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Integration of GIS and CAD data to perform preliminary environmental analyses at district scale

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Keywords: CAD, GIS, data integration, Grasshopper, solar analysis, wind analysis.

Extended Abstract

With the current high speed and scale of urbanisation, there is a growing demand for affordable housing – together with all other aspects that are tightly related to it: infrastructure for transportation, utility networks, etc. For this reason, integrated planning is playing more and more a crucial role as the impacts of a new construction project should be investigated, evaluated and minimised from the very early stages of the design process (Josuf *et al.*, 2017; Agugiaro *et al.*, 2020).

However, there still exists a “scale-dependent” dichotomy between the different disciplines involved in the different types of analyses (Ohori *et al.*, 2017). For example, a new building is generally planned and designed by practitioners (architects, engineers, etc.) using tools from the AEC (Architecture, Environment and Construction) domain that, traditionally, follow the CSG (Constructive Solid Geometry) modelling paradigm and use a local coordinate system. On the other hand, in order to estimate the impacts of the new building in the urban context (e.g. at district level), information about the “surroundings”, i.e. its urban context, is needed. As a matter of fact, such information is more and more digitally available nowadays thanks to the growing availability of 3D city models that however generally consist of GIS data. The recent advances of spatial data acquisition and processing technologies have brought a considerable yield of 3D data, with particular focus on the built environment. These data often consist either in point clouds, or in polygon-based models – the latter following the B-rep model. Additionally, data are georeferenced, and semantics may be also added, as in the case of city models based on the international standard CityGML (Gröger and Plümer, 2012). Collecting, harmonising, integrating and merging these kinds of heterogeneous data (both from AEC and from GIS domains) can still be a challenging task for a practitioner that may lack deep knowledge on data integration strategies.

This work provides a possible solution to this problem when it comes to performing speedy and interactive preliminary environmental analyses at the district scale in the case of a newly planned project (e.g., a building). The proposed methodology is the result of an initial analysis

in terms of data and software requirements carried out between GIS specialists and practitioners from the AEC domain. In particular, the latter have expressed their needs in terms of data and functionalities as well as set some limitations in terms of software solutions. The reason behind these choices, both in the form of functionalities and constraints, stems from the desire not to create a new *ad hoc* tool, but to extend and adapt (as far as possible) existing tools and workflows that are mostly used by end users, that is, AEC practitioners. The main topics that have been subject to specific research work are summarised in the following text.
First, regarding the software platforms to be used and the accompanying constraints, a set of tools to be used within Grasshopper/Rhinoceros[1] 3D was developed. This is because Grasshopper is one of the most commonly used software solutions in the AEC domain for parametric modelling and design. Additionally, it has been decided to avoid, as far as possible, adding or linking to existing external libraries, unless already natively supported by Grasshopper, as this would represent a welcome simplification in terms of software management within a large(r) company (Figure 1).

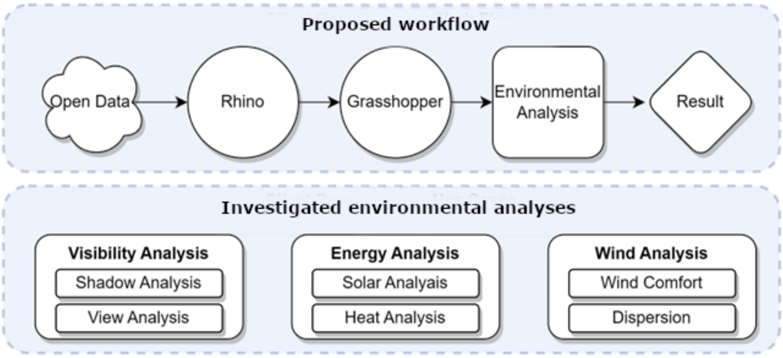

Figure 1. Schematic overview of identified workflow and of the use cases resulting from the interaction between GIS and AEC specialists.

Second, regarding the initial step of GIS data import, the availability of open geospatial data (e.g., buildings, vegetation, terrain, and land use) has been explored in 10 different countries, together with the possibility of accessing these data sources ideally via existing web-based APIs instead of file downloads (Figure 2). Although Grasshopper scripts have been developed to import and integrate the GIS-based "urban context" data into Grasshopper, research in different countries has highlighted the extreme heterogeneity of open data available (or not) and *de facto* a lack of common solutions to access such data despite the existence of open standards.

[1] https://www.rhino3d.com

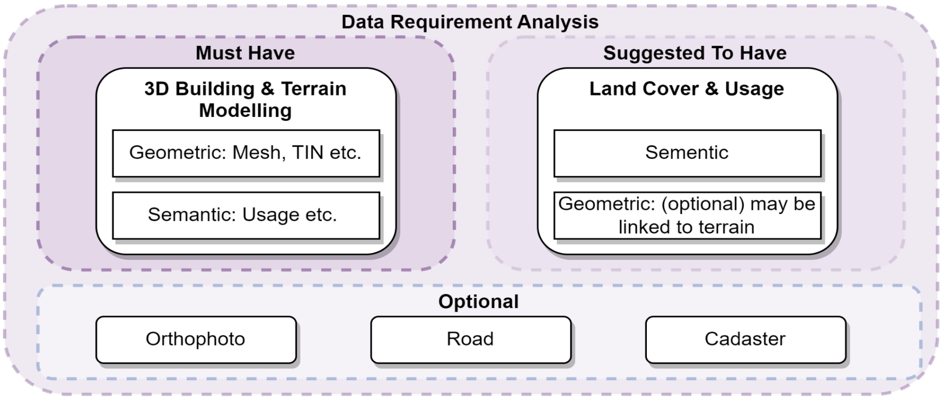

Figure 2. Schematic overview of the data requirement analysis resulting from interaction between GIS and AEC specialists.

