement learning is the final variety of machine learning. In this kind, data scientists frequently employ reinforcement learning to instruct a machine using a multi-step procedure with clear rules. Data scientists create algorithms to perform tasks and provide them with encouraging or discouraging inputs as they learn how to accomplish them. However, the algorithm often chooses the steps to be taken at each stage [11].

Supervised Machine learning (SML)

The first machine learning technique, supervised learning, train a computer to predict outcomes more correctly by using labeled data. Finding a function that converts input variables into output variables is the aim of the SML algorithm. IoT performs better and faces fewer difficulties thanks to SML algorithms. The ANN algorithm is utilized for mistake detection and data aggregation, while the NNS algorithm boosts the IoT's placement effectiveness [12]. Several SML methods, including the following, have been shown in prior research to increase IoT performance.

K Nearest Neighbors (KNN)

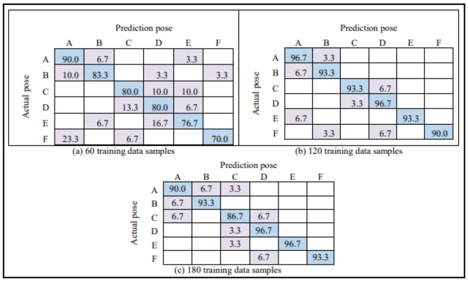
Despite having straightforward arithmetic operations, the supervised learning method KNN may not be accurate when working with huge datasets. Based on the labels of surrounding data samples, it categorizes individual data samples. KNN uses straightforward techniques to determine the average measurement of close-by devices within a specified range, such as computing the Euclidean distance between IoT devices. ANNs are employed in IoT for data collecting and error detection [13].

$$D(x,y) = \sqrt{\sum_{i-1}^{n}(x_i - x_t)^2 + (y_i - y_t)^2} \quad (1)$$

In addition to testing the coordinates using (xt, yt), the equation displays the Euclidean distance between the target position and the position specified by D (x, y) as well as the mass position of the position defined by (xi, yi).

$$Acc = (TP + TN)/(TP + TN + FP + FN) \quad (2)$$

Equation (2) demonstrates that is the precision (%), FP is false positive, TP is false negative, TN is true negative, and TP is true positive. The classification of the human mode is depicted on the confusion matrix in Figure 2 as a result of testing conducted for each distinct mode. Test findings relating to accuracy performance in posture recognition using the KNN technique, are presented in a confusion matrix [14].



Prediction pose

Actual pose	A	B	C	D	E	F
A	90.0	6.7			3.3	
B	10.0	83.3		3.3		3.3
C			80.0	10.0	10.0	
D			13.3	80.0	6.7	
E		6.7		16.7	76.7	
F	23.3		6.7			70.0

(a) 60 training data samples

Prediction pose

Actual pose	A	B	C	D	E	F
A	96.7	3.3				
B	6.7	93.3				
C			93.3	6.7		
D			3.3	96.7		
E	6.7				93.3	
F		3.3		6.7		90.0

(b) 120 training data samples

Prediction pose

Actual pose	A	B	C	D	E	F
A	90.0	6.7	3.3			
B	6.7	93.3				
C	6.7		86.7	6.7		
D			3.3	96.7		
E			3.3		96.7	
F				6.7		93.3

(c) 180 training data samples

Figure 2. Classification performance of accuracy for poses A – F using KNN

Support Vector Machine (SVM)

Powerful supervised algorithms like SVM perform best on smaller datasets, however, they also do well on complex ones. Support vector machines, often known as SVM, can be used for both classification and regression tasks, but they work best for the latter. They were relatively well-known when they were developed in the 1990s, and with a little tweaking, they remain the standard for reliable algorithms. The fundamental objective of SVM is to find the best hyperplane, which is the one with the greatest distance between two classes. This is accomplished by identifying many hyperplanes that accurately classify the labels and then selecting the hyperplane that is most remote from the data points or has the highest margin [15].

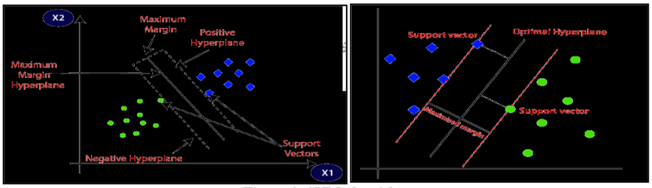


Figure 3. SVM algorithm

As seen in Figure 3, we must establish a judgment rule to categorize a point as positive or negative. can provide a decision rule as Currently have a method for determining how to project one vector onto another. Using the dot product of two vectors, accomplish this.

