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Search & Rescue

Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in SAR operations

D3.4 BIM based visualisation support integrated with VR interfaces

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Executive Summary

The current deliverable D3.4 "BIM based visualisation support integrated with VR interface" aims at documenting the technical activities that were undertaken towards the definition of the second and final iteration of the Building Information Model (BIM) that was developed in the context of the S&R project and will be useful tool for the first responders during a search and rescue operation. The BIM model comprises a RESTful web service that exposes specific interfaces with the aim of representing building data and a Building semantic model that facilitates the data manipulation towards the creation of the necessary correlations towards the representation of the Building semantic model. The present deliverable will document the core components and the specific requirements of the web service, as well as the completed semantic model for the building data. In this frame, a RESTful web service is implemented to facilitate the building data manipulation towards the creation of the necessary correlations which constitute the semantic model. These correlations will be defined in order for the first responders to have a clear overview of the building during a S&R operation. Finally, the main functional components of the BIM management system are introduced, as well as the process of the BIM model data visualization through the VR technology devices of S&R that allows the first responder to obtain a well-defined conceptual model of the buildings, geometric properties and structural elements in the field.

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List of Abbreviations

Abbreviation	Explanation
D	Deliverable
SA	Situation Awareness
UC	Use Case
GIS	Geographic Information Systems
IGIM	Integrated Geospatial Information Model
RDF	Resource Description Framework
S&R	Search and Rescue
BIM	Building Information Model
VR	Virtual Reality
IFC	Industry Foundation Classes
DoF	Degrees of Freedom

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1 Introduction

1.1 Scope and Objectives

This deliverable constitutes a report aiming at documenting the technical activities undertaken within the context of T3.2 "Situation Awareness Model", along with the specification of the Building semantic model. These technical activities, which are described in the present document, provide a coherent overview of the BIM's web service as a whole, highlighting the interactions among its components and emphasizing on how both the Situation Awareness (SA) model and the Building model can be exposed and utilised by other components in order to ensure, through several correlations, the most up to date operational picture during rescuer operations. Based on this principle, the Building semantic model aims firstly at representing the building data in a way where the first responders will be assisted during their operations, and secondly at representing these data through the Virtual Reality (VR) technologies utilized in the frame of S&R.
Taking into account the aforementioned statements, the main objective of D3.4 is to provide a comprehensive documentation of the semantic model web service, highlighting the key technical aspects of how building data can be utilised through specific interfaces, as well as the methodology for visualizing these data through the VR technologies of S&R.

1.2 Relationship with Other Tasks and Deliverables

The present deliverable documents the technical activities undertaken in the frame of Task T3.2 "Situation Awareness Model". The main objective of this document is to provide a coherent version in terms of technical implementation for both the semantic model web service and the Building semantic model specification. Therefore, it receives input from the following deliverables:

- D3.1 "Requirements to knowledge management and SA Model", where general requirements, entities and actors that interact with each other are described.
- D3.2 "Situation Awareness Model - specification", where the Situation Awareness model and its core concepts are specified. In this deliverable the SA model that is going to be utilized through the semantic model web service is presented.
- D3.3 "BIM based services and applications – review and service design" where the first version of the BIM model service is described
- D7.3 "Component interface specifications for interoperability within S&R" where the list of technologies of end users are thoroughly presented.

1.3 Structure of the document

In order to address all the aspects relevant to the scope of D3.4, the present deliverable is structured as follows:

- Chapter 1 introduces the work performed and the scope of this deliverable along with its relevance to other deliverables and the deliverable's structure.
- Chapter 2 provides an overview of the working methodology by highlighting the way which the Building semantic model has been defined and how it is utilized through the corresponding web service. Furthermore, the main objectives of the semantic model and its utilization are provided.
- Chapter 3 provides an overview of existing approaches around semantic models that expose knowledge-based building data.
- Chapter 4 provides a comprehensive documentation of the semantic model web service, which relies on what its components are expected to support from the technical point of view and how the service interacts with other components.
- Chapter 5 offers an overview of the Building Semantic Model, its core components, and correlations along with how all this information can be exposed.

- Chapter 6 provides the details of the BIM model service representation through a virtual environment generated by the appropriate VR tools as well as the BIM Management system together with its core and functional modules.
- In chapter 7, the final conclusions are provided along with a summary of the main outcome of the BIM based service.

