

DETECTING BUILDING COMPONENTS WITH ARTIFICIAL INTELLIGENCE FOR INTEGRATION INTO BUILDING PHYSICS SIMULATIONS

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ABSTRACT

This study suggests that artificial intelligence-based detection process of building components can be integrated into building physics simulations (specifically for daylight, thermal comfort, and acoustic analysis). The automatic detection of the building components may significantly enhance the accuracy of the building physics simulations. Accordingly, it has been concluded that the identification of window locations in the interior, along with their locations, can contribute to daylight simulations; the identification of window and door elements, along with their locations and, to some extent, material identification, can contribute to thermal comfort simulations; and the identification of various material types in the interior, along with window and door identification, and to some extent, the identification of objects such as furniture, can contribute to acoustic simulations.

Keywords: Artificial Intelligence, Building Physics, Simulation, Building Components.

1. INTRODUCTION

Building physics can be defined as a branch of science that examines parameters affecting indoor environmental quality, such as daylight, acoustics, thermal comfort and air quality. In building physics studies, measurements are taken by considering these parameters with the aim of improving indoor environmental quality. In this way, occupants can enjoy a more comfortable living space in terms of visual, auditory and sensory aspects.

With the development of new artificial intelligence technologies, there has been an increasing integration of these technologies into the field of building physics. Under the umbrella of artificial intelligence, there are various subfields shaped primarily by different algorithmic structures. These include machine learning, deep learning, and swarm intelligence (Agirbas, 2019; Agirbas, 2024; Agirbas and Aydin, 2024). Computer vision, which is typically studied in conjunction with deep learning (LeCun et al., 2015) algorithms, is particularly relevant to building physics. This is because it involves the automatic recognition and differentiation of objects, a key aspect in this field.

Objects, human faces and other elements can be identified in images or videos using computer vision algorithms. Examples of such algorithms include VGGNet, SegNet, YOLO, U-Net, and Mask R-CNN (Agirbas, 2024). These algorithms are continually evolving and diversifying. As a rapidly advancing field of artificial intelligence, computer

vision algorithms can be modified in various ways to address different problem-solving needs. For instance, if the goal is to recognize a specific number of objects in an image, fine-tuning the algorithm can enable it to identify that exact number of objects (Agirbas and Aydin, 2024). Additionally, to expand the training dataset, pre-existing datasets can be added to enhance the variety and size of the data. This approach helps create larger datasets for training computer vision algorithms, making the training process more effective. Furthermore, augmentation techniques (Shorten and Khoshgoftaar, 2019) can be used to modify the images in the dataset (e.g., rotating, shrinking, adjusting colors, adding blur or glossy effects), thereby increasing the amount of data.

The identification of objects in spaces through computer vision algorithms and their integration with building physics simulations may be possible through artificial intelligence. For example, in thermal comfort simulations, various objects in the space, such as walls, flooring types, window openings, window types are key parameters affecting thermal comfort. By detecting these parameters using artificial intelligence and integrating them into simulations, it may be possible to automate the simulation processes and increase the accuracy of simulation results. The same applies to acoustic simulations. For example, in addition to the impact of the space's shape on acoustic quality, the materials used in the space also play a role (Agirbas, 2022; Agirbas and Yildiz, 2023). The identification of elements such as sofas, carpets, windows, beds, and tables, as well as the location of walls, floors, and ceilings through artificial intelligence, could enable faster and more realistic acoustic simulations. The use of artificial intelligence in daylighting simulations for a space may also be equally important, since the size and orientation of the windows in the space have a significant impact on daylight intake (Agirbas, 2018; Agirbas and Dal, 2024).

The identification of objects through artificial intelligence can enable building physics simulations to be conducted more realistically and efficiently. Based on this concept, the aim of this study is to make preliminary determinations regarding which parameters in indoor environments can be identified using computer vision algorithms.

2. MATERIAL AND METHOD

The fundamental inputs for the building physics simulations in this study were determined based on the building physics simulations available in Grasshopper (Figure 1). Subsequently, those inputs that have pixel-based data—and thus the potential to be detected by computer vision algorithms—were identified.

The fundamental inputs for the thermal comfort simulations that can be performed in Grasshopper using Ladybug Tools (2024) have been determined as the following parameters.