$$(x2 - x1).\frac{\vec{w}}{\|w\|} \quad \frac{x2.\vec{w} - x1.\vec{w}}{\|w\|} \qquad (3)$$

Since x2 and x1 are support vectors they lie on the hyperplane, hence they will follow **y_i* (2.x+b)=1** so we can write it as:

For the location point y = 1

$$1 * (\vec{w}.x1 + b) = 1$$

$$\vec{w}.x1 = 1 - b \qquad (4)$$

Also, for negative points y = -1

$$-1 * (\vec{w}.x2 + b) = 1$$

$$\vec{w}.x2 = -b - 1 \qquad (5)$$

Unsupervised Machine Learning (USML)

The second method of applying ML that searches for patterns in data is known as unsupervised learning. Unsupervised learning is a second kind of ML strategy that scans datasets for patterns without labels. Because it uses unlabeled data to find patterns rather than labeled data, USML requires less supervision and produces less biased results than other machine learning techniques. IoT system optimization and data dimensionality reduction are possible with the USML algorithm [16].

K-means algorithm

One of the most used "clustering" algorithms is the unattended K-Means algorithm. Cluster definition is done using k centroids, which are stored by K-means. If a point is closer to one cluster's centroid than any other centroid, it is said to be in that cluster.

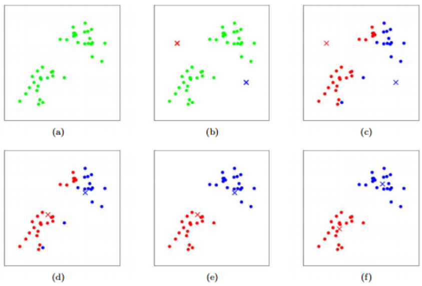


Figure 4. K-mean Algorithm

Figure 4 demonstrates how the K-Means algorithm determines the best centroid by alternately (1) assigning data points to clusters based on the current centroid and (2) picking a centroid (the point that is the center of the cluster) based on the assignment of the current data point to the cluster [17].

In a clustering problem, we are given a training set $\{x^{(1)}, \ldots , x^{(m)}\}$ and want to group the data into some contiguous "clusters". Here, as usual, we get the feature vector $x^{(i)}\in \mathbb{R}^n$ for each data point; but without the label $y^{(i)}$ (which makes it becomes an unsupervised learning problem). Our goal is to predict k centroids and labels $c^{(i)}$ for each data point. The k-means clustering algorithm is as follows:

For every i, set $c^{(i)} := \arg\min_j \|x^{(i)} - \mu_j\|^2$ (6)

For each j, set

$$\mu_j := \frac{\sum_{i=1}^{m} 1\{c^{(i)} = j\} x^{(i)}}{\sum_{i=1}^{m} 1\{c^{(i)} = j\}} \qquad (7)$$

Comparing Supervised Vs. Unsupervised Learning

To choose the best algorithm, this section compares the main features of supervised and unsupervised learning. The differences between supervised and unsupervised learning algorithms are summarized in Table 1, and when it comes to data mining, supervised learning can be classified into two categories of problems: classification and regression. Clustering, association, and dimensionality reduction are the three basic tasks that unsupervised learning models are utilized for. The comparison table above highlights the key distinctions between supervised and unsupervised learning, allowing us to select one of them when deciding which algorithm to use in the framework [18].

Table 1. Comparison between supervised & unsupervised learning

Supervised Learning	**Supervised Learning**
The two different sorts of issues that can be solved using supervised learning are classification and regression.	H. Clustering and association problems can both be solved via unsupervised learning.
the output is fed into the model along with the input data.	Unsupervised learning requires simply input data.
output prediction	Used to uncover hidden patterns in data.
Algorithms are trained using labeled data and	Algorithms are trained on unlabeled data.
Using supervised learning models, accurate results are attained.	Results from models of unsupervised learning are less precise.
When fresh data is supplied to a model, supervised learning aims to train it to anticipate an output.	Unsupervised learning aims to extract relevant insights and hidden patterns from unfamiliar datasets.
Various algorithms, including Bayesian logic, decision trees, logistic regression, linear regression, multi-class classification, support vector machines, etc. are used in supervised learning.	Unsupervised learning uses a variety of strategies, including clustering, prior algorithms, and artificial neural networks.
Direct feedback is provided to supervised learning models to determine whether the desired outcome is predicted.	Models do not accept feedback
Supervised learning and artificial intelligence are not very similar since in supervised learning, the model must be trained to correctly anticipate the output for all data.	In that it continuously learns new things as it gains more experience, unsupervised learning is more similar to artificial intelligence.
The total number of classes in supervised learning is known.	Unsupervised learning has an undetermined number of classes.
In circumstances where the output and input data are known, supervised learning may be applied.	When just the input data is known and not the output data, unsupervised learning can be applied.
The computational complexity of supervised learning is significantly higher than that of unsupervised learning.	Unsupervised learning is less computationally complex than supervised learning.
Offline analysis is used for supervised learning.	Data analysis is done in real-time for unsupervised learning.
Spam detection, handwriting recognition, pattern recognition, speech recognition, etc. are some examples of supervised learning applications.	Data preprocessing, fraud transaction detection, and other uses for unsupervised learning.