2 Methodology

The present deliverable documents the update of the BIM model as well as the extension of technical activities which have been undertaken within the context of this task in order to define and describe the framework of the BIM model and web service integration and is the second version of the D 3.3 ”BIM based services and applications - review and service design” (M15) which included a detailed roadmap of the main concepts that exist around semantic models and Building data as well as the extensions and features of them. The main purpose of the BIM model is to integrate the heterogeneous information needed for an emergency response which becomes a challenge for responders to gain a comprehensive understanding of their decision-making by a) providing the semantic models as a service and for storing the data in an efficient database b) representing the main spatial topological elements of a building as well as the interactions between them and c) creating a well-defined conceptual model of the buildings and all the architectural details, by enabling the 3D visualization of a building or a structure.
In the frame of T3.2 "Situation Awareness Model”, the definition and documentation of the Building semantic model and relative web service are delivered in two releases. The first release was documented in D3.3 "BIM based services and applications – review and service design” provided a coherent overview of the Building model semantic model web service and aimed to highlight the key technical aspects of how building data can be utilised through specific interfaces, as well as the description of the interactions among its components. The current deliverable documents the further enhancements of the BIM model service, based on the demands of the end-users of S&R and emphasizes on the virtual representation of the heterogenous information of the search and rescue operations through the VR technologies and tools that are provided in the S&R project as well as the definition of the BIM Management system and its functionalities in relation to the storing, checking, updating, and querying of BIM models.

2.1 Working methodology

The current document presents the methodology that was followed for the definition and final release of the and description of services of the proposed BIM model. To this end, further enhancements of the model will be documented, based on the emerging demands for real-time situation awareness during the course of the project, while possible deviations from the original plans of the BIM model will be discussed.

The methodology that has been followed for the second version of the definition of the BIM model includes the following steps:

1. Revision of input and original methodology of the first iteration of the BIM model.
2. Refactoring, and corrections of the existing model.
3. Processing of the new needs of the project, which have occurred during the development process.
4. Definition of new main concepts which have been identified from technical workshops in the frame of WP3, WP6 and WP7, as well as from D7.3, "Component interface specifications for interoperability within S&R”, where the interoperability of devices and services of S&R is documented.
5. Construction of the new ontology which will represent the BIM model by interconnecting the new concepts among them, in order for the proper information flow to be established.
6. Integration between the existing/old ontology and the new one.
7. Development of a rules engine to support real-time inference of alerting events.
8. Provision of the BIM model as a RESTful service.

3 Existing Approaches Around BIM

The information needed for emergency response is usually heterogeneous, coming from different sources, which becomes a challenge for responders to gain a comprehensive understanding of their decision-making. Digital technologies, such as BIM, could be of assistance in managing and supplying desired information to on-site participants of search and rescue operations in a more effective and convenient way. This section presents a review of existing approaches in BIM semantic models, which will be the starting point of the conceptual representation of the Building semantic model in the context of the project.

Several approaches have already been introduced around Building information modelling (BIM) and Geographic Information Systems (GIS), based on using semantic web services technologies. One interesting work introduces a model which uses BIM capabilities to accurately provide existing information about the indoor environment of buildings and the GIS, to support the wide range of spatial analysis functionalities used in the logistics and management of buildings within their surroundings [1]. Moreover, another approach aims to tackle the challenge which derives from the difficulty of data exchange between two different modelling domains. The proposed solution comes from the benefits of integrating BIM and GIS technologies into one unified model, a so-called Integrated Geospatial Information Model (IGIM) [2]. Additionally, several approaches which introduce the semantic representation of the BIM model have also been recently presented in literature. Matějka et al. [3] propose a BIM ontology by using schematics, and explaining the role of BIM in traditional project life cycle phases. Zhong eta al. [4] present a framework which integrates building information from BIM, environmental information provided by sensors, and regulatory information based on building regulations and design requirements. In this framework, four specific ontologies are developed to represent relevant knowledge. Another study by Niknam et al. [5] presented a shared ontology approach to the semantic representation of building information which facilitates finding and integrating building information distributed in several knowledge bases. Liu et al. [6] introduces a State-of-the-Art analysis on BIM and GIS approaches, as well as the integration methods between them. In recent years, VR technologies have been introduced for visualizing 3D models and imagery, which consist of the technical core of BIM. VR simulates a virtual world instead of a real presence with the use of a special device, therefore it is an ideal candidate for creating a realistic perspective of the 3D building models of BIM. Existing VR devices and tools can offer an efficient visualization environment for the representation of 3D BIM building models and stimulate the user with a more intuitive physical experience by mixing simulated models with an actual environment [7]. VR solutions can also enhance decision making in construction logistics processes with faster identification frameworks [8]. Taking into consideration the necessity of the combination of the BIM model with the Geospatial Information, as well as the fact that existing approaches focus on the construction of a unified model which incorporates both, specific ontologies which represent these data models conceptually are also considered. First and foremost, the BOT ontology [9] provides the vocabulary to describe the topology of a building as well as the relationships between their main components such as storey, zones, spaces, and building elements. This ontology will be utilized by the Building semantic model in order for the core concepts of a building to be represented. Additionally, The OGC GeoSPARQL [10] standard will be reused, since it supports the representation of geospatial data on the Semantic Web. GeoSPARQL defines a vocabulary for representing geospatial data in RDF, and it defines an extension to the SPARQL [11] query language for processing geospatial data.

