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Edge Computing and Artificial Intelligence Semantically Driven. Application to a Climatic Enclosure

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Abstract

Climatic chamber are enclosures where the ambient conditions, i.e. the temperature and humidity, are finely controlled. This one can play multiple roles such as the cultivation of plants (phytotron), the breeding of insects or habitat for exotic animals. The availability on the market of a wide variety of equipment makes it difficult to share settings and operating recipes. In this paper, we propose a versatile and automated modular climatic enclosure system that can be adapted according to the use cases and available material. In this paper, we use IoT device virtual representation, data validation by means AI algorithm, the semantic description of material, and ontology locally deployed from the cloud allowing to automate the local installation with container technology.

Keywords: phytotron; climatic enclosure; growth chamber; pogona; semantic rules; Internet of Things

1. Introduction

Nowadays, Edge Computing, Edge IoT, and Edge AI allows to achieve autonomous, performant and more intelligent systems. Semantic encodes meaning into IoT data to create situation awareness and facilitate their sharing and integrating, modeling and querying information, resource discovery, and inferring new knowledge. Semantic representations and reasoning technique should ideally be distributed between cloud and edge device [25].

Furthermore, semantic Web technologies have been extended to the IoT domain to alleviate the data heterogeneity issues and allow IoT systems interoperability. The semantic annotation use shared and interpretable vocabularies to exchange information between applications without loss of meaning.[2].

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The most common tool used for semantic annotation and inference is RDF, which is a graph-based data model consisting in statements (subject, predicate, object) structure which can be serialized in RDF/XML [5], JSON for Linked Data (JSON-LD) [23], N-Triples [3], N-Quads [8], Turtle [4], RDFa [16], Notation 3 (N3) [6], Entity Notation [26], etc.

RDFS [7] provides a data modeling vocabulary with concepts such as class, subclass, domain, and range. OWL [17] extends RDFS with a more comprehensive vocabulary for modeling complex ontologies. Apache Jena [19] is a framework used to build semantic applications to perform reasoning based on RDFS and OWL ontologies by means of a rule-based inference engine which infers logical consequences from a set of explicitly asserted facts or axioms and discover new relationship based on data and additional information in the form of vocabulary.

In this paper, we build our proposition around two different use cases: a vegetal use case with an individual phytotron and animal use case with a husbandry of *Pogona sp.*

Phytotron, also called growth chambers, are research facilities where environmental parameters such as temperature, humidity, irrigation, conductivity, lighting and CO_2 are precisely controlled. This pleasant installation allows on the one hand to measure the modification of the impact environmen, and on the other hand to optimize the natural growth of plants. With the democratization of hardware, cloud computing and the new possibilities offered by the Internet of Things, it is possible to develop a personal phytotron at low cost [1]. Bearded dragon lizards (*Pogona vitticeps* Ahl also named *Amphibolurus vitticeps* Ahl) are one of the most popular reptiles kept as exotic pets. Native to the semi-desert areas of Australia, they are ectothermic, regulating their internal temperature by external environment heat sources. They needs a controlled temperature and an exposition to ultraviolet.

The remainder of this paper is organized as follow: In section 2, we describe our background in terms of cloud and edge computing and the contribution and the integration of this paper with previous papers. Afterwards, we envisage successively some works related with our contribution in the edge computing reasoning, edge Artificial Intelligence and finally specification of breeding conditions of *Pogona sp*. In section 3, we detail our contribution based on heterogeneous micro cluster place at the edge of the network able to deploy micro-services and neural networks algorithms. In the section 4, entitled experimentation, we implement the two use cases on our micro Edge AI-IoT cluster. Finally, in section 5, we conclude this works with an analysis and perspectives.

2. Related Work

2.1. Background

In our previous papers, we have described an Edge Computing and Artificial Intelligence Architecture[9] that we have progressively developed with diverse use cases: cattle behavior [11], smart poultry [10], and landslides monitoring [14]. In this paper, we improve our previous architecture with the deployment of micro services and neural network by means of containers. We experiment it on our open phytotron previously described in [1].

2.2. Related works

This section contains a literature review of remarkable edge computing reasoning works, and a description of Pogona sp. and Mentha spicata environmental parameters used to respectively implement the animal and vegetal use cases.

2.2.1. Edge Computing reasoning

Su et al., 2018 [25] have compared and analyzed the semantic reasoning in Cloud and Edge Computing applied to a smart transportation use case. We have shown that the average ratio between Cloud Reasoning time and first results time from edge node is 5.1 times for RDF/XML, 4 times for Turtle, 6.6 times for JSON-LD, and 8.9 times for EN. Sahlmann et al., 2018 [22] have proposed to use ontology based on Virtual IoT Devices at Edge Level to hide real devices and aggregate device capabilities. The proposed architecture is model-driven and scalable in hierarchical way.

Lan et al, 2019 [18] have proposed to use an IoT Unified Access Platform based on Edge Computing decoupling upper applications with the lower sensing device. This access platform promotes consistent view of heterogeneous sensing devices and enable more responsive IoT applications hosted in the cloud. Also, it provides an efficient privacy protection.

