PhD proposal - Interoperability in Decentralized Goal-Directed Building Asset Management System

Employer: MINES Saint-Étienne, an IMT graduate school

Lab: Connected Intelligence, a team of the Laboratoire Hubert Curien UMR CNRS 5516

Location: Saint-Étienne, France

Advisors:

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Keywords

Linked Building Data, Semantic Interoperability, Semantic Web, Multi-agent systems

Requirements:

Master in computer Science with good theoretical and practical knowledge of Semantic Web Technologies, Multi-Agent systems and Artificial Intelligence. Programming skills.

- Education: MSc (with distinction)
- Specialties: Computer Science, Artificial Intelligence, Linked Data, Semantic Web, Multi-agent systems
- Languages: English (French is a plus)
- Programming skills: Java, Web development technologies

Application

Applications should be submitted by e-mail to olivier.boissier@emse.fr and maxime.lefrancois@emse.fr with the reference: **PhD_BAMS_2018**

The position is available immediately and application evaluation will be continuous until the position is filled. Interested candidates should submit:

- Curriculum Vitae
- Motivation letter of two pages
- Names and contact of three references

Context

The digital transformation in the Building Information Management (BIM) domain lets envision a wide deployment of services for managing assets of various domains (e.g. energy, water). Each of these services has to react and adapt to continuous changes (e.g. environment, energy prices, preferences of the householders and of stakeholders) [1]. To face the complexity and the time response constraints, human decisions are fully or partially delegated to building management systems. BIM systems are thus shifting from purely data-driven systems to share information, to goal-directed ones, able to discover and coordinate themselves, exchanging knowledge and decisions, to achieve high-level goals.

These IT infrastructures cover a large set of integrated technologies from IoT to Cloud technologies with increasing use of distributed ledger technologies. They involve various data protocols and representation formats. BIM systems are thus becoming extremely complex, dynamic and heterogeneous, bridging across different specialized management systems (e.g. electricity, gas, water, HVAC) and enlarging at multiple scales (from building, neighborhood, region to continent). Keeping all these individual systems interoperable is a mandatory issue. Moreover, each of the asset management service should be able to initiate, participate or end cooperation with others at any moment, building a flexible and decentralized decision infrastructure. Ensuring the convergence of such an open network where centralization is not possible is a key issue for the safety and efficiency of the underlying physical infrastructures.

Ensuring interoperability first requires solutions to cope with the problem of data, protocol, and services heterogeneities. This is addressed at the syntactic and semantic level by ongoing standardization efforts such as BuildingSMART ifcOWL [30], ETSI SmartM2M SAREF [26,27], W3C Web of Things , W3C Linked Building Data [28,29]. Ensuring convergence requires coordination and regulation models able to flexibly cope with the numerous local and possibly conflicting goal-directed behavior of the autonomous asset management services that locally aggregate global external constraints stemming from preference profiles. Business considerations being not sufficient to ensure acceptability and trust in this digital infrastructure, coordination and regulation models support ethical considerations such as fairness of allocation, privacy of the users, wellbeing and transparency. Interoperability requirement naturally extends to the coordination and regulation models in order to enable autonomous asset management services to operate in heterogeneous and open infrastructure operated by different stakeholders.

Objective and challenges to consider

In this context, Multi-Agent System technologies (MAST) are promising solutions [1, 2]. Since the preliminary work that considered communities of autonomous agents in smart buildings [3], several proposals have been made that integrate building asset management to optimize energy consumption or the agent comfort [4,5,6]. In that direction, the goal-directed autonomous asset management units will be defined as autonomous agents able to control one or several services participating to the management of the building, able to coordinate and regulate.

Semantic web technologies (SWT) have been proposed to explicit regulatory systems accessible to autonomous agents [22, 21]. SWT offer ontology-based languages that can be used for specifying knowledge domains and reasoning over them. They foster uniformity of data formats, as well as modularization and reuse of specifications (ontologies), by making it possible for ontologies to include and refer to information provided by other ontologies. In the recent years, different work used SWT for representing various dimensions of MAS (e.g., agents [14, 15], reputation [16], interaction protocols [17, 18], norms [19], organizations [20, 21]).

SWT have already been applied to exchange knowledge and reason with it in smart building for ambient intelligence [7], context description [8], or building diagnosis [9]. According to best practices, existing ontologies have been combined [10], and currently converge to become standards for describing the building itself [11] or the assets and their functions [12]. Besides these domain ontologies, knowledge models used within multi-agent systems are related to meta-level knowledge such as ethics and moral values [23], and also related to coordination [24] and regulation models [25]. Several proposals are or have already been done in MAST when considering communication languages, interaction protocols (e.g. IEEE FIPA), regulation and organization capabilities among the heterogeneous normative coordination models ruling the cooperation among agents [22].

However, there doesn't exist a fully integrated infrastructure where all these proposals are interoperable and easily accessible to any types of agents so that they are able to reason on ontologies, realize ontology matching and make effective use of machine-readable knowledge sources to discover and use resources, to discover and use coordination models, to discover and reason on the constraints imposed by regulation models, etc.

The main objective of this PhD proposal is to define models and technologies to define fully interoperable decentralized goal-directed management systems, applied to Building Asset Management Domain.

Two main challenges have to be considered:

1. **Discoverability and interoperability of knowledge models.** Even if several knowledge models already exist for assets in the building domain, there is a lack of well-defined ontologies to define coordination or regulation strategies between asset management services as well as shared value system such as ethical or moral values. This is an important issue to consider since ever evolving autonomous building asset digital twins will participate to various coordination schemes according to what they contribute to in the building. Defining distributed and efficient discovery processes (service description, reasoning on these descriptions, trust and reputation) will need to be considered.
2. **Coordination and regulation of goal-directed ethical autonomous entities.** The building asset management units will have to be equipped with abilities to do goal-directed reasoning on knowledge. The challenge is to make them able to effectively discover and reason on machine-readable knowledge descriptions of resources, coordination models, regulation models, and moral or ethical values. The main objective is to ensure global, coherent, and flexible, functioning of the system while reacting and adapting to the dynamic evolutions of the building eco-system (e.g. change of user preferences, of prices, of global laws).

Scientific and industrial impacts

This PhD aims at bridging two research domains that are producing models and technologies that are not yet enough integrated to address the challenging problem of goal-directed behaviors in heterogeneous and decentralized systems. Such features are the common properties of current and future industrial systems. Developing an integrated infrastructure bringing altogether the technologies to develop goal-directed behavior in a decentralized and heterogeneous setting will foster the development of innovative applications in the industry of the future.

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