4 BIM and Situation Awareness models as a Service

4.1 Semantic Representation

In order to provide the semantic models as a service, a robust technological stack is utilized, both for offering the required REST [12] functionality and for storing the data in an efficient database. The latter is particularly important due to the nature of Search and Rescue, where performance and immediate data processing can be a determining factor between failure and success in operations. To that end, the semantic model web service aims at providing specific interfaces by handling the Building semantic model in a scalable and efficient way. Towards this direction, some core functionalities need to be fulfilled in order for the proper interfaces to be exposed to the proper actors. Having said that, the core functionalities of the semantic model web service which denote its scope can be summarized as follows:

- **Data storage**: The semantic model web service aims at persisting the correlations among resources and metadata which have been retrieved by utilising its Resource Description Framework (RDF) triple store. The RDF triplestore is a type of graph database which stores semantic facts. More specifically, triplestores data as a network of objects with materialized links between them. This makes RDF triplestores the preferred choice for managing highly interconnected data. They are often called semantic graph databases, and they are also capable of not only handling powerful semantic queries, but also inferencing for uncovering new information out of the existing correlations. Based upon these benefits, the semantic model web service utilizes its RDF triplestore instance, which is capable of persisting data from two different data sources and semantic models distinctly.
- **Data transformation into a unified model**: In order for the RDF triplestore to be utilised, the data which have been retrieved by the other components need to be transformed in a specific format. For this purpose, the RDF model is used, which is a standard for describing web resources and data interchange, developed and standardized with the World Wide Web Consortium (W3C). By transforming the data into RDF triples, heterogeneous data from various domains can be interlinked easily, and these interconnections ensure the timely delivery of proper information.
- **Semantic model enrichment**: Another key aspect of the semantic model web service is the need to handle two different semantic models. On the one hand, the Situation Awareness ontology is developed and documented in D3.2 and on the other hand the ontology for Building data has been incorporated, which is composed of different concepts and correlations. This web service has been designed in a way where both ontologies can be utilised effectively and without conflicts, due to the intervention of a specific component which is going to be presented in section 4.2.3.

4.2 Architecture

The scope of the semantic model web service is to ensure the timely delivery of proper information flow for the building-related data that will be retrieved and properly interconnected in the context of the project.
The semantic model web service consists of three subcomponents, namely the Semantic Databases, the Data Transformation Handler and the Semantic Data Model Interceptor. Due to the fact that the Situation Awareness model is documented in D3.2, the focus in terms of the architecture and the data which will be handled by the semantic model web service, mainly lies on the Building semantic model and how the respective data can be retrieved. To that end, not only the components of the semantic model web service will be presented, but also the other relevant S&R components and data sources which can feed the stored semantic models accordingly.
In brief, as also depicted in Figure 1, the main functional parts which compose the overall architectural design of the semantic model web service are the following:

- The **Backend service** that is composed of the Data Transformation Handler and the Semantic Data Model Interceptor. Both components will be analysed in the following

subsections and constitute the core business logic of the semantic model web service. The aforementioned components will be described in sections 4.2.2 and 4.2.3 respectively.
- The **Semantic Models** where the correlations and the knowledge-based information of each domain are stored. In the context of the project, two separate semantic models are stored and more information will be provided in section 4.2.3 respectively. On the one hand there is the Situation Awareness (SA) model which has been documented in D3.8 "Situation Awareness Model - specification_V2" and on the other hand, the Building semantic model that is documented in the present deliverable.
- The **Communication** with the CONCORDE platform through a RESTful interface, where the services can be consumed via HTTP requests to the COncORDE platform API. A request can be the following: GET /api/incidents/incident/{id}. Through this request, the user can retrieve data for a specific incident (e.g "fire in a building") as well as details such as the name of the incident, the type of hazard (e.g earthquake) and more.
- The **Retrieval of Historical data** whenever it is necessary. These data can be an important factor towards the enrichment of the Building semantic model. To that end, the exact metadata and the methods with which they can be retrieved, constitute another key functional part of the semantic model web service. Historical data additionally serve as a rich addition to the model, because components can derive changed state status based on the original (historical) data of a building compared to the current state, as provided by sensors and other means, in real time. Historical data are hosted in specified URLs, such as http://server_ip:7070/global_landslide_catalog and can be retrieved with HTTP requests. A database where building information modelling (BIM) historical data can be retrieved is the NBS, National BIM Library[1]. In order to save and maintain historical BIM data, the platform/model makes use of a containerized Autodesk cloud-based database. All files uploaded to BIM 360 are stored in the cloud on encrypted storage. The storage solution uses 256-bit advanced encryption (AES-256).