III. Artificial Intelligence of Things (AIoT)

AIoT refers to the fusion of internet technology and artificial intelligence (AI) technologies. Internet of Things (IoT) infrastructure and artificial intelligence (AI) technologies are combined to form AIoT. AIoT processes and analyzes the vast amounts of data generated by IoT devices. It then applies machine learning and other artificial intelligence models to identify patterns that could provide insights and aid in decision-making [19]. AIoT aims to enhance data management and analysis, enhance human-computer interaction, and make IoT operations more effective. AIoT is revolutionary and advantageous for both technologies because AI adds value to IoT through connectivity, signaling, and data exchange, while IoT adds value to AI through machine learning capabilities and improved decision-making processes. AIoT may enhance businesses and their services by generating value from data produced by IoT. IoT devices may leverage gathered massive data to analyze, learn, and make decisions more effectively thanks to AI [20].

A. Implementation of AIoT

AI is included in infrastructure elements, such as programs, in AIoT devices. AI is included in IoT networks-connected infrastructure elements including software and chipsets in AIoT devices [21]. Then, APIs are utilized to make sure that every piece of hardware, software, and platform functionality and interoperability occur without any input from the end user. IoT devices generate and gather data while in use, which is then evaluated by AI to offer insights and boost productivity. AI generates insights using techniques like data-driven learning. AIoT data can also be handled at the edge, which refers to processing IoT device data as closely as possible to the source device to reduce the bandwidth needed to transport the data and prevent potential analysis delay [22].

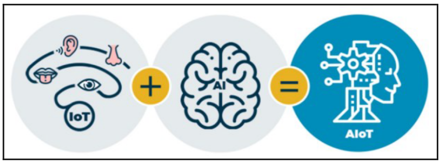


Figure 5. IoT (sensory organs) + AI (brain) = AIoT

The concept of integrating artificial intelligence capabilities into Internet of Things (IoT) devices to create an intelligent, interconnected system is depicted in Figure 5. IoT serves as the system's brain, while AI serves as its sensory organs. IoT systems use real-time data collection, analysis, and decision-making to achieve intelligent outcomes. A network of linked devices transforms into an intelligent machine with the combination of AI and IoT that can not only learn and react (in real-time) but also improvise [23].

B. Benefits of AIoT

AI-enabled IoT devices may analyze data to find patterns and insights and then change system operations to operate more efficiently. This is just one of the numerous advantages of AIoT. The capacity for quick adaptation is an additional benefit. The system can be adjusted as necessary by generating and analyzing data to discover flaws. AI performs data analysis, which is another benefit of AIoT. IoT device monitoring takes place with fewer staff members, saving money. Scalability is a benefit of AIoT as well. To improve current operations or add new capabilities, the number of devices connected to an IoT system can be raised. The primary advantages of utilizing AIoT are listed below, as shown in Figure 6 [24].

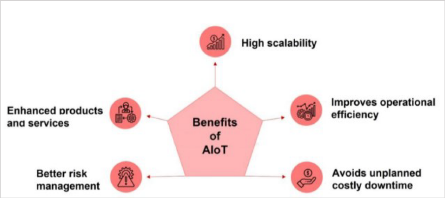


Figure 6. Benefits of AIoT

C. AIoT in Smart home system

A linked house is one benefit that an Internet of Things (IoT) smart home system offers the consumer. An Internet of Things (IoT) smart home system gives consumers access to a networked platform that enables remote automation programming and smart device control. When you combine that system with artificial intelligence (AI), you have a linked smart system that can manage your smart home appliances and understand your preferences. Artificial intelligence for the Internet of Things (AIoT) refers to this fusion of AI with IoT. Applications of AIoT systems are numerous. Just a few instances are provided below [25].

- Security: AIoT employs facial recognition technology and connected cameras to separate family members from unauthorized visitors. The AI can turn off safety mode and open the door for a family member as soon as they arrive home. On the other hand, if an unauthorized guest is discovered, the AI will promptly notify your family and the authorities by sounding the alarm.

- Safety: AI may leverage a variety of linked devices in an IoT system to protect your family. AI, for instance, can utilize cameras to spot when a toddler enters a pool or an old person trips and alert you to these events. Using a gas sensor, it can find gas leaks and instantly turn off the furnace.

