



## The Internet of Everything System for the Papal Basilica and Sacred Convent of Saint Francis in Assisi, Italy

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### Abstract

The purpose of this work is to illustrate the methodology and show the results obtained from the study and the design of the Internet of Everything system for the Papal Basilica and Sacred Convent of Saint Francis in Assisi, Italy, considering all the sub-projects that have already started and the new sub-projects that are going to start.

Keywords: Smart Cultural Heritage Sites, Internet of Things/Everything, Integrated Multidisciplinary Model for Safety and Security Management.

### 1. Introduction

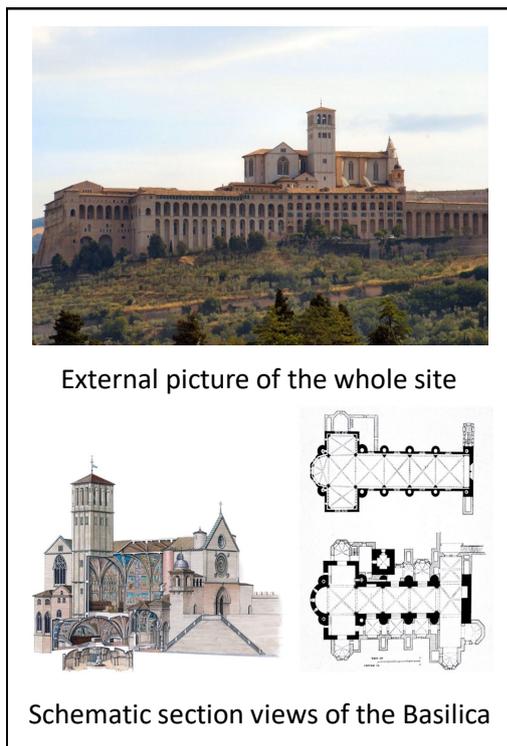
The Papal Basilica and the Sacred Convent of St. Francis in Assisi, Italy, together represent a unique and specific cultural heritage site where the mortal remains of St. Francis have been housed since 1230 AD (Fig. 1). Millions of pilgrims and visitors from all over the world visit this site each year. In 2000 AD, together with other Franciscan sites in the surrounding area, it achieved UNESCO World Heritage status. Important international events, such as those related to world peace and dialogue between religions, are organized in this site and are often attended by thousands of people. The Papal Basilica, where unique frescos by Giotto and other famous painters are displayed, comprises three stratified structures:

- the tomb of St. Francis, located at the lower level;
- the lower Church, whose altar is just above the tomb of St. Francis; and
- the upper Church, located above the lower Church.

Inside the Sacred Convent there is a museum, a library and sufficient space for hosting spiritual and cultural activities. Unique and complex cultural heritage sites, such as this, require a significant effort to ensure visitor security and safety. Along with such needs are cultural heritage preservation and protection as well as accessibility for visitors, with particular reference to visitors with disabilities, and for personnel normally present for site management, including the Friar's community. From this point of view, it is necessary to consider other important aspects such as energy management, maintenance management and a plenty of other aspects that must be managed in an efficient way, using possibly a proper integrated technological system.

These aims can be achieved using integrated systems [1 - 5] and innovative technologies, such as Internet of Everything (IoE) which is capable of connecting people, things (mobile terminals, smart sensors, devices, actuators; wearable devices; etc.), data/

Figure 1. Papal Basilica and Sacred Convent of Saint Francis in Assisi.



information / knowledge and particular processes [6 - 10]. The IoE system must also provide all the actual and future IoE services planned and implement and support an integrated multidisciplinary model for security and safety management (IMMSSM) [11, 12] for this specific site.

The purpose of this work is to illustrate the methodology and show the results obtained from the study and the design of the Internet of Everything system for the Papal Basilica and Sacred Convent of Saint Francis in Assisi, Italy, considering all the sub-projects that have already started and the new sub-projects that are going to start.

## 2. An Integrated Technological Framework for IoE Services and IMMSSM

The proposed IoE system is designed to support an integrated multidisciplinary model for security and safety management (IMMSSM) [11, 12] for the considered context as shown in Fig.2a. In addition, it needs to be flexible to incorporate advanced IoE services and make provisions for the inclusion of future IoE services.

