Information Modeling and Information Retrieval for the Internet of Things (IoT) in Buildings

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ABSTRACT

The ability to monitor and analyze real-time information generated by sensors and devices is a vitalto maximize employee effectiveness and productivity in organizations, reduce unscheduled downtime, increase production quality and minimize the risk of accidents. The implementation of aneffective smart building requires deep study of information systems, monitoring with data collection and analysis and reflection on concepts, representation, goals and occupations of buildings. This research is focused on the application of technologies within the domain of Architecture, Engineering and Construction (AEC), with the following objectives: to identify the current state of literature on the topics Information Modeling, Information Retrieval and Internet of Things (IoT) in buildings in the context of Information Science; discuss concepts and advances Smart Building, Building Automation, Intelligent Building and Information Modeling Building (BIM); and prepare a proposal for the implementation of IoT in a research laboratory of UFMG. The smart lab experiment is a proof of concept proposal that through practice makes simulations for real solutions like validation. The results demonstrate that the implementation of IoT provides new insights into the behavior of people and the environment, supporting the identification of standards and setting precedents for optimization.

Keywords: Information Modelling, Information Retrieval, Internet of Things (IoT), Smart Buildings, Smart Cities.

1. INTRODUCTION

In the current global economic context, intense competition, dynamism and high complexity of the market and the emergence of new technologies make organizations face more and more challenges, which makes it increasingly evident that information retrieval provides supports in decision-making. The need for survival and growth in an increasingly demanding and competitive market requires companies to constantly develop new products and more efficient and innovative processes.

The Internet of Things (IoT) appears to integrate physical and virtual elements with Internet connected networks, allowing these "things" or elements to collect, exchange, and store a volume of data generated through those processes in cloud structures. Such integration should allow for its processing and analysis, enabling the generation of services and perspectives never before explored. The ability to monitor and analyze real-time information generated by sensors and devices increases the effectiveness and productivity in organizations [2].

Information modeling produces benefits in the representation and organization of information in different contexts. Concomitantly, IoT provides well-structured and documented information systems with the capability of presenting better quality results. Both models aid in

increasing market knowledge, while also reducing costs, risks and failures in projects, and helping the management of the complexity of growth [7].

Information retrieval addresses the representation, storage, organization, and access to information. The aim is to provide quick and easy access, dealing with the need for retrieval of information by the user. It can also be considered as both the process of searching for a set of documents and the identification of related subjects [6]. The information retrieval becomes useful to IoT by allowing the capture of relevant information generated by the sensors and devices, enabling the efficient use of such information, for example, preventive actions related to security, information management, and more assertive decision making.

The first motivation of this research is the filling of a gap in theory, which does not openly discuss Information Retrieval from IoT, and the importance of Information Modeling in structuring and building systems geared to these technologies. Another motivation is to further explore the application of IoT in building processes.

In this context, the literature review identifies theories and concepts of Information Modeling, Information Retrieval and IoT employed in building processes.

In the other hand, the concepts in Smart Building, Building Automation, Intelligent Building and Building Information Modeling (BIM) are expanding. They are based on classical concepts of environmental control, energy efficiency that support studies of urbanism and the effective use of space. The application of the new technologies and the possibilities of collecting, storing, analyzing and making available a large volume of information regarding the monitoring of spaces, things and people occupying a building, a set of buildings and a city, arise.

Next, the proposal of IoT implementation in a laboratory of Research of the Graduate Program in Knowledge Management and Organization (PPG-GOC), at the School of Information Science of UFMG is made.

2. INFORMATION MODELING

The models are important for the structuring and progression of knowledge and for human development. Humans share knowledge by developing a culture, a system of coded behaviors. Knowledge can then be structured on a micro level according to logical schemes. At a high level, the human being structures knowledge in basic and confirmed models and theories. Structural knowledge simplifies the process of knowledge acquisition and sharing [14].