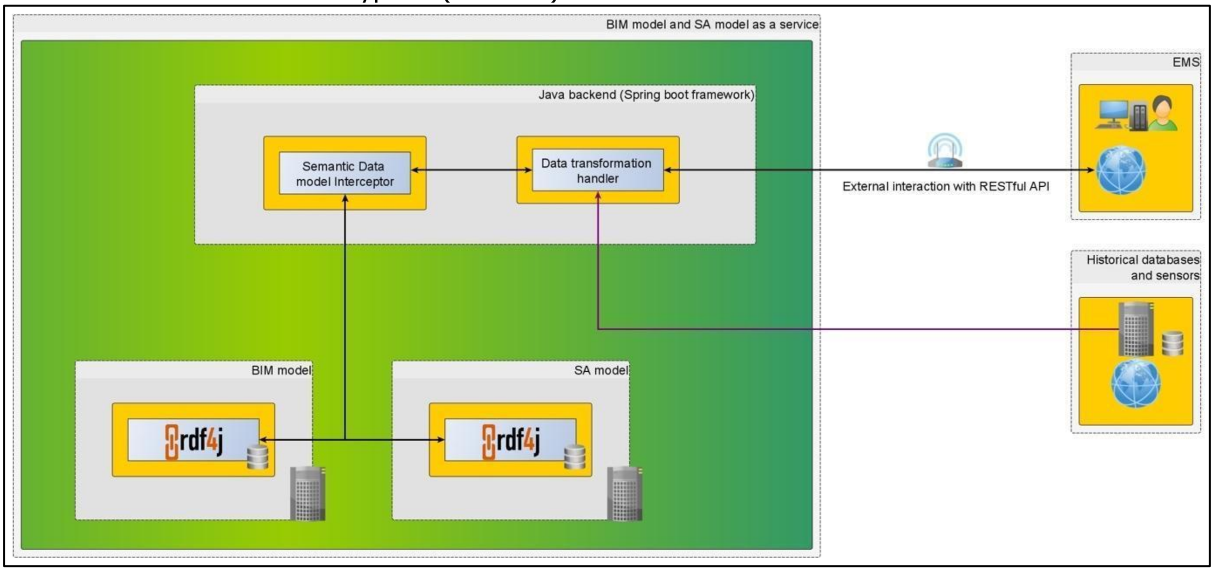

Figure 1: Semantic Model Web Service Architecture

In addition to the core functional parts and the components, the specific technological approach which constitutes the backbone of the web service will also be described. More specifically, the Building ontology (just like the SA ontology) can be provided as an endpoint with Spring boot [13] REST at its backend and written in Java. The Spring Framework is an application framework and inversion of control container for the Java platform. The framework's core features can be used by any Java application, but there are extensions for building web applications on top of the Java EE [14] (Enterprise Edition) platform. The Spring Framework is open source. As a result, the provided

[1] https://www.nationalbimlibrary.com/en/

backend is compatible with state-of-the-art technological stacks and offers a reliable way to extend its functionalities, as the requirements of the project evolve.

Due to the semantic representation of the semantic models and, more specifically, of the Building semantic model, a database with the traditional paradigm of tables (e.g., MySQL [15], PostgreSQL [16] etc.), or other paradigms such as key-value stores (e.g., Redis [17]) cannot properly represent semantic relations, especially when taking into consideration the temporal nature of data, as is the case in Search and Rescue. The nature of semantic data is much more fitting to a graph-based format, where nodes represent entities and the edges linking them represent relations between them. As such, the most proper paradigm is triple stores, which host serialized RDF [18] data. Moreover, triple stores include powerful inferencing engines and thus offer indirect data extraction, an ability which could be utilized to discover critical information hidden in the existing data.

The Resource Description Framework (RDF) is a family of World Wide Web Consortium [19](W3C) specifications originally designed as a metadata data model. It has come to be used as a general method for conceptual description or modelling of information which is implemented via web resources, using a variety of syntax notations and data serialization formats. It is also used in knowledge management applications. A triple store or RDF store is a purpose-built database for the storage and retrieval of triples through semantic queries. A triple is a data entity composed of subject-predicate-object.

There are a few triple store implementations available, but for the purposes of the project, RDF4J [20] is currently used. Originally known as OpenRDF Sesame, it is one of the very first triple stores, it has thorough documentation and support for Java [14], while it offers good performance and flexibility due to its mature implementation.