The IMMSSM is based on the following points: risk analysis, impact analysis, risks mitigation and residual risks management [13, 14]. Risks mitigation can be performed using fundamental operative factors or tools (OTs) which are represented by: countermeasures (physical/logical technology, and physical/logical barriers) and Security/Safety policies

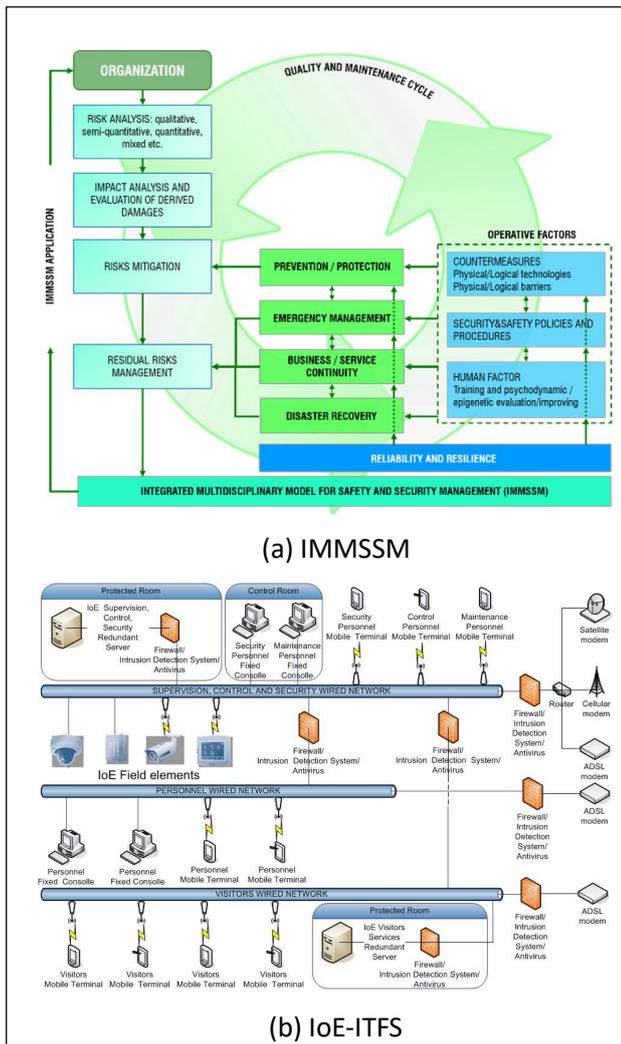
and procedures, considering also human factor and psychological aspects [15, 16]. Residual risk management can be done using fundamental tools, aided by OTs, which are represented by: emergency management, service and business continuity, disaster recovery [17].

The IMMSSM can be implemented and supported using a proper Integrated Technological System Framework based on IoE (IoE-ITSF) which allows the full functionalities of the IMMSSM with high flexibility and modularity. In this way, it is possible to translate any eventual modification of the IMMSSM into a fast and low-cost modification of the ITSF at any time, ensuring always the best performances of IMMSSM and the possibility of providing the planned IoE services. The goal of the ITSF is to ensure: the maximum level of security and safety of people and of tangible and intangible assets, the maximum integration of all the IoE objects to produce high intrinsic-value solutions characterized by an optimal cost/benefit ratio, the maximum simplicity of utilization, using local and remote automation systems, the maximum level of reliability, resilience and flexibility, the maximum level of modularity and expandability, including IoE services. The general scheme of the proposed ITSF is shown in Fig.2b.

The system is characterized by a high modularity that allows for the addition at any time of any device, element, system etc. that needs to be integrated in the IoE system. Since the ITSF is designed to be a general system usable by most of organizations that can also plan for the presence of external visitor's presence. For security reasons, the networks used to perform supervision, control and security/safety services, internal personnel services and visitor's services are properly separated by physical and logical points of view. The system is characterized by a high modularity which allows for the addition at any time of any device, element, system etc. that needs to be integrated in the IoE system. Since the ITSF is designed to be a general system usable by most of organizations that can also plan for the presence of external visitor's presence, for security reason the networks used to perform supervision, control and security services, internal personnel services and visitor's services are properly separated by physical and logical points of view.

The different wired networks serve the different access points that ensure Wi-Fi services to security/safety and control personnel, internal personnel, including the Community of Friars, and visitors, increasing the security level of the communication and the protection of the system against cyber-attacks [15]. The system can communicate with all the "IoE objects", signalling any

Figure 2. (a) Scheme for IMMSSM (b) IoE based Integrated Technological System Framework (IoE-ITSF) enabling current and future technologies.



dangerous or critical situation to the operators (security / safety personnel, maintenance personnel, Police, Fire Brigades, Civil Protection, Medical etc.), in real time, using any kind of communication medium [15].