Models can be hypotheses, untested or insufficiently tested, theories, data syntheses, functions, relations or equations. They can also be structured ideas, connecting arguments that have some explanatory power. They are structures that represent a reality, presenting supposed characteristics or relations in a generalized way [16].

The information modeling does not have clear boundaries of its internal and external domains. Its importance is due to the increasing demand of the people and organizations in relation to the information systems. [8] The proposal of the information model is that the domain of possibilities
has a one configuration, that is, in one hand is the human being with his personal reality and knowledge, and in the other hand is the information system with its limited reality. Between these two extremes lies the representations, which try to bridge the gap between physical resources and information management systems with end users.

The models users, the system and the interaction between them, are also denominated conceptual models, however, there are clear limits between these models [15]. The only definition clear is the distinction between the individual view of reality - the cognitive model - and the view that someone else has of how a group of individuals be seeing some aspects of an Information system - conceptual model" [8].

The conceptual model emerged in response to the computer in the mid- twentieth century. Conceptual modeling is a response to the difficulties encountered throughout the development of computerized systems. The conceptual modeling exceed limits [14].

An information system can be visualized on three levels: internal, conceptual and external. The conceptual level focuses on the comprehensiveness of the meaning of information. "The task of developing a conceptual schema is called information modeling. Its primary objective is to develop a stable and coherent description of the meaning of the data, is a conceptual schema (...)." Lyytinen (1987 apud [16]). These author proposes two instances for modeling information. The first is called "reality mapping", which is essentially a descriptive technique to represent something understood and that behaves unambiguously. A process of mapping the "real world" in conceptual schemas. According to this view, "an information system is a completely predictable formal system that mirrors the deterministic behavior of a universe of discourse". A limitation to its applicability is the need for certainty at all levels. The second is called "formal language development" whose focus is on the representation, structure, content and use of the linguistic message, it can deal more accurately with the essentially ambiguous nature of most reality settings.

3. INFORMATION RETRIEVAL

According to Jacob and Shaw (1998 apud [3]), representation involves individuals and groups, cognitive aspects, and is essential for the processes of acquisition, organization, storage and retrieval.

The data that make up an information system, the database are structured with information representation “the representation has the purpose of recovery. In the process of representation, the document or set of documents may be replaced by a set of information to make it possible for the user to locate and retrieve it [5]”.

The representation of information is classifies into two types. The primary one, which addresses the perception, identification, reflection and codification of human thought. It focuses on cognition and transdisciplinarity, which aims at the knowledge the secondary representation represents the context of files, libraries or other documentation or information services, for recovery purposes [3].

The term Information Retrieval (IR) was deployed by Calvin Moores in the 1950s, and deals with representation, storage, organization, and access to information items. The aim is to provide quick and easy access, which meets the need for recovery information by the end user. It can also be considered as the process of searching for collection of documents and identification of related subjects [6].

Over the past 20 years, the information retrieval area has expanded far beyond the primary objectives of indexing texts and finding useful documents in a collection. IR research includes modeling, categorization, systems architecture, user interfaces, data visualization, filtering, languages, among others. In the 90's, with web, that the area was more disseminated among computer users, and tools were developed for multimedia and hypertext applications [4].

Information retrieval in two directions: “The first focuses on the forms of representation of knowledge and the way of framing a particular search within the pre-established parameters. The second focuses on natural language as a way of retrieving information and systems seek solutions to solve problems that come in the most variable forms possible without any type of standardization or pre-established formatting [6]".

With the web the deterritorialization of the document, and the exponential growth of information, structured or unstructured, information retrieval has a challenge, in the systematization of this data, information and knowledge, especially the unstructured, in a coherent and unified and the policy of access to this information.

4. INTERNET OF THINGS

Internet of Things (IoT) refers to the integration of physical and virtual entities in networks connected to the Internet, allowing these "things" to collect, exchange and store the large volum of data generated in these processes in cloud structures, thus allowing their processing and analysis, enabling the generation of new services and perspectives [2].