2.2.2. Mentha spicata L. environmental parameters

Farooqi et al., 1999 [15] have shown that long photoperiods (24h of low light in addition to sunlight) increase the growth of different subspecies of Mentha while short photoperiods (8h of light/16h of dark) increase the amount of essential oil.

2.2.3. Pogona sp. environmental parameters

Oldfield, 2014 [20] encourages the using of a combined heat and ultra-violet (UV) lamp for 12 hours during the day and only heat during 12 hours during night-time with a minimum temperature of 24°C. Stahl et al., 1999 [24] recommend an ambient daytime temperature in cage of 27° to 29°C with basking site temperature range between 32° to 35°C, and a night-time temperature drop to 21°C. The lights cycle in the summer must be between 12 to 14 hours and 10 to 12 hours in the winter. Raiti et al., 2012 [21] suggest as Oldfield a photo-period of 12 hours of full spectrum light containing ultraviolet B (UVB: 290-320nm) and infrared (IR) and 12 hours of darkness. The cooler part of the enclosure should be not less than 27°C. A drop of 5-10°C is permissible in the evening for adults.

3. Proposed Method

The aim of our method is to allow the exchange of common semantic rules between users about a common use case (i.e. pogona sp breeding) but using material from different vendors. The method is applicable to various use cases.

In our architecture, each installation is potentially different and uses an IoT Device Virtual representation that facilitate the using of common semantic rules for each one. Semantic rules are reusable for specific installations of each user. On the op of IoT Device Virtualization layer an artificial intelligence algorithm (i.e. GRU) is used to predict future evolution data value. By comparing the real data acquired locally by the sensors with the models for predicting their evolution, it is possible to detect abnormal behavior of the system, detect failed sensors or temporary problem in data acquisition. Afterwards, when data is verified and possibly corrected, they are describe and enrich thanks to Local instance of Domain Ontologies and Semantic Ontology imported from the cloud, before to be stored in a local database. This stored data serves as input data of the local reasoner which apply semantic rules to deduce consequences and triggering of actuators.

As illustrated by the Fig. 1, the Message Queuing Telemetry Transport (MQTT), which is a publish-subscribe messaging protocol based on the TCP / IP protocol that allows communications between cloud and the edge level. The Combination of semantic rules with MQTT communication protocol provide multi-device, multi-domain, multi-vendor interoperability in IoT [25].

The knowledge is represented and maintained on the cloud by means of domain ontologies adapted to an application domain and completed with a semantic ontology specific to certain use case. These ontology ared coded in RDF(S) and can be shared between users and reused by multiple installations composed of different material. The semantic rules are specified using a semantic model to ensure the independence from the installation, process automatically knowledge, and be reusable.

Finally, an interface, hosted on the cloud, allows users to visualize by means of graphs last data collected on their installations, and adapt parameters which are translatde by a semantic rules adaptation. Docker container technology is used to easily deploy all software needed on the local installation.