4.2.1 Semantic Databases

As it was previously mentioned, the instances and their correlations of two separate semantic models will be stored in RDF triplestores, or alternatively in a graph database. A graph database uses graph structures for semantic queries with resources, and properties to represent and store data. The graph correlates the data items in the store to a collection of classes and properties, where properties represent the relationships between the classes. The relationships allow data in the store to be linked together directly and, in many cases, retrieved with a single operation. Taking all these into account, in the context of S&R, each semantic model will be represented by its own graph, where the resources and the relevant correlations will be defined and stored distinctly.

4.2.2 Data Transformation Handler

The Data Transformation Handler is the communication channel among the data sources and the respective data which will have been received by other S&R applications, and the semantic models which are stored in the semantic model web service. This component is responsible not only for handling the data which are going to be retrieved, but also contains the functionality which transforms the data in a unified format (RDF) in order to be stored in the actual database instances properly. Consequently, the Data Transformation Handler creates the correlations among the resources and these correlations are subsequently stored into the individual graphs.

4.2.3 Semantic Data Model Interceptor

The semantic model web service, as it has already been pointed out, aims at exposing data from two separate semantic models. To this end, both the gathered and the stored data must be handled properly in order for the proper semantic model to be used during the data exchange. The Semantic Data Model Interceptor will ensure that the proper model will be utilised, based on some predefined rules, which will be triggered each time a data request or a response is required by the other S&R components.

5 BIM Service

5.1 Overview

The purpose of the BIM Ontology is to represent the main spatial topological elements of a building. This model, in combination with the SA model, acts as the core module within the semantic model web service, where knowledge-based information is manipulated and delivered in order for the first responders to have a clear view of the incident itself. The model is constructed as an extension of the BOT ontology that provides the vocabulary to describe the topology of a building as well as the relationships between their main components such as storey, zones, spaces, and building elements.

5.2 BIM Semantic Representation

The most important concepts related to the Building domain, based on the literature review and the needs of the S&R project are the following:

- **Building:** Represents a structure which provides shelter for its occupants or contents and stands in one place. The building is also used to provide a basic element within the spatial structure hierarchy for the components of a building project (together with site, storey, and space).
- **Storey:** The building storey has an elevation and typically represents a (nearly) horizontal aggregation of spaces which are vertically bound.
- **Space:** A space represents an area or volume bounded actually or theoretically. Spaces are areas or volumes which provide certain functions within a building.
- **Zone:** A part of the physical world or a virtual world which is inherently both located in this world and having a 3D spatial extent.
- **Apartment:** A self-contained housing unit which is composed by several spaces.
- **Element:** An element is a generalization of all components which make up an AEC product.

The topological element can be considered as one of the following:

- building:Building
- building:Storey
- building:Apartment
- building:Space.

Each of these elements should have an identifier which uniquely identifies them in the model and corresponds to the IfcGlobalId attribute in that schema. The model builds around the root concept building:Building, which incorporates attributes to indicate its physical location by means of geospatial coordinates (wgs84_pos:long, wgs84_pos:lat, and wgs84_pos:alt), as provided by the W3C geo vocabulary. The relationships between the topological elements are taken directly from BOT. A building may have several stories, which may in turn contain one or more residential apartments. These relationships are materialized by the object properties bot:hasStorey and building:hasApartment respectively.
An apartment has different spaces such as a living room, a kitchen or bedroom, and these spaces are comprised by building components which delimit the zone itself and can be summarized as follows:

- building:Door
- building:Slab
- building:Window
- building:Wall

5.3 Data Exposure

In order to maximize the utilization of data resources, the compatibility with standards and to reduce the risk of errors by converting data into multiple formats, all data requests will rely on JSON [21] format. One additional reason that JSON was chosen, is because an extension of it, JSON-LD [22], is

entirely based on semantic representations, and therefore, it offers us the ability to exchange even semantically annotated data with the represented information.
JSON-LD (JavaScript Object Notation for Linked Data) is a method of encoding linked data using JSON. One goal for JSON-LD was to require as little effort as possible from developers to transform their existing JSON to JSON-LD. It allows data to be serialized in a way that is similar to traditional JSON. It was initially developed by the JSON for Linking Data Community Group before being transferred to the RDF Working Group for review, improvement, and standardization, and is currently maintained by the JSON-LD Working Group. JSON-LD is a World Wide Web Consortium Recommendation and is also openly supported by Google.
In order to support the storage of dynamic data structures representing vital information, and maintaining compatibility with RDF standards, we serialize/store them in XML [23] format. In RDF terms, such information is an XMLLiteral [24], a string containing a serialized XML structure. When such information is required, it is offered in JSON format as a whole, while the receiver can get the XML data and deserialize them, perhaps even converting them back to JSON as well, in order to successfully process them. However, it should be noted that depending on the structure of the original JSON data, it might not be possible to convert into XML at all. This is particularly true for fields which start with a number (XML does not allow this), as well as array fields, because XML cannot (automatically) name them as elements.
In the current section and, more specifically, in both Table 5-1 and Table 5-2 sample Endpoint examples towards the manipulation of the data are provided.