The IDC's 2015 survey estimates a market of 1.7 trillion dollars in 2020, IoT is a concept considered old. [15] attributes the term to the British researcher Kevin Ashton of the Massachusetts Institute of Technology (MIT) (1999) and explains that "with the Internet everything will be connected: smartphones, refrigerators, fire alarms, tablets, computers, garage doors, traffic lights, road signs and more" and the need for security and that this is a discussion that is just beginning.

As a result of the convergence of several technologies, IoT is part of the large number of devices that have been proliferating. It is estimated that by 2020 [1] there will be more than 40 billion connected devices, a fact associated with the miniaturization and popularization of the most varied types of sensors and the advancement of wireless for the growth of the concept and dissemination of its applications.

The application brings and will have a great impact on the life of people, be it in the way they take care of health, work, inhabit, dress or relate to the environment. Some examples: BioHackables, Augmented Reality, Digital Tatao (Wearables), Smart Devices (Surroundables) and Smart Pills (Swallowables) [16]. Almost human with entities that exist only in the digital environment [14] its impact may be as great as major advances already achieved by medicine and other areas.

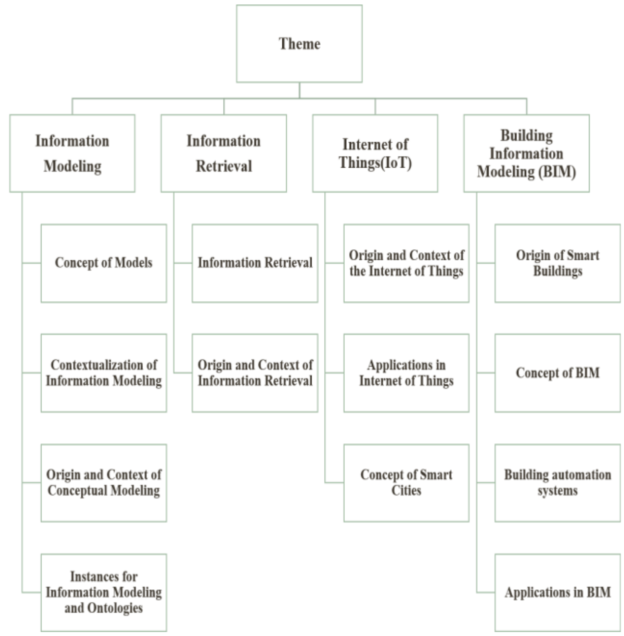
5. METHODOLOGY

In order to search the concepts of Information Modeling, Information Retrieval and IoT, the method of bibliographic research was chosen, the point of view is elaborated from material already published, such as books, articles, newspapers, Internet, etc [12]. To meet this objective, the Web of Science, Scielo, LISA, Academic OneFile, ScienceDirect, Scopus and ACM Digital Library databases were used as sources of information.

The research is an exploratory study that provides greater familiarity with a problem, involving a bibliographical survey [11]. It can be considered exploratory in Brazil, because the theme is relatively new and has few empirical studies of greater depth realized.

In order to identify the contexts and authors featured in the survey of the bibliographic research, a Literature Map (Figure 1) based on the tool developed by [11] is presented. It assists in the organization of the literature review, and illustrates how the study will be positioned in the body of the research.

Figure 1 – Literature Map.



Source: Created by the author (2017).

Literature map is a result of the systematization of the fundamental concepts for the development of research.

After the bibliographical research and the understanding of the themes raised, a proposal was made for the implementation of IoT, in a research laboratory of the Graduate Program in Management & Organization of Knowledge, at the School of Information Science of UFMG. The objective was to map the possibilities of implementing sensors and devices in a controlled environment, called Smart Lab, aiming the future development of information management, through systems that foster integration between the virtual organization and the implementation in the form of physical reality projects.

