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Automatic verification of requirements in BIM models for building permit

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Introduction

Nowadays, the digitalization of the Architecture, Engineering, Construction and Operation (AECO) industry is challenging many interdisciplinary stakeholders. People involved in this field are used to do their job using traditional approaches based on many years of experience. However, digitalization requires a change and adaptation to today's occupational requirements. A greater specialization in many areas within the construction sector necessitates a deeper analysis to allow checking compliance of processes, with greater control and clarity of the workflow aimed at the success of projects. It is well known that AECO is one of the most fragmented sectors, where it is quite difficult to achieve a detailed overview of a whole project. However, the introduction of Building Information Modeling (BIM) has helped to manage issues related to the exchange of information between different stakeholders (e.g., clients, architects, engineers, construction companies) [1]. However, further steps need to be taken to achieve a clear interoperability of data within the construction process [2]. This is useful for creating greater cooperation between the various stakeholders involved in the project, in order to achieve better coordination.

The adoption of these technologies and processes is still an open issue for public authorities. The authorities that issue building permits should specify the path to be followed. The review of models for a specific property regarding local legal conditions is an elementary component and, in a modified form, essential in many countries. In this way, the control carried out by the municipalities from the 2D drawings to the BIM models could improve the quality of the inspections concerning the requirements expressed in building regulations. The following *Figure 1* is a list of the requirements it has been attempted to verify.

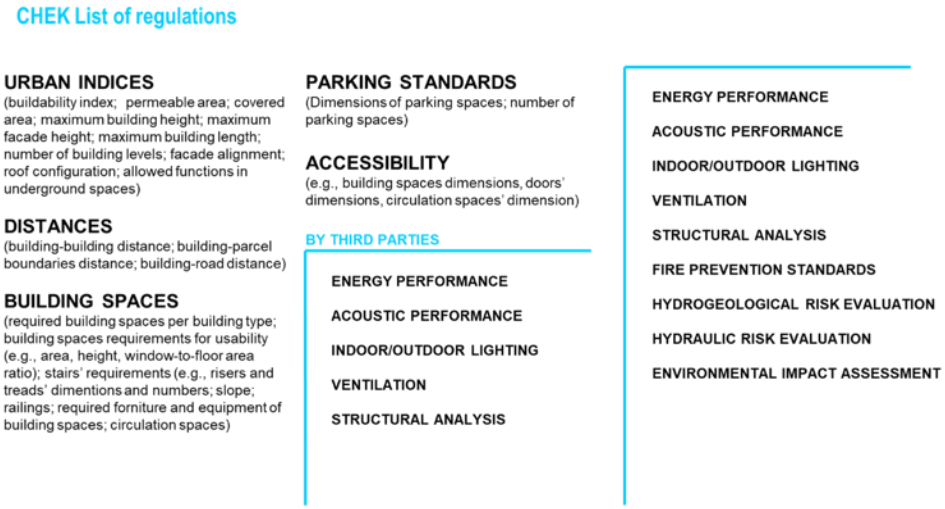

Fig. 1: Requirements considered

Moreover, all these steps could be carried out more quickly and cost-effectively by the authorities [3]. Unfortunately, the interpretation of building regulations and the resultant information extraction to be understood by an automated process through a software is quite challenging. [4] [5] Typically, building requirements are written to be human-readable, not machine-readable: for analysis by a machine, sentences should be very clear, without the possibility of having different interpretations. In addition, Artificial Intelligence (AI) tools must be able to quantify each sentence of a normative text logically and mathematically.

Various authorities are organizing themselves to solve this issue, often through joint projects and research efforts. At European level, Horizon Europe funded projects CHEK (Change toolkit for digital building permit) [6], ACCORD (Automated Compliance Checks for Construction, Renovation or Demolition Works) [7] and DigiChecks [8] are working on this, and Germany is currently trying to introduce an automatic building check into the workflow for issuing building permits. Even international projects such as Dubai's Mandatory BIM Submission for Building Permits [9] that are currently addressing this issue resulting in a high level of importance for the topic in science and practice.

