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Internet of Intelligent Things (IoIT)

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Abstract

Internet of Intelligent Things (IoIT) is a combination and integration of Internet of Things (IoT) and Artificial Intelligence (AI). The first brings the physical world into the digital world and the second takes advantage of this fact to bring intelligence to form an artificially intelligent physical world. This paper attempts to humanize the physical objects of the IoT so that they become conscious, committed to collective objectives and educable like humans. This is possible and achievable thanks to the grandiose contribution of Artificial Intelligence. A specialized Transportation variant of the IoT is cited as a practical example of this marriage between IoT and AI. This practical example is the Internet of Vehicles (IoV) which concerns the field of land and air transport. This air transport takes advantage of Artificial Intelligence to make life easier for aerial objects and their human users.

Keywords: Internet of Intelligent Things (IoIT); IoT; AI; IoV; Conscious Objects (CO); Engaged Objects (EO); EDucated Objects (EDO)

1. Introduction

The Internet of Things (IoT) [1,2] is an emancipation of sensor networks from a local space to a planetary space that is the Internet. IoT augmented objects may be available in space granted to other augmented objects and other human users. An augmented object is a real-world object that has been augmented by a device attached to or embedded in it. A device provides the object with capabilities for capturing data from the object and for communicating these data to its immediate or distant surroundings. The device can also, in an autonomous or commanded way, act on the object to activate an ability of it. Considering the low computational and storage capacities of augmented objects due to the smallness of their device ICs, an IoT system can allocate computing service or huge data storage on a cloud.

Artificial Intelligence (AI) [3] is an intelligence intended to dress machines. Thought by men (having a natural intelligence) who know how to make useful most of the calculation and memory capacities of a machine, this artificial intelligence can bring enormous benefits in terms of automatic learning, game programming, vision processing, understanding and generating natural languages and other domains. Artificial Intelligence can above all analyze a large volume of data (Big Data) and issue decisions following this analysis.

The question this article tries to answer is how can we mix these two technological worlds: IoT and AI? And what are the benefits of this mix? We call this mix Internet of Intelligent Things(IoIT). Other researchers name it Artificial Intelligence of Things (AIoT). We prefer to keep the term “Internet” to preserve the scope of these technologies and their applications. AI can serve as a utility sub-domain to any other domain supported by information and communication technologies. This is indeed the case with the IoT. In this article we try to identify the aspects of AI that can help a smarter IoT. The remainder of this paper is structured as follows. In section 2 we will see how AI can help transform augmented objects into conscious objects. Indeed, the awareness of objects in their local or distant environment allows a better match between the context of this object and the behavior of this object in response to this

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context. In section 3 we explain how machine learning can help "educate" objects how to behave taking into account their past experiences. In Section 4, we present the contribution of AI on the Internet of Vehicles (IoV). IoV is a subdomain of IoT. Finally, the conclusion presents a synthesis and perspectives of the work presented in this article.

2. Conscious objects

You can be intelligent but not sociable. This is the case for IoT objects. The question that arises in this section is "Do the objects in an IoT environment know each other well enough to cooperate?". To this end, we introduce the concept of "conscious object".

A "Conscious Object" (CO) is an object who has a knowledge of its local or distant environment. It has a knowledge of objects of its environment it impacts or who impact it. An object X has as an "Object who Impact" (OwI) an object Y if the behavior or the state of Y can impact or affect the behavior or the state of X. We define "Object who Impact Set" (OwIS) for an object X the set of "OwI" of X. An object Y that an object X can impact, or affect is called "Object to Impact "(OtI). The set of all these "OtI" is labeled "OtIS". We call "Object to who Impact Set" 'OtwIS" the union of "OtIS" and "OwIS". OwtIS= OtIS U OwIS. If, for a given object, OwtS = {} then the object is called an "Isolated Object" (IO). If for a given object OtIS = {} then the object is said to be a "Passive Object" (PO). If for a given object OtIS ≠ {} then the object is said to be an "Active Object" (AO).

Given the above, a conscious object (CO) is an object who has a certain knowledge of the objects of its OwtIS.

A conscious object must, in principle, be an augmented object, i.e. an object to which an intelligent device is attached or embedded. The intelligence and knowledge necessary for the consciousness of an augmented object can be local to this augmented object or delocalized on a cloud on which artificial intelligence algorithms are deployed.