6. SMART BUILDING, BUILDING AUTOMATION, INTELLIGENT BUILDING, BUILDING INFORMATION

The different concepts of smart building are intertwined with common goals. It is integration between the systems and the relationship with the occupation of spaces, the interaction of technology and the human experience. This includes understanding the needs and uses of buildings as a basis for monitoring information that defines patterns of behavior from the most private and individual to large networks of relationship, infrastructure.

The Intelligent Building Institute (IBI) in Washington, DC, first used the term "intelligent buildings" in the US in the early 1980s. An intelligent building is one that can integrate multiple systems to efficiently manage resources in a coordinated way, with the goal of maximizing technical performance, investment savings and operating costs, as well as flexibility [10]. Intelligence can be considered a general cognitive ability innate to humans. However, when Piaget defines intelligence as information processing skills in the adaptive balance between the individual and his / her environment, it is possible to broaden the definition to understand how people use buildings and interact with the internal environment, their constructive elements, and the external environment. Thus, intelligent buildings expose knowledge-based systems that are used to perform tasks that require knowledge. However, to fully utilizethis intelligence in buildings intelligence must be applied in the concept, construction and operations of a building, both by clients, designers (architects and engineers), builders and maintenance professionals [10].

Building Information Modeling (BIM) technology works with a virtual building. It is possible to do studies, simulations, visualize and anticipate the behavior of the building before it is built and exists physically. It is possible to create a virtual model, in the design phase, optimized for the construction and operation, throughout its life cycle that can be used as a reference in these phases. In a BIM model, it is possible to predict and simulate energy consumption, water use, and air conditioning performance in a building. These predictions serves as the foundation and baseline for future monitoring. With the installation of sensors in the building there is the possibility of carrying out measurements, evaluations, knowing the behavior of the space and the people occupying the space. The intelligent monitoring of a building is used to verify the design phase predictions made in the BIM model and, to allow a more efficient maintenance during its operation. To collect, store and analyze the data to provide a record of the life and history of the building. The 3D virtual model BIM and the monitoring of building data can be usefulnot only in the design phase, but also in the construction and maintenance, going beyond geometry and planning, involving the use of this model in the operation, maintenance, management, evaluation, follow-up, and refurbishment. The entire building life cycle, up to dismantling, demolition, recycling and disposal.

BIM technology focuses onsupporting the construction of buildings, mainly in the concept, design and construction phases. Designers and builders, architects and engineers use BIM models to design projects and building function. Next step is to use BIM technology for the operation and maintenance stages of the building integrated with the previous steps by professionals in charge of the management, administration and maintenance. In an intelligent building, the project should facilitate the maintenance operations of its constructive elements and spaces throughout the life cycle of the building. Some features of BIM technology are fundamental to intelligent buildings. A BIM model of a building is a digital representation, with geometric 3D features associated with the other functional features of the elements, in a single model with centralized and integrated information. Modeling is consistent with AEC concepts, with hierarchical and semantic organization, unambiguous interpretation, automatic extraction of information and preserved meaning throughout the life cycle. The BIM model is shared knowledge of information about a building that forms a reliable basis for decision making during the construction lifecycle.

BIM models work on the relationships between modeled objects and components and space. These relationships are linked to four main strands: level, discipline, family and environment. Each object of the model is linked to a level, which can be a real or conceptual habitable floor. One level is created for each floor or other required building reference, such as first floor, top of the wall or bottom of the foundation. Each object is linked to a discipline, Table 1.

Table 1 – Discipline – Object.

Discipline	*Object*
• Architecture	walls, doors, windows, columns, ceilings, floors, railing, ramps, stairs
• Structure	pillars, beams, contraventos, trusses, structural walls, foundations, structural floors;
• Mechanical	ducts, accessories, connections, air terminals
• Electrical	conduits, connections, luminaires, devices, equipment, cable tray and wiring
• Hydraulics	pipes, connections, parts and equipment;
• Construction:	parts and assembly

Source: Created by the author (2017).