Objective

The aim of this research is to develop an automated process for checking building models based on municipal building regulations. Once the building regulations have been processed using Natural Language Processing (NLP) methods, instead of being analyzed by municipal employees, the requirements to be met are automatically checked on the digital model of the building submitted for the building permit.

However, translating human-readable requirements into machine-readable ones, as previously mentioned, appears to pose a considerable challenge. Furthermore, the manual process of analyzing requirements, whereby humans must read extensively and extract pertinent information, is exceedingly time-consuming. Automated analysis of these documents may potentially provide a solution to the problem. The BERT (Bidirectional Encoder Representations from Transformers) [10] [11] model is a prominent example of transformer models. Projects are already initiated to extract information from regulatory texts [12] [13] [14] however, it is crucial to establish a direct connection between the extracted requirements and the model being analyzed.

Additionally, in order to improve the interoperability between different stakeholder and develop an automated rule checking, it is essential to consider the IFC dataset created by buildingSMART International, which stakeholders use to exchange projects. The complexity of the IFC data schema presents challenges for its versatility and conversion to other file formats. These difficulties arise from the underlying language used in the IFC format, specifically the architecture of the EXPRESS structure [15]. The main objective regarding create a more flexible data scheme is to improve alternative file formats that provide better manageability for automatic checks on the model's information requirements. An example of this is the Information Delivery Specification (IDS) [16], which was one of the first to be developed by Building SMART. However, there are still some technical limitations that need to be addressed. One significant approach considered in this work is the use of ontologies in linked data [17]. For an introduction to the use of ontologies applied to graph data, please refer to the following works [18] [19] [20].

Methodology

First and foremost, it is essential to distinguish between two distinct processes that require analysis, as explained in *Figure 2*. The examination of building regulations and their conversion into information requirements, and the workflow of the building from its inception to the preparation of information requirements that necessitate verification by public authorities in order to obtain a building permit - colloquially referred to as formal building checks.

When analyzing building regulations, there are two main steps. The first step involves standardizing the building regulations according to the NISO STS standard [21]. This is done as a precautionary measure to ensure that any changes or alterations made to the regulations can be traced. Additionally, this step is useful for NLP to extract the requirements that need to be verified. This work utilizes a Bidirectional Encoder developed by Google known as BERT. An explanation of the functioning of BERT can be found in the paper of Schönfelder and König [22]. The second part of the work utilizes ChatGPT, one of the most important Large Language Models (LLMs). As stated in [23], ChatGPT has demonstrated high capabilities in creating queries in SPARQL [24] format to be submitted to the building model translated into RDF.

After verifying that the model is formally compliant, it is translated into RDF files using the relevant ontology from the Linked Data approach developed in [25]. The workflow for verifying the presence and subsequent verification of requirements using ontologies is expressed in the following works [26] [27] [28]. These works consider the principles that ontologies should contain [29] [30]. The requirements are then checked using queries generated by ChatGPT and applied to a viewer such as GraphDB [31], which can import any type of model in RDF format and submit different types of SPARQL to verify the building regulations required by municipalities. Once the procedure has undergone all necessary checks as per the considered regulations, the process is complete. Otherwise, modifications to the model are required. Subsequent research will necessitate a formal evaluation of the model, in addition to the technical check. Technical checking should be performed after rule inspection.