Table 5-1: GET API call Example

Description	**GET** /building Data Returns the building data for the specified parameters.
Parameters	buildingId: The building identifier for which the caller requires data for. timestampStart: A start for a range to filter building data timestamps. Useful for performance and getting updated status on S&R operations. Optional. timestampEnd: An end for a range to filter building data timestamps. Useful for performance and getting updated status on S&R operations. Optional.
Body	*None*
JSON Response Message	{"buildingId": "21332564", "buildingData":"<Serialized XML information>", "timestamp": 12345324}
Input Example	**GET** /buildingData?**buildingId=**21332564

Table 5-2: POST API call Example

Description	**POST** /notification Posts a new notification message, alongside the metadata it carries.

Parameters	*None*
Body	{"buildingId": "1124", "data": "<Serialized XML information>", "timestamp": 2123245345}
Response Message	Request status (200 for successful incorporation to the triple store, or error code in case of an error)
Input Example	**POST** /notification

6 BIM Model Design and Development

The information needed for an emergency response is usually heterogeneous and needs to be collected from different sources, which becomes a challenge for responders to gain a comprehensive understanding for their decision-making. Digital technologies, such as BIM, could be of assistance in managing and supplying desired information to on-site participants in a more effective and convenient way. The main purpose of a BIM model is to create a well-defined conceptual model of the buildings, geometric properties, structural elements, and all the architectural details, by enabling the 3D visualization of a building or a structure. The model allows the data to be extracted, analyzed and applied to generate new information, appropriate to various user's needs. Virtual technology (VR) can provide a visualization tool for effectively representing information and 3D models contained in a BIM model. A VR device can enable the user to fully immerse in a 3D BIM model, and manipulate and interact with its objects. Although the BIM service is not requested by the end-users of the S&R project (see D8.2 - D8.8), we developed a BIM model service that can be used for testing purposes. The process of the BIM model data visualization through the VR technology devices of S&R is described in the following sections.

6.1 BIM model data

BIM Data refers to the large amount of data generated, stored and shared during a design process managed by BIM methodology, by the different disciplinary groups involved in the project. These data are an integral part of the BIM model and play a fundamental role because they enrich the project with elements and information useful for the development of the subsequent phases. Through BIM Data, in fact, it is possible to transform 3D modelling into a much more useful tool that goes far beyond the design and construction phase and guarantees maximum efficiency in the management of the lifecycle of the structure. It should be noted that the S&R Project does not provide any technology for building data generation, such as spatial maps or 3D building models, therefore any implemented data will be derived through a set of BIM model data libraries [25]. The BIM model 3D representation will be based on non-proprietary file formats which are vendor-neutral and open source. The most common non-proprietary software for BIM is the Industry Foundation Classes (IFC) which is an open and neutral data file format. IFC is designed to process a building's data model throughout its entire life cycle, from feasibility up to its realization and maintenance, passing through the various design and planning phases. It's an open file format, neutral, not controlled by individual software houses and created to facilitate interoperability between different operators. This format is being developed by the buildingSMART alliance [26], which coordinates the global effort towards improving the file format to capture more types of data.
There are 3 types of IFC file formats [27] . These are the following:

1. .ifc: This is the default IFC file format
2. .ifcXML: This is an XML type file which is generated by sending an application from an IFC data file using conversion according to ISO 10303-28, the XML representation of express schemas and data.
3. .ifcZIP: This is the compressed IFC file format created from a .ifc or .ifcXML file.

It should be noted that through the course of the project the BIM service was not included in the pilot trials or the end-users (as described in D8.2 - D8.8) however that the service remains available for any testing purposes or requests by end users.

6.2 BIM model representation though VR modelling

VR is a simulated environment that implements a special device in order to simulate a virtual world instead of a real one. The user typically is required to wear a headset while specialised software and sensors allow him to be immersed in a simulated environment. VR technology is suitable for developing an interactive 3D communication environment for design, allowing users to explore the greater potential of design scenarios and the ability to evaluate 3D BIM models. Spatial mapping is the technology that enables the VR device to place holographic objects into the context of the real

world, by representing the real-world of the represented object geometry as a single spatial map. A mesh represents the geometry of the scene by surface, as a set of watertight triangles defined by vertices and faces. An example of a spatial mapping mesh for a room is depicted in Figure 2.
In S&R there exist the following two devices that allow the visualization of information through VR technology:

- The Oculus Quest 2 VR headset developed by SIMAVI. The headset contains two high resolution screens and provides the user with 6 degrees of freedom (6DoF) head and hand tracking technology that allows any user to perform actions in the virtual environment. A more in-depth hardware specification of the VR headset can be found at Section 2.11 of D7.3 "Component interface specifications for interoperability within S&R".
- The 3D Mixed Reality Command Centre developed at CERTH allows the user to experience the virtual world by visualizing contextually relevant and online spatial information from different data sources to the decision makers. More information about the component can be found in Section 2.11 of D7.3 "Component interface specifications for interoperability within S&R".