Another link relates to the family that contains the geometric definition and the parameters used by each element of the model. An element inserted into a template is an instance of a type of family. Each instance of an element is defined and controlled by the family. These elements can have properties, which control their appearance and behavior, common to all elements of their family or properties that may vary in each instance.

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Finally, and perhaps more important for the integration between BIM and IoT technologies, are the links to environments, which are subdivisions of space in a BIM model, based on dividing elements such as walls, floors, roofs and ceilings, which are Defined as environmental delimiters. In addition to the obvious use of the environments in a model to calculate distances, areas, and volumes, the sharing of information from environments between BIM systems and IoT equipment management systems is critical.

In a deeper analysis for intelligent buildings it is necessary to establish relationships between environments, spatial relationships and use. The use of ontologies can be useful. Which environments are physically connected to what environments: people passing, air, piping, visual aesthetics. Which environments are or can be frequented by which people.

Integrating a vision of a variety of design, construction, maintenance and monitoring technologies including advanced and integrated systems is required. Intelligent buildings, in addition to being sustainable and safe, must be flexible and adaptable, and the integration between BIM and IoT technologies can aid in this process. At AEC, IoT enables the management and automation of activities in buildings and cities. In this scenario, the BIM (Building Information Model) technology and the Internet of Things (IoT) have much to contribute. In addition to the monitoring, one must consider the use of space by the user. These tasks can be carried out in the field by sensors and no longer need to be done by the direct observation of human beings. IoT is transforming the role of technicians, architects, engineers and building maintenance and management professionals.

The propose teste by creating an experimental implementation in a laboratory room. The smart lab experiment is a proof of concept proposal that through practice makes simulations for real solutions like validation.

7. SMART LAB

The implementation for effective smart building requires depth studies on information systems, the objectives of monitoring with the collection and analysis of data and a reflection on the concepts, representativeness, objectives and occupations of buildings.

After the bibliographical research and the understanding of the topics raised, the implementation of IoT in a research laboratory of the Graduate Program in Management & Organization of Knowledge, at the School of Information Science of UFMG is proposed. At this stage, the goal is to map the chances of implementing sensors and devices in a controlled environment - a Smart Lab. Once implemented, the system will provide for data collection, storage and analysis regarding information management, through systems that foster integration between virtual organization and the implementation in the form of Physical reality projects.

In order to initially prepare the proposed implementation of IoT, the existing equipment in the research laboratory of the PPG-GOC (shown in Figure 2) are as follows: a) a coded electronic lock is installed in the entrance door of the Laboratory as a safety feature; b) an LCD television, four microcomputers and a server, as technological resources; c) an air conditioner, as an air conditioning element; d) a white board, a large meeting table, a cabinet, tables and chairs for microcomputers, as infrastructure elements.

From the identification of the existing elements in the research laboratory and its objectives, it was possible to carry out analyzes to select appropriate IoT technologies, based on specific case studies of real application [13, 15]. The first step in the Smart Lab implementation will be to provide differentiated connectivity through a new segmented network with advanced encryption capabilities, unique to PPG-GOC researchers whose Wi-Fi access will be controlled by a new portal authentication. The goal is that information transmitted and captured in Smart Lab is restricted to only a group of authorized users, ensuring the security of this process.

Next, it will be necessary to adopt IoT elements that serve three main functions: a) access control and security; b) control of luminosity and temperature; c) control of energy consumption.

To provide access and security control, an access control HC-SR04 ultrasonic sensor, must be installed at the entrance door; a Neoyama static RFID reader and six Alien Uhf RFID tags for microcomputers, server and TV; a surveillance camera and two Wi-Fi positioned at different ends, also allowing the monitoring of the movement of the devices inside the laboratory through the triangulation of their signals.