More conscious objects imply a highly conscious environment that influences and is influenced by each of its objects. The evolution of such an environment is only the fruit of the action of its objects. Therefore, it is difficult to predict and manage but it is highly efficient if its objects are. The behavior of this environment depends on its components, their articulation and their interaction. The fact that the objects in an environment are intelligent or smart cannot hide the importance of articulation and the exchange relationships of collaboration and cooperation between objects. The overall activity or passivity of this environment determines its evolution. If at the level of each object learning is possible, say, thanks to AI techniques, the objects will be able to adapt their behavior to the different situations already experienced. This will be more explained in section 4. Consciousness can only be a notion of the collective. Apart from whether an object is conscious of its state or self-conscious it is always conscious of something outside itself. It's a kind of culture if we can really talk about culture for non-humans. This culture is implemented by the designers of these objects. It's really a question of design and perhaps a design paradigm that can benefit and leverage AI and IoT techniques and technologies. The following section will allow us to know more about the usefulness of a collective consciousness for a collection of objects and especially for the objectives it pursues.

3. Engaged objects

In this section, we are interested in the role that objects can play for their community. To this end, we introduce the concept of "engaged objects".

An "Engaged Object" (EO) is an object sharing with other objects the pursuit of a collective objective. An objective can be the state(s) of an object or a set of objects. It can be a stage of realization of the collective work of these objects. i.e. in the object-oriented design paradigm, the state or result of a behavior of an object or a set of objects. An "Engaged Objects Set" (EOS) is a set of objects sharing a common objective. An objective can be thought of or modeled as the set of states or behaviors of a subset of objects chosen from among the set of objects. To be an EO for a given objective an Object X must verify the following:

- X is not an Isolated Object (IO) that is the X's OwtIS is not empty,
- X is conscious: X is a CO,
- For a given objective, and for X, EOS ∩ OwtIS ≠ {}.

We deduce from what precedes or we infer (this depends on the precedence of things) what precedes by what follows.

An isolated object (point a) cannot be part of a community or group of objects and therefore it cannot contribute, or it cannot be aware (point b) that it contributes to its development. Point c means that the object in question must be able to communicate to be imbued with sufficient knowledge of other objects to share their objectives.

Mathematically, this can be modeled by an application or function between the set of objectives and the set of objects. This function can be ensured by a programmatic structure based on a multi-agent design. Multi-agent programming makes it possible to distribute the achievement of an objective or a set of objectives between different agents. This collaboration or cooperation is possible thanks to an open programmatic infrastructure, which poses a challenge for these future infrastructures. Indeed, "Current trends in computer science are facing up the challenges of building distributed and open software systems operating in dynamic and complex environments, interacting with and acting on the behalf of humans" [15]. This challenge is met by the combination of IoT and its objects and artificial intelligence and its agents. In that way, the intelligence required for an engaged object to pursue a collective goal can be implemented by intelligent agents running within the engaged object or on a remote cloud.

The dynamicity and complexity of such open programmatic systems allow easy change of the mission of these objects without changing the composition of an entire IoT application. This allows dynamic planning of objectives and configurable distribution of their achievement between agents. The next section will teach us more about the education of objects by learning from their experiences in achieving collective goals that can also be done by intelligent agents or processes.

4. Educated Objects

"Educated Objects" are objects which are told how to behave in different situations during their lifetimes. This means that they learn to deal with new situations they have never encountered before thanks to this education. The recommended behavior is the one which is most accurately, most efficiently and most quickly to achieve the objective currently pursued. The experiences of conscious or engaged objects can be exploited to teach these objects how to behave to better be informed or pursue an objective. Can a conscious object predict the state or behavior of objects that are part of its OwtIS? Knowing its OwtIS, how should an engaged object behave to reach a partial or total objective? All these questions can be addressed by artificial intelligence (AI) and particularly by machine learning (ML) and expert systems (ES). In one hand, when we manage to master the behavior of an IoT system and learn the operating rules of this system, we can build and develop an expert system that serves to support this system. In the other hand, when the knowledge and mastery of the system is not feasible because of the impossibility of constituting rules of behavior of the system, we can use machine learning. This proves once again the magical combination between AI and IoT in the learning of objects equipped with means of processing and communication whether they are local or remote. Local intelligence is slower and offers independence from centralized infrastructures. However, this intelligence is less flexible to modify and update. Centralized intelligence, for example on a cloud, is less rapid especially given the cost of communication. The advantage is that the evolution of intelligent code is easier and less expensive. Educated objects become mature and autonomous over time, which reduces the need for human intervention formerly necessary for their operation. In the next section, we will talk about the Internet of Vehicles (IoV), which is a specialization of IoT in the field of transportation. We will learn about the role of the AI in transport, which makes it possible to limit this human intervention.

