Indoor Pilot 3D Representation of Comfort Conditions in Mixed Reality Environment

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Abstract. This theoretical description of interdisciplinary research combines different scientific fields, to present a spatial digital interactive 3D representation system of indoor spatial properties, such as unhealthy emissions and building's energy rates, in virtual or mixed reality environment in order to record and evaluate both the energy and health status inside a building in an understandable way for the average habitant. A method of a 3D grid of modern sensors records rates based on voxels / point clouds technology is proposed with also a final comparison and an interactive sensor values evaluation in terms of health and energy. This results a 3D digital thematic representation of "cloud" rates of energy and health status inside the building in a mixed reality environment with a superimposed rates evaluation understandable table. Finally, the representation system allows both the average habitant and the political leaders to evaluate energetically and hygienically an indoor environment, by sensing appropriate actions and creating a social health policy.

Keywords: Immersive spatial 3D Representation · Augmented Reality · Mixed Reality · Digital Design · Energy & Health Building Design · Energy conditions simulation

1 Introduction

During the last decade, many 3D representation systems are deployed for maintaining optimal comfort conditions with the aid of live streams of sensor data. The Internet of Things (IoT) has been applied in various platforms to enhance the quality of life [1], while IoT and other digital sensors provide real-time feedback to building occupants and this information will be of great value since indoor conditions have a huge influence on the quality of their well-being [2] by using simulations of spatial elements and descriptive forms [3] with interdisciplinary approaches. The self-aware building systems aim to acquire dynamic faithful knowledge of