To provide brightness control, it is necessary to implement a GUVA- S12SD sensor in the lamps, in order to adapt to external natural light; and for temperature control, it will be necessary to implement a BME680 sensor in the air conditioning, with the objective of adjusting the temperature of the laboratory according to the number of people in the place and to monitor the quality of the air.

To provide control of energy consumption, it will be necessary to implement eight MEX / TENTA MKP sensors in microcomputers, server, TV, air conditioning and light bulbs. Figure 2 illustrates the proposed implementation of IoT in Smart Lab.

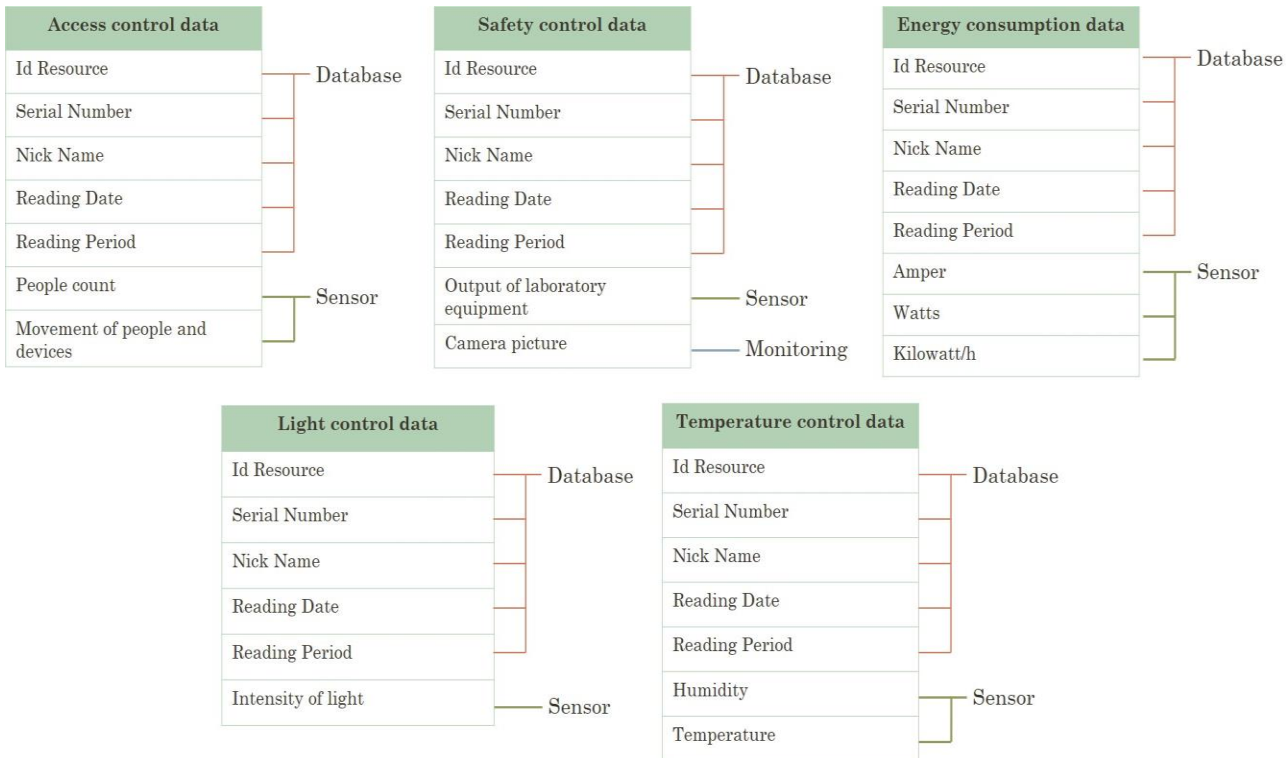
Figure 2 – Smart Lab. PPG-GOC research laboratory.

Source: Created by the author (2017).