5. Internet of Vehicules (IoV)

In general, the vast revolution in the IoT helped to reduce traffic accidents by embedding some IoT objects in vehicles; and this created the Internet of Vehicules (IoV) concept [4]. IoV is a new concept that comes with Intelligent Transportation Systems (ITS) that combines IoT integration with existing Vehicular Ad-hoc NETworks (VANETs) capabilities [16]. IoV has dominated transportation systems because of numerous unique characteristics, including dynamic topo-logical frameworks, fast scalability, dependable internet access, high processing, etc. The IoV ecosystem contains large amounts of delay-sensitive data for real-time processing. Due to being equipped with long-distance communication protocols, it simply utilizes any level of processing type of equipment. Cloud computing, Vehicule Fog Computing (VFC) [17], and Mobile Edge Computing (MEC) [18] are hierarchical intelligent computing platforms that analyze large amounts of data and accelerate real-time processing in the IoV ecosystem [14].

The IoV allows vehicles to interact with drivers, other vehicles, environments, and road objects via different wireless networks. Vehicle connection with other infrastructures such as buildings, lights, stations, etc., is called Vehicle to Infrastructure (V2I) connection, while connecting vehicles with other vehicle systems are called Vehicle to Vehicle

(V2V) connection. The combination of both connection types V2I and V2V is known as Vehicle to Everything (V2X) connection [5].

The IoV is an Internet-enabled scalable network derived from vehicular ad-hoc networks (VANETs), that benefits from drones to promote information propagation speed and ensure real-time application support [11]. An unmanned aerial vehicle (UAV) or drone is an air vehicle that does not need a pilot and can fly independently. Now we talk about internet of drones (IoD). The Internet of drones (IoD) can be described as an infrastructure designed to provide control and access over the Internet between drones and users. Drones are rapidly becoming available commodity items, allowing any user to fly different missions in controlled airspace using these multiple items [13]. Also, interacting with the environment, UAVs can fly autonomously with predetermined flight schedules or create their designs in the middle of the flight. UAVs on the IoV help vehicles find suitable locations in a tree-dimensional space (3D). UAVs can make and maintain constant contact with vehicles due to changes in altitude, speed, and obstacles [12].

Successful implementation of Artificial Intelligence (AI) on drones and unmanned vehicles allows the development of self-piloting systems, thus doing away with the need for human operators. This saves manpower and expenses as well as being more efficient for certain tasks that humans cannot perform as quickly as a computer. It may also be one of the keys to unlocking commercial BVLOS (beyond visual line of sight) drone operations at scale.

UAVs (unmanned aerial vehicles), UGVs (unmanned ground vehicles) and other robotic platforms may use AI for a variety of applications, including Obstacle avoidance, Swarm operations, Real-time data analysis, image classification, Autonomous precision navigation and landing.

AI empowers a drone or robot to make decisions based on inputs from its sensors and may also allow the vehicle to continue with its mission even when it loses communications with its base of operations.

6. Conclusion

In this article, we present the strength keys of the combination and integration of IoT and AI. The internet as a global scope makes this marriage universal and extends its solutions world-wide. Making the world accessible to all, and intelligible to all, is the goal of science and technology. The physical and sensible world is, more than the world of ideas, what we all share. To this end, the IoT facilitates the integration of this world and especially its inhabitants into the magical digital sphere. Thanks to artificial intelligence, this physical world can become better understood and shared. In this article, we have borrowed the qualities of the human such as being aware, being committed to one's fellow human beings, being educable and being a learner to transfer them to the objects of the physical world so as not to forget the human in the design of an intelligent physical world. We must think about the machine while having thought about man in the back. We thought that the field of transportation can be one of the best practical examples with which we can illustrate this magical combination and effective integration between IoT and AI by focusing on air transport, which can see enormous progress in the coming decades. Finally, one of the extensions of the LIDO model [1] that we designed during our doctoral thesis can consider this AI that disrupts transport in the air and on land.

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