A proper privacy-compliant app, designed for the site, can be installed directly by security/safety personnel, internal personnel, including the Community of Friars, and visitors on their mobile terminals directly when they arrive in the site or in advance. This app allows access to all services planned for the user profile (general and augmented reality information, security & safety information, positioning services useful for emergency management, VoIP services for ordinary, security & safety and emergency communications with the related personnel, etc.) and allows the system to consider the mobile terminals as 'IoE objects' to reach the specific desired goals of the considered organization. Thanks to the app, it is possible to position people using both GPS system of

mobile terminals and the Wi-Fi positioning capability of the system (that works correctly even in underground environments where the GPS signal is shielded or weak). This way, it is possible to manage an eventual emergency, communicating directly with people, if necessary, using the text and VoIP functionalities of the app. The ITSF is endowed with all the countermeasures necessary to prevent cyber-attacks, using firewall / intrusion detection system / anti-virus devices properly installed plus other prevention/protection countermeasures.

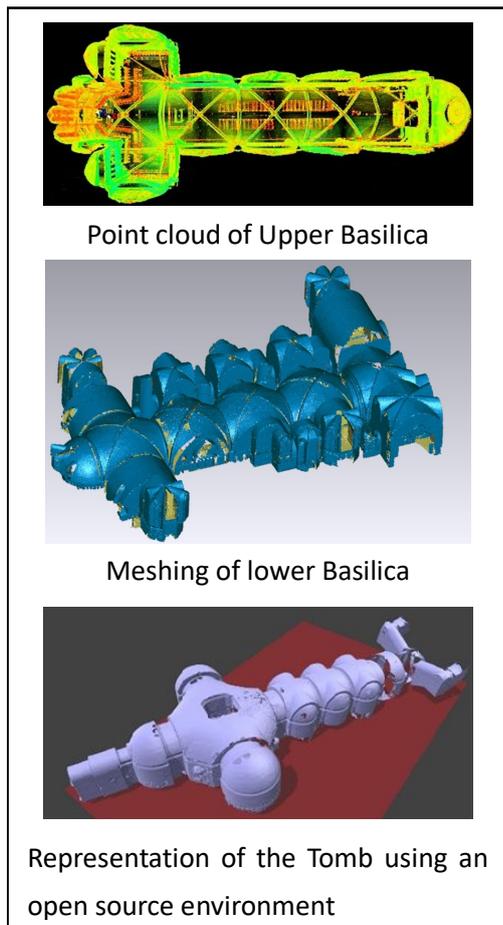
### 3. Design and Development of IMMSSM and IoE-ITSF System and Initial Results

The methodology adopted consists of several activities carried out both sequentially and in parallel, as a function of the available resources, always considering the final goal. Thus, a set of preliminary and fundamental series of multi-disciplinary activities formulated as subsystems of the IoE system are considered. These include:

- 1) Laser scanning to acquire useful 3D information regarding the site [18, 19];
- 2) Building Information Modelling (BIM) to have a powerful and flexible informative tool for site management [19 - 21];
- 3) New communication network that represents the backbone of the IoE system [22];
- 4) Risk analysis and assessment, emergency management, disaster recovery, service continuity [13 - 15, 17];
- 5) Human Factor study and analysis to keep into consideration the psychological aspects regarding all the IoE services provided both to visitors and for personnel normally present for site management, including the Friar's community, to improve the quality and the efficiency of the IoE services themselves and of the ordinary signalling inside the site. These activities imply also the use of suitable tool for social opinion mining using social network [16];
- 6) Experimental microclimate monitoring system of the Papal Basilica [23];
- 7) New and suitable IoT/IoE services for the considered site, including Augmented Reality (AR) and Virtual Reality (VR) aimed at improving the visiting experience of the visitors [6, 24, 25];
- 8) Biometric solutions for the considered site, with particular care to privacy aspects [26 - 30];
- 9) Fluid dynamic analysis of the interior of the site to improve the quality of air with regards to people wellness and pictures preservation plus further activities related to the energy management / optimization / preservation and renewable energy [31 - 35];
- 10) Cybersecurity aspects of the IoE system. [15];
- 11) Big Data, security analytics for Big Data infrastructure, machine learning techniques for the site [36 - 38].

With this multi-disciplinary work, an international group started working remotely, first of all with a laser scanning activity of the Papal Basilica and of the Tomb (Fig .3). This is aimed at obtaining a 3D model of it [18- 19] that is going to be translated into a Building Information Modelling (BIM) and to use a powerful tool for all the necessary activities, including safety and security management [20]. This activity is fundamental due to the presence of strong architectural restrictions, which requires to take particular care in the installation of wires and devices [21, 39].