The workflow of the visualization process starts with the creation of the IFC file. The next step is to create the spatial mapping mesh that will be used in the colliding option with the items of the BIM system. The VR device uses its depth camera to generate the depth map and then its processors generate a mesh grid according to the depth map. Depending on the geometric properties of the mesh grids generated by spatial mapping, the Oculus Quest 2 VR device can understand the environment, such as area and topology. This way the existing objects of the environment can be viewed by the user through the transparent glasses of the Oculus Quest 2. The user can edit the structural building elements to make the necessary adjustments and to export the modified IFC file.

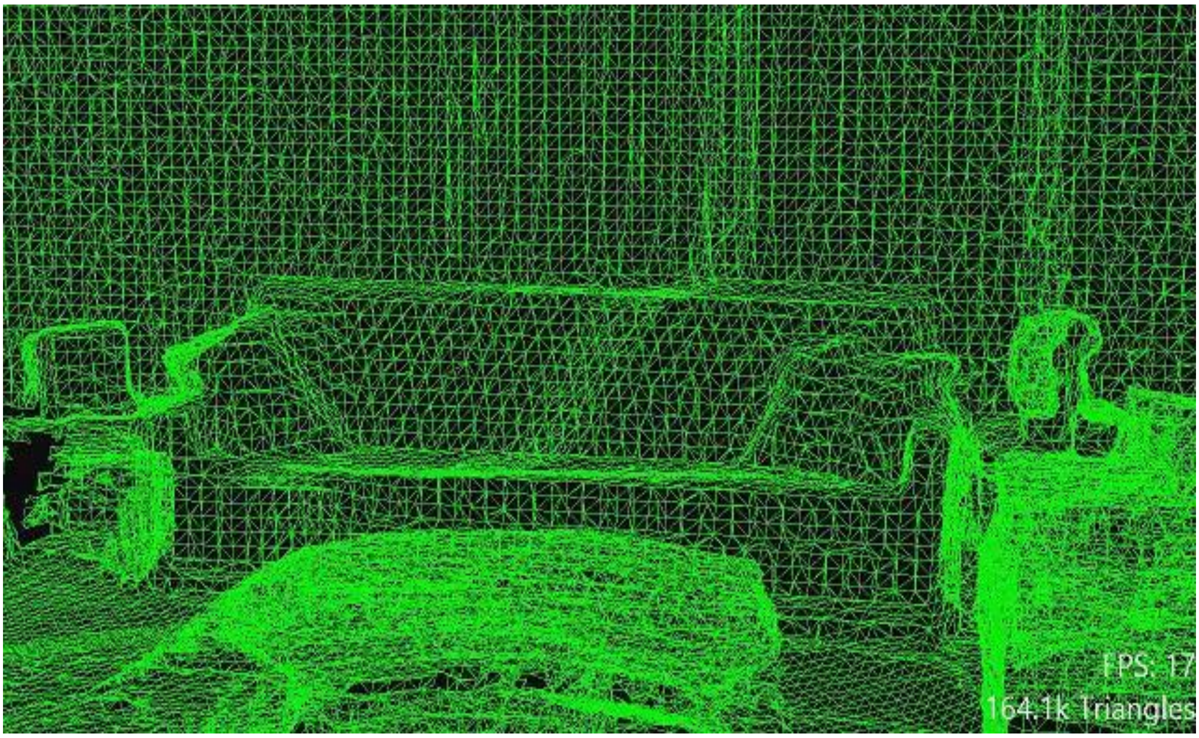

Figure 2: Example of a Spatial mesh mapping

6.3 BIM Management System

The BIM Management System is responsible for providing functionalities in relation to the storing, checking, updating, and querying of BIM models. These models conform to the openBIM International Foundation Classes (IFC) standard (ISO 16739:2018) which contains a rich set of classes designed to provide a robust interoperability solution for data exchange between different built environments software applications. BIM-MP includes a core and a set of reusable modules to support synchronous and asynchronous requests in a unified manner. Some modules can respond to requests immediately while others require more time depending on the complexity of the BIM models.
The BIM Management system implementation follows the SOA design approach. The distributed nature of the platform requires orchestration techniques and a messaging framework that provides a loose coupling between components, to achieve performance and reliability. The use of asynchronous messaging offers many benefits, but also brings challenges such as the delivery sequence of messages and the concurrency between the different BIM modules (Figure 3).