- Convenience: AI can learn each family member's living routines by using data from all of your connected gadgets. It automatically modifies the lighting, temperature, music, and blinds when it recognizes that you are in your room. When you leave your room, everything is turned off.

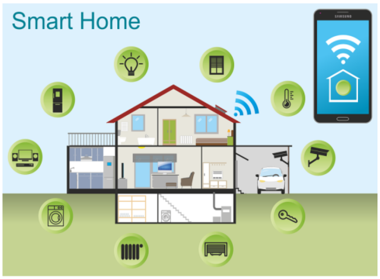


Figure 7. Smart Home System

Figure 7 demonstrates the vast array of house improvements that are possible with smart home technology. There are some illustrations of various technologies and their various applications. For instance, you can turn on specific lights in your house by pressing a button on a tablet, keyboard, or cell phone. In any room of the house, you may use voice control to start playing a certain song or playlist. Smart home security equipment allows you to watch live feeds from your security cameras from a distance and keep an eye on every area of your house. By programming lawn sprinklers to deliver water at the right time of day, gardens can be automated. The finest garage door opener may be your phone, which enables you to open your garage door with a straightforward voice command. With the smart home hub, you can efficiently monitor, manage, and control any integrated device [26].

IV. Discussions Results

The rapidly growing network of interconnected things known as the "Internet of Things" uses embedded sensors to collect and exchange data in real-time. When artificial intelligence is combined with the Internet of Things (IoT) infrastructure, we get Artificial Intelligence of Things (AIoT), which enables more effective IoT operations, enhances human-machine interaction, and improves data management and analytics. Thermostats, cars, lights, refrigerators, and many other devices can all be connected to IoT. Devices that can use the AIoT will be proactive rather than reactive. This simply means that IoT systems with AI integration are more reliable, secure, and even scalable. However, the majority of AI and machine learning models rely on data to make inferences.

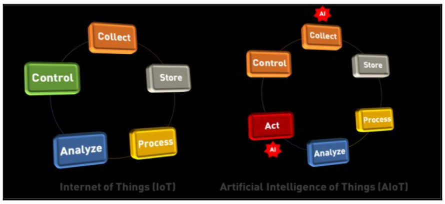


Figure 8. IoT v.s AIoT

Figure 8 briefly outlines the distinctions between IoT and AIoT while describing the significance of AIOT technology in general. Security, operational efficiency, and scalability are all improved by an AIoT. The distinctions between IoT and AIoT are outlined in Table 2 which follows.

Table 2. Comparison between IoT & AIoT

IoT	AIoT
Utilize the network to connect the gadget.	Utilize the network to connect the gadget.
significantly lowers the cost of data transfer.	Reduce data crossover and lower the barrier to entry for cognitive analytics.
The capabilities of the device are already known.	The method is always being improved, and device capabilities are known beforehand.
Centralized monitoring is the main focus of IoT.	The actionable insights produced by automated AI are another area of interest for AIoT.
You need to interface with computers and people.	No need for human interaction
Artificial intelligence is a must for IoT to work.	IoT & AI are required for AIoT. AIoT is not merely a division of IoT.
Smart wearables, smart homes, smart cities, and water quality monitoring are a few examples of IoT applications.	Applications for the Internet of Things (IoT) span business and industry, autonomous vehicles, delivery robots, and more.

In all sectors, AIoT holds great promise for assisting businesses in identifying and establishing distinctive competitive advantages in terms of operational management, quality assurance, and productivity. The technologies that enable AIoT are developing concurrently across industries.

V. Conclusion

These days, smart home systems are essential since it's critical to manage the operation of all devices, offer users accessible solutions, and improve energy efficiency. The Internet of Things (IoT) for smart home systems offers a networked system that allows for the setting of automation and remote control of smart gadgets. Applications leveraging IoT technology are powered by machine learning (ML), a component of artificial intelligence (AI), to more correctly predict outcomes. The efficiency of IoT operations is increased by artificial intelligence of things (AIoT) technologies, which also enhance human-computer interaction and data management and analysis. This study analyzes the use of AIoT technology to strengthen the relationship between the Internet of Things and artificial intelligence and better the smart home system's decision-making process through methodical research. In this study, the potential for comprehending the significance of IoT and the effects of AI on general decision-making processes and machine learning, in particular, is the main goal. How does AIoT decision-making operate and how might IoT and AI interact more effectively? We advise that future studies concentrate on methodical analyses of algorithmic implementations that can be utilized to enhance decision-making in smart home systems. focused on testing new algorithms on current systems and enhancing algorithm performance using AIoT technology.

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