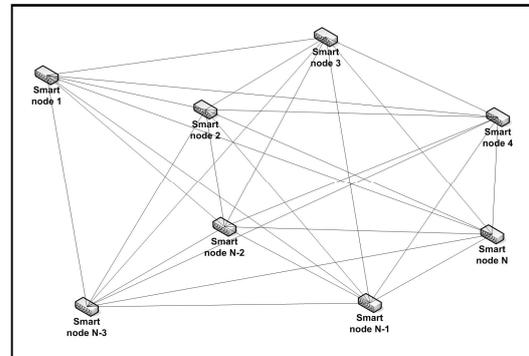
Fig. 3 Laser scanning results.



At the same time all the preliminary activities necessary to set up the IMMSSM [11 - 17] have started, included the other activities necessary to study and design the Site Management System (SMS), for the specific site, based on IoE (SMS-IoE), including the communication network that is essential to guarantee that all the information needed for the planned IoE services could be carried with the required level of security, safety, reliability and resilience granting the required confidentiality, availability and integrity [15, 22]. An apt Genetic Algorithm (GA) based technique has been studied and tested to design the connections between the different IoE Field Elements and the different smart nodes that comprise the network (Fig. 4) to ensure a

reduction of final costs and an elevated level of reliability and resilience of the system itself, keeping, into consideration, the typical artifacts and restrictions of unique and peculiar cultural heritage sites such as the considered one [22].

Fig. 4 Architecture of the IoE system backbone network.



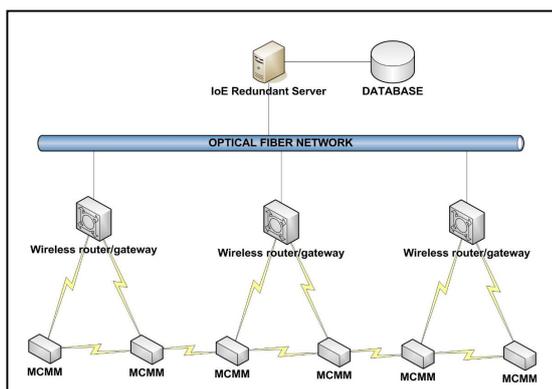
In parallel, a study and analysis regarding human factor was made and is on-going. This takes into consideration the psychological aspects of the ordinary signalling and all the IoE services provided both to visitors and for personnel normally present for site management, including the Friar’s community. This improves the quality and the efficiency of the IoE services themselves and of those inside the site. These activities require the use of suitable tools for opinion mining of social networks to receive feedback from visitors on perceived safety/security versus real safety/security [16].

Another activity in parallel relates to an experimental microclimate monitoring system (MMS) of the Papal Basilica, based on suitable microclimate monitoring modules (MCM), has been studied and realized [23] and its architecture is shown in figure 5. The MMS is aimed at controlling the microclimate conditions to avoid reaching critical conditions that could activate damaging processes of the unique frescos of the Basilica. This system is able not only to monitor in real time the microclimate but also to forecast the future microclimate as a function of the actual situation, thanks to a proper designed artificial neural network (ANN) so that it can send this information to the SMS-IoE that is going to be realized and which can activate all the necessary countermeasures such as reduce the number of visitors, activate proper cooling/fanning systems etc.

Further work is devoted to new and suitable IoT/IoE services for the considered site, including Augmented Reality (AR) and Virtual Reality (VR) aimed at improving the visiting experience of the visitors [6, 24 - 25]; biometric solutions for the considered site, with particular care to the privacy aspects [26 - 30]; fluid dynamic analysis of the interior of the site to improve

the quality of air with regards to people wellness and pictures preservation plus further activities related to the energy management/optimization/preservation and renewable energy [31 - 35]; cybersecurity aspects of the IoE system [15]; Big Data, security analytics for Big Data infrastructure, machine learning techniques for the site [36 - 38] etc., with the aims of reaching, step by step and with the contribute of all the people and subjects that are working on it, the desired goals.

Fig. 5 Architecture of the microclimate monitoring system.



#### 4. Conclusions

In this work the methodology and the results obtained from the study and the design of the Internet of Everything system for the Papal Basilica and Sacred Convent of Saint Francis in Assisi, Italy, have been illustrated considering all the sub-projects that have already started and the new sub-projects that are going to start.

The whole SMS-IoE represents and always-going-on-project and it is opened to future solutions and contribution by anybody, with the aim of improving constantly the goals of it.

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