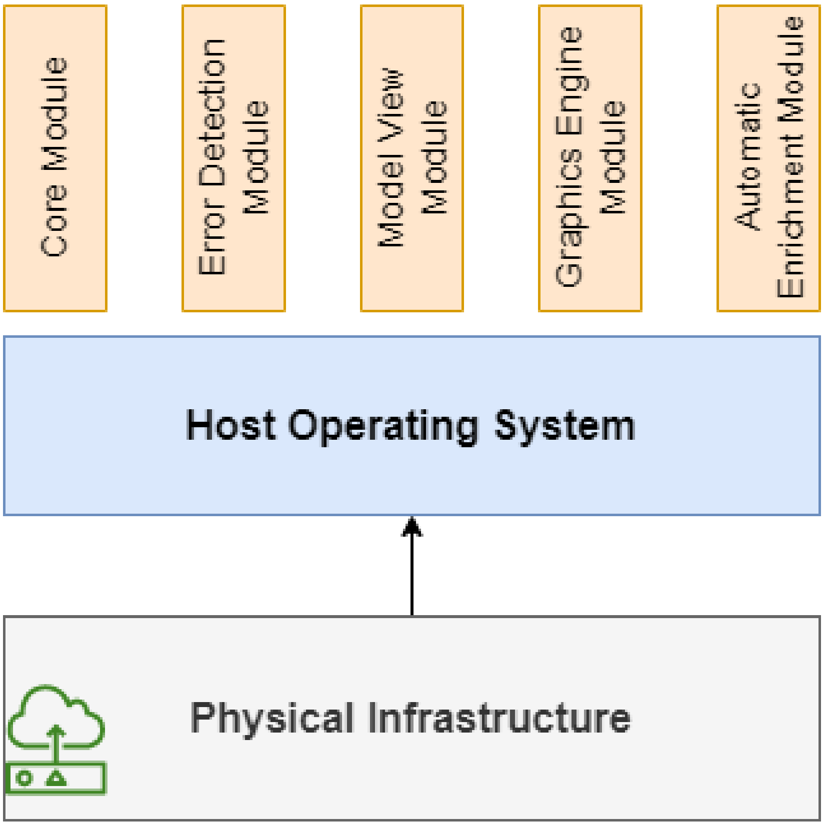

Figure 3: BIM Management system Architecture

In the proposed architecture, BIM Management system modules are standalone applications based on the Spring Boot Framework. Each of them contains high-level and low-level libraries to perform its business logic operations. We defined the following modules as a basis for the prototype implementation of the platform:

- **Core Module** contains the GUI implementation and REST API of BIM Management system. It uses high-level libraries to parse BIM models and extract the necessary information used by the functional modules.
- **Spatial Error Detection Module** integrates geometric model-checking functionalities into the platform helps BIM designers to create an error-free model in terms of geometry in the

scope of building energy performance simulation analysis. The module reports detected errors to the designer in a visual form using OBJ and BCF data.

- **Model View Module** helps BIM designers to validate BIM models in terms of data completeness based on predefined rules following the mvdXML specification.
- **Graphics Engine Module** uses the geometric information of BIM models to generate B-Rep solids of the structural and non-structural building elements. It stores the B-Rep solids in BIF using OBJ files. Additionally, the embedded WebGL viewer of the BIM-Management uses the B-Rep solids for a visual representation of the model through the GUI.
- **Automatic Enrichment Module** uses geometric information to generate the geometry of the spaces and enriches the BIM model.

Each of these modules exchange information using data structures which conform to open standards. The Core Module itself controls the binding between the BIM-Management front-end system and the functional modules.

7 Conclusions

The current deliverable documents the technical activities undertaken towards the definition of the second and final iteration of the Building Information Model (BIM) and the BIM semantic model web service that were developed in the context of the S&R project and will be useful tool for the first responders during a search and rescue operation. In comparison to the BIM model first release, which presented the first version of the BIM model service and was documented in D 3.3 "BIM based services and applications – review and service design", the current deliverable presents the enhancements of the BIM model service, based on the specific needs of the end-users of S&R that were identified through the project's UCs and emphasizes on the virtual representation of the heterogenous information of the search and rescue operations through the VR technologies and tools that offer first responders and other end users a quick and efficient decision making. In this context, the working methodology in designing the appropriate web service and Building semantic model was described, focusing on the details of its components and the main functional parts, while the design and development process for the BIM model data visualization through the VR technology devices of S&R was presented. Finally, the design methodology of the BIM Management System was introduced as well as the main functional components that it comprises.

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