- Geometric data (locations of walls, ceilings, doors, windows, dimensions of the space),
- Material properties (thickness, thermal conductivity, density, specific heat, roughness, thermal absorption, solar absorption, visible absorption of wall layers, U-value, solar heat gain coefficient, visible transmittance of glass materials, etc.),
- Location and orientation (information about the geographic location of the building),

- Nearby room characteristics,
- Space air conditions (air temperature, relative humidity, air speed, radiant temperature, etc.),
- HVAC system details (information about heating, ventilation, and air conditioning systems, operational hours of the systems, their capacity),
- Occupant characteristics (number of occupants, occupants' activity levels, clothing insulation values, personal thermal preferences),
- Building program,
- Time and date parameters (for evaluation of thermal comfort over a specific period).

The fundamental inputs for the acoustic simulations that can be performed in Grasshopper using the Pachyderm (2024) add-on have been determined as the following parameters.

- Geometric data (locations of walls, ceilings, doors, windows, dimension of the space),
- Material properties (absorption coefficients, reflection properties, transmission loss),
- Source and receiver locations and their properties (e.g., sound power level, cut-off time, number of source and receivers, etc.),
- Noise levels (if the acoustic measure parameter requires it),
- Space air conditions (air temperature, relative humidity and static air pressure etc.),
- Building program,
- Other elements such as furniture and occupants.

The fundamental inputs for the daylight simulations that can be performed in Grasshopper using Ladybug Tools (2024) have been determined as the following parameters.

- Geometric data (locations of walls, ceilings, doors, windows, dimensions of the space),
- Material properties (window glass properties such as transmittance and refraction values, reflectance and roughness values for walls, floors, and ceilings),
- Location and orientation (information about the geographic location of the building),
- Surrounding buildings (for shading information),
- Occupancy schedule,
- Building program,
- Time and date parameters (for evaluating daylight availability for a specific period).

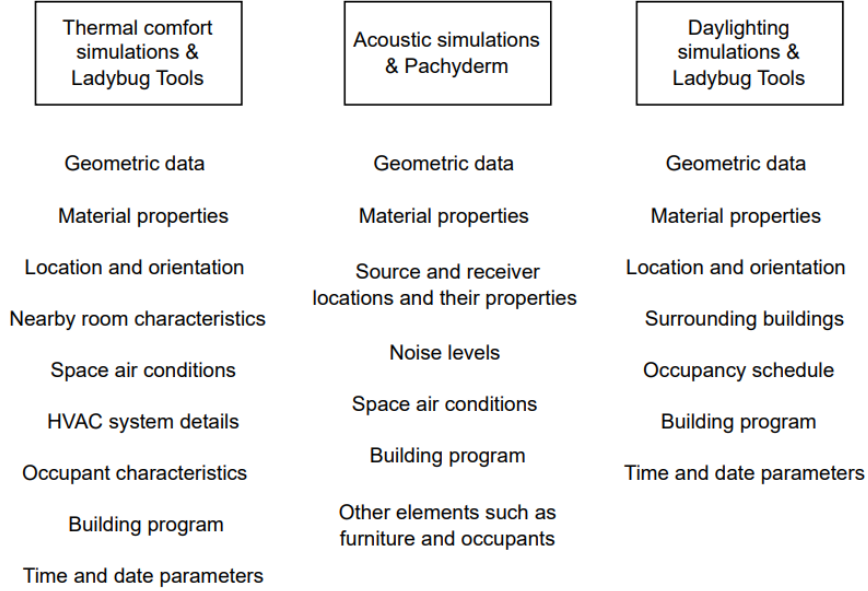


Figure 1. The fundamental inputs for the building physics simulations available in Grasshopper plugins

3. RESULTS

3.1. Elements Detectable by Computer Vision Algorithms for Thermal Comfort Simulation

Elements that can be automatically detected in building physics simulations using computer vision algorithms have been identified. Accordingly, the detection of the following elements using computer vision algorithms is possible for integration into thermal comfort simulations (Figure 2). These elements can only be detected with current computer vision algorithms, and they do not constitute a complete set of data required for the execution of thermal comfort simulations.

- **Material Detection:** The automatic detection of materials used on the wall, floor, and ceiling (such as plaster, ceramics, wood panels, etc.) can be made possible using computer vision algorithms. However, even though the automatic detection of these materials may be feasible with computer vision algorithms, it is also necessary to provide information about the layering of the materials for thermal comfort simulations. For instance, the insulation properties in the layering of a wall are a significant parameter that can greatly affect the thermal comfort level. Furthermore, it should be noted that, for thermal comfort simulations, it is

essential to know whether there are spaces beside, below, or above the area in question. The temperature levels of adjacent spaces can significantly impact the temperature level of the space being analyzed.