Third, when it comes to the actual data usage in Grasshopper, the integration of the GIS data of the "urban context" with the parametric model of a building (representing the actual object being planned or designed by the AEC practitioners) has been investigated. This means that the resulting urban scene model (building + surroundings) had to be prepared in order to be compatible with the Ladybug tools[2], that is, a set of tools for environmental building design that can also be used in Grasshopper, which have been identified by AEC practitioners as target tools. Therefore, several tests were conducted in this study. The goal was to evaluate and compare the simulation results and the overall usability and user experience of the workflow of the operations carried out on the urban scene model (either as B-rep or voxelised) for a) visibility analysis, b) solar irradiation, and c) wind simulation (Figures 3 and 4). Finally, an assessment of the developed methodology (and the implemented prototype) was carried out by both GIS specialists and AEC practitioners to identify current strengths and limitations, and to reason for possible future improvements. Further information and details regarding the entire project can be found in Tsai *et al.* (2024). The developed software and Rhinoceros scripts were freely available on GitHub[3].

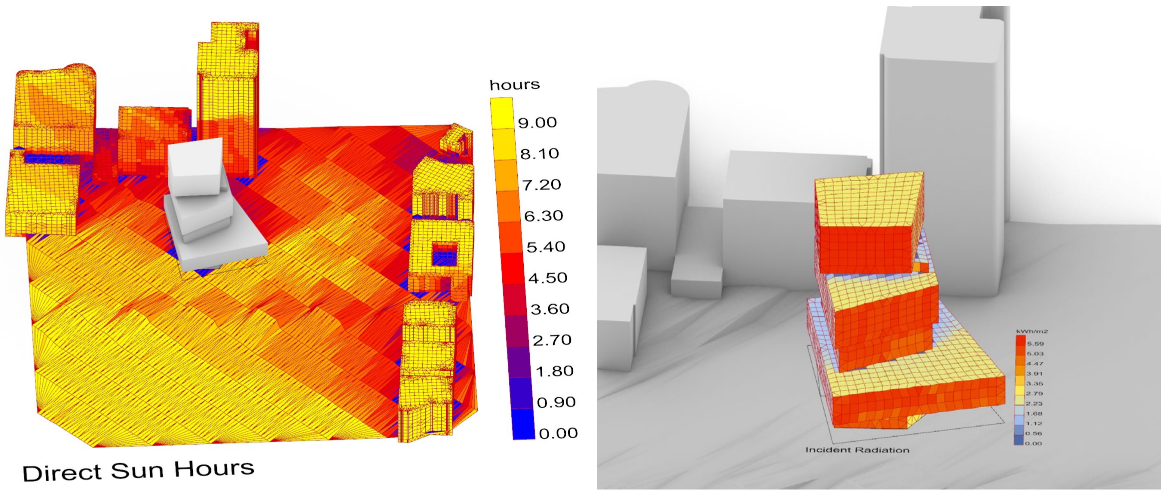

Figure 3. Example of visualisation of results from solar simulation on the urban context [left] and on the planned building [right].

[2] https://www.ladybug.tools
[3] https://github.com/biscuittsai1022/Synthesis-project_1-repository_2023

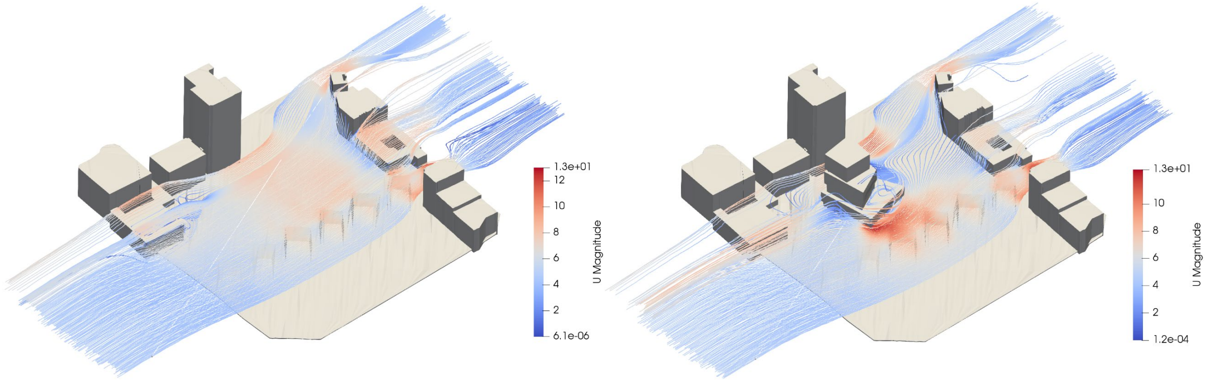

Figure 4. Example of visualisation of results from wind simulation before [left] and after [right] insertion of the planned building in the urban context.

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