The purpose of this IoT platform is to capture information in volume and variety that enables the applied study of the concept based on a real environment, providing new insights into the behavior of people and the environment, subsidizing the identification of standards and setting precedents for optimization. In the future, it will be possible to plan which services can be structured for this laboratory, such as: intelligent lighting; smart stations with scheduling of use per researcher; efficient energy consumption; security from camera monitoring.

To collect and persist data from the IoT platform, it will be necessary to use the B-Scada supervisory system, a cloud-based solution, for real-time monitoring of devices, databases, web services, sensors, key performance indicator (KPI).

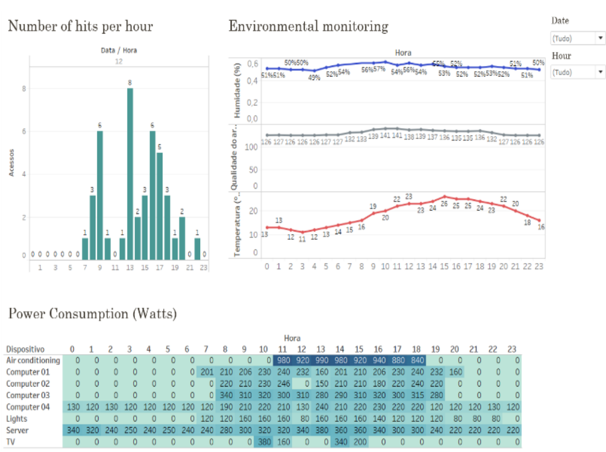
Figure 3 – Information Modeling.



Source: Created by the author (2017).

From the survey of the data collected and persisted in the supervisory system, through the modeling, an example (Figure 4) of a dashboard with the main indicators for the analysis of the data of the sensors and devices was proposed, with fictitious data.

Figure 4 – Smart Lab monitoring Dashboard.



Source: Created by the author (2017).

Examples of possible analyzes are the proposed dashboard: to monitor access and accumulation of people in the laboratory by period, for better planning of use by researchers; monitor and control the temperature and humidity in the laboratory per period, to adjust the amount of people in the place; monitor the operation of the air conditioning, for corrective actions; monitor the energy cost of all technologies present in the laboratory, to generate savings and less environmental impact.

Other possible analyzes of Smart Lab are: improving inventory control of equipment; analyze the camera images as an audit of anomalies presented by the sensors; analyze the movement and use of space by researchers; capture how many devices are connected to the lab's Wi-Fi network to optimize network access.

8. CONCLUSIONS

The issues raised in the research address relevant and ever expanding themes in Brazil, especially IoT and Smart Cities. The relationshipbetween the principles of Information Modeling and Information Retrieval for IoT is still underrepresented in the academic and business environment. With this, this work sought to focus on the concept of the main themes of the research and its applications, for a greater understanding. The expansion of IoT and Smart Cities implementation must be well structured and modeled so that it is possible to retrieve the information generated by these thousands of sensors and devices in a comprehensive and organized manner. The aim is for these technologies not to become obsolete over time due to lack of knowledge or analysis and that the sensitive and unstructured data is adequately stored.

In AEC, the use of IOT extends the use of equipment that improves the monitoring and maintenance of a particular building or even entire urban systems, such as the use of sensors to control burned-out lights and the consumption and distribution of water or electricity.

BIM and IoT systems are complementary technologies. The "things" connected to the internet generate accurate and reliabledata about the systems of a building in a given "space". This data will assist the BIM models giving them more utility. BIM models can also be used as a spatial locator of IoT devices.

It is considered that the research collaborate for the understanding and structuring of IoT and Smart Buildings, and its correlations with the subjects Information Modeling and Information Retrieval. As a limitation of the study, it highlights the lack of application in the real environment of Smart Lab, to prove the perceptions and benefits of the proposed study. There is a need for future and in-depth discussions on the current topic, capable of subsidizing the implementation of the Smart Lab proposal in a real environment and seeking innovations from IoT in a research laboratory.

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