- **Object Detection in the Space:** Objects that could impact the thermal conditions of the space, such as carpets, can be detected using computer vision algorithms. These objects can be detected with algorithms like Mask R-CNN (He et. al. 2017), which not only performs location detection but also enables masking, allowing both the location and dimensions of the objects to be identified.
- **Window and Door Detection:** Windows and doors, along with their types, can be detected by computer vision algorithms. The automatic detection of these elements, along with their location, provides valuable information about how they influence the thermal comfort level of the space. It is important to note that detailed information on the thermal transmittance of windows and doors should also be integrated into the thermal comfort simulation. For instance, the presence of double glazing versus single glazing can have a significantly different impact on the thermal comfort level of the space.

3.2. Elements Detectable by Computer Vision Algorithms for Acoustic Simulation

Elements that can be automatically detected in building physics simulations using computer vision algorithms have been identified. Accordingly, the detection of the following elements using computer vision algorithms is possible for integration into acoustic simulations (Figure 2). These elements can only be detected with current computer vision algorithms and do not constitute a complete set of data required for the execution of acoustic simulations.

- **Material Detection:** The automatic detection of materials used on the wall, floor, and ceiling (such as plaster, ceramics, wood paneling, etc.) can be achieved using computer vision algorithms.
- **Object Detection in the Space:** Objects such as sofas, tables, cabinets, beds, rugs, and curtains can be detected using computer vision algorithms. These objects can influence sound absorption in the space. Algorithms like Mask R-CNN can enable 2D detection of these objects. However, the 3D characteristics (volume) of these objects are also important for acoustic simulations.
- **Window and Door Detection:** Windows and doors, along with their types, can be detected by computer vision algorithms. The automatic detection of these elements, along with their material properties, provides valuable information about how they affect the acoustic properties of the space.

3.3. Elements Detectable by Computer Vision Algorithms for Daylighting Simulation

Elements that can be automatically detected in building physics simulations using computer vision algorithms have been identified. Accordingly, the detection of the following elements using computer vision algorithms is possible for integration into daylighting simulations (Figure 2). These elements can only be detected with current computer vision algorithms and do not constitute a complete set of data required for the execution of daylighting simulations.

- **Window Detection:** Windows, along with their characteristics, can be detected by computer vision algorithms. The automatic detection of these elements, along with their location, provides valuable information about how they influence the daylighting level of the space. However, additional material-related information may need to be included in daylighting simulations (for example, transmittance and refraction values of glass).

4. CONCLUSION

Artificial intelligence technologies have made a rapid entry into many scientific fields. These technologies automate many processes, leading to more efficient workflows, minimizing errors, and enabling optimization.

Building physics simulations can take a long time. The ability of artificial intelligence to automatically identify various inputs (such as objects and materials) and include them in simulations could accelerate the process. It could also enable more realistic results. Thus, this study identified which parameters detectable by computer vision algorithms can be included as inputs in building physics simulations. Based on this, it was concluded that for thermal comfort simulation, computer vision algorithms could contribute by detecting materials, objects, doors, and windows, along with their locations; for acoustic simulation, by detecting materials, objects, doors, and windows, along with their locations; and for daylighting simulation, by detecting windows and their locations.

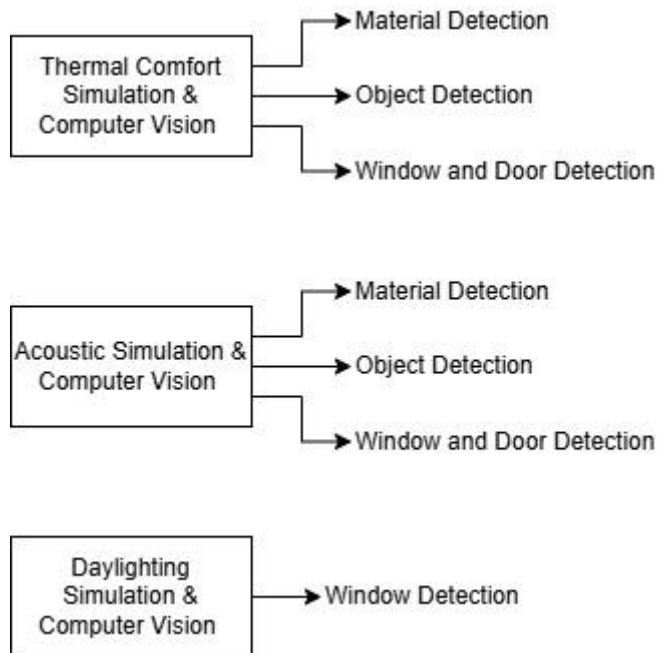


Figure 2. Elements detectable by computer vision algorithms for building physics simulations

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