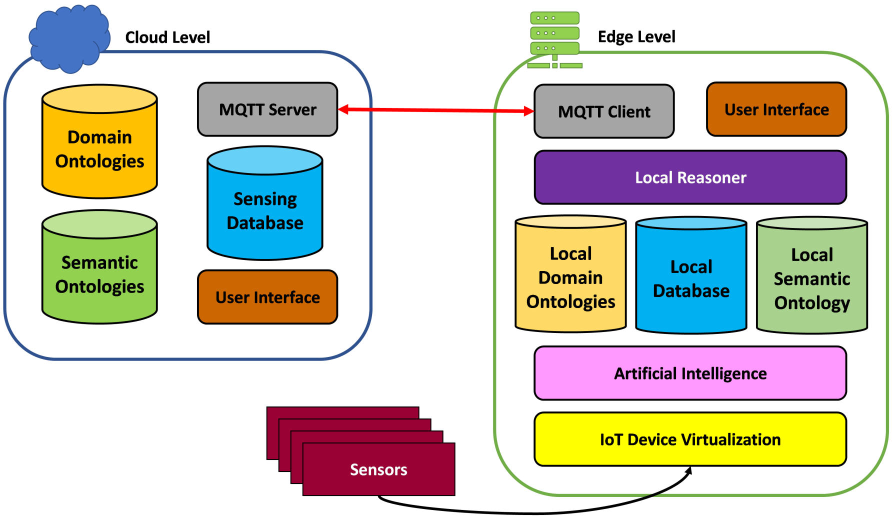
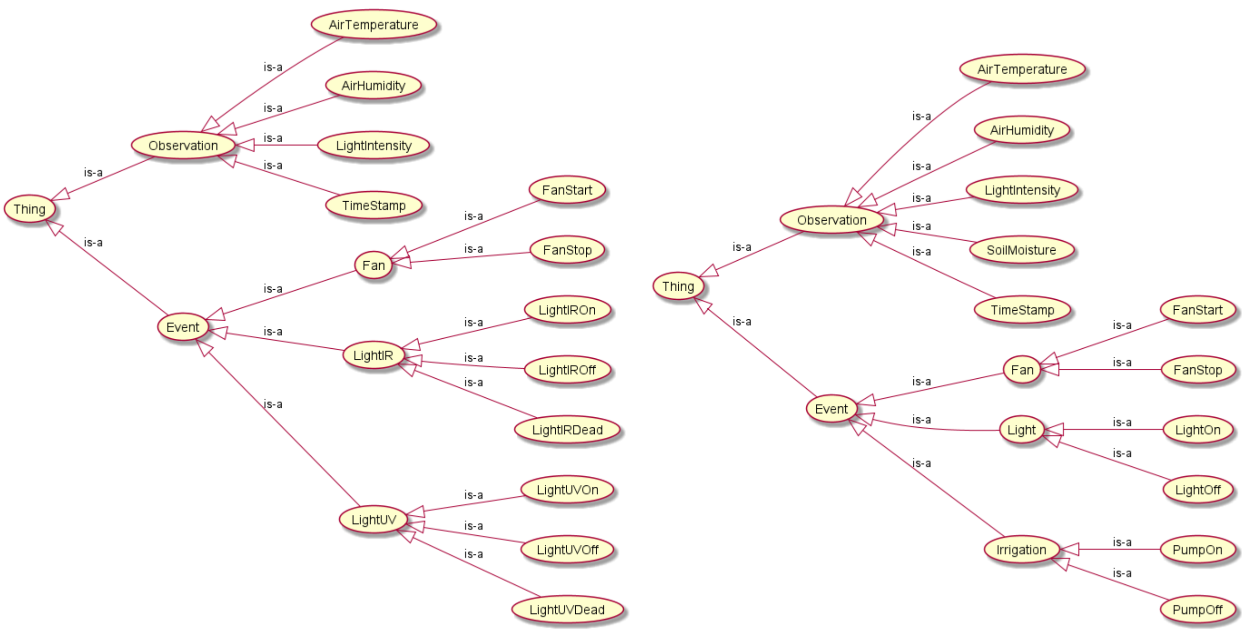


Fig. 1: High Level Scheme of our architecture

4. Experimentations

For our experimentations, we have implemented the Edge Level on our Architecture on a Jetson Nano equipped with a microSD card with Nvidia Jetpack 4.3 containing L4T 32.3.1, TensorRT 6.0.1.10, cuDNN 7.6.3, CUDA 10.3.0326, and OpenCV 4.1.1. The local reasoner used is Apache Jena.



(a) Pogona Use Case (b) Phytotron Use Case

Fig. 2: Static Knowledge

Fig. 2 provides a class representation of the two use cases implemented for our tests. Each installation is represented by the class *Thing* which inherits the classes *Observations* and *Events*. All sensors inherit *Observations* class while actuators inherit *Events* class. The different states of an actuator are specified by means of class inheriting a actuator class.

The Table 1 show examples of rules applied in the vegetal growth of *Mentha spicata* L. and in the table 2 for animal use case of *Pogana sp.* husbandry on the basis of the class diagram presented in Fig. 2.

Table 1: Example of Vegetal Semantic Rules.

Fact	Triggering Rule
FanStart	Observation hasTemperature > 25°C ∨ Observation hasHumidity > 50% → ns:FanStart
FanStop	Observation hasTemperature < 20°C ∧ Observation HasHumidity < 30 → ns:FanStop
LightOn	LightOff hasDuration > 900s → ns:LightOn
LightOff	LightOn hasDuration > 900s → ns:LightOff
PumpOn	Observation hasMoisture < 300 → ns:PumpOn
PumpOff	Observation hasMoisture > 700 → ns:PumpOff

Table 2: Example of Animal Semantic Rules

Fact	Triggering Rule
LightIROn	Observation hasTemperature < 24°C → ns:LightIROn
LightIRDead	LightIROn hasIntensity < 100 → ns:LightIRDead
LightOff	Observation hasTemperature > 35°C → ns:LightIROff
FanOn	Observation hasTemperature > 40°C ∨ Observation hasHumidity > 40% → ns:FanOn
FanOff	Observation hasTemperature < 27°C ∧ Observation hasHumidity < 35% → ns:FanOff
LightUVOff	LightUVOn HasDuration = 43200s → ns:LightUVOff
LightUVOn	LightUVOff HasDuration = 43200s → ns:LightUVOn
LightUVDead	LightUVOn HasIntensity < 100 → ns:LightUVDead

5. Conclusion and future works

In this paper, we propose a methodology to use a climatic enclosure for various use cases using an IoT device virtualization, an AI algorithm to validate data acquired by sensors. Afterwards data are enriched by means of domain ontologies and semantic ontologies. This data is used by a semantic resonator to apply semantic rules ton configure the enclosure for the specific use case selected by the user. The aim of this method is to provide means for users using material of different vendor to apply and exchange common semantic rules.

In our future works, we will implement our architecture on the research installation described previously in [12][13].

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