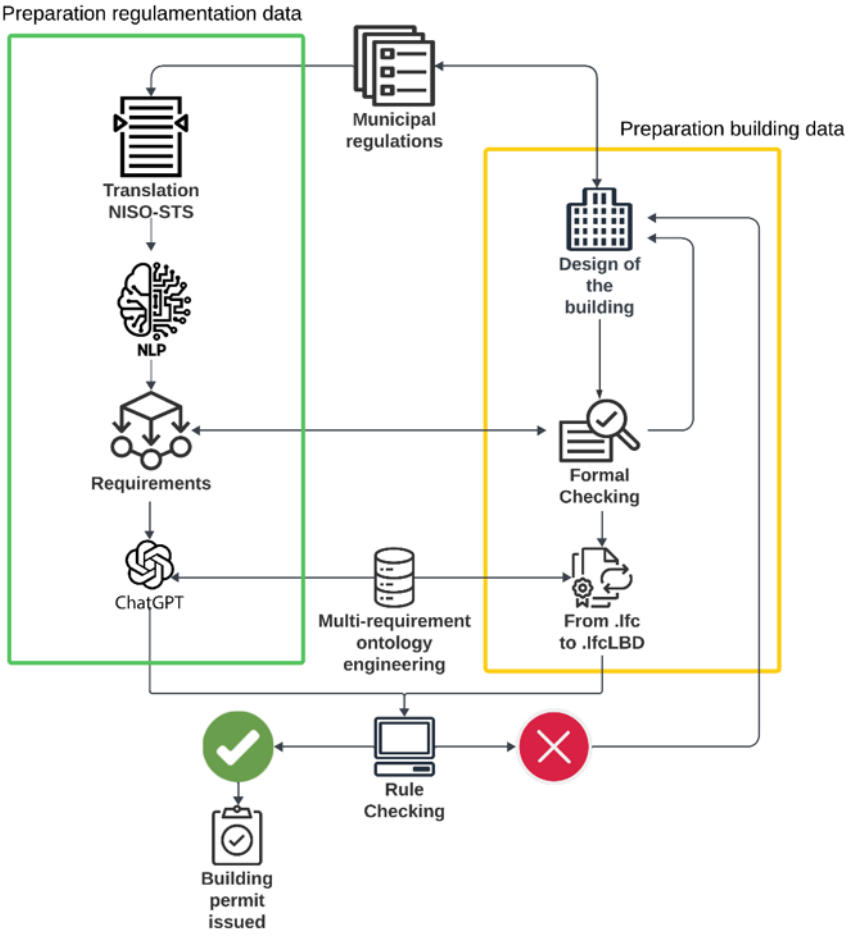

Fig. 2: Workflow approach

Expected research findings

The methodology presented is an academic contribution that firstly allows municipalities to develop standardized building regulations with a view to analyzing and verifying them using artificial intelligence methods, and secondly proposes a flexible approach to analyzing the data present in the model according to the principles of linked data.

On the other hand, the development of standardized building regulations would enable greater effectiveness of an NLP model capable of extracting and verifying compliance with these requirements in projects. In this view of building permit approval, the project manager would only be responsible for developing a project model that includes the required building requirements and ensures their compliance. The responsibility for verifying and analyzing building regulations would fall to the public administration, thus enabling compliant analysis across the entire national territory.

Regarding the application of the analyzed building regulations to a practical case, it has been considered the building regulations of the four municipalities used as pilots within the CHEK project: Ascoli Piceno, Prague, Lisbon, and Vila Nova de Gaia. The results aim to improve upon F1 score of 95% predicted by previous research [18]. To verify the accuracy of the translation of building models from IFC to IFC-LBD, we considered simple residential buildings.

In future works, Geographic Information System (GIS) could be integrated into research as a means of checking urban regulations and building regulations for which the interaction of the building with the urban context has to be considered (e.g., urban indices and distances).

This research aims to address building permit issues that impede the entire AECO sector and hinder the shift to digital control of projects. Primarily, adopting a digitalized approach could bolster the assessment's quality by exploring alternative solutions and determining the optimal choices to ensure a safer building for people and more environmentally sustainable infrastructure. Indeed, enhanced familiarity with the digital model of the project and its various aspects, courtesy of the prospective mandatory implementation of BIM models in private and public projects, can effectively address challenges related to building permit issuance. Consequently, through an automated digitization check, authorities can reduce the time taken to issue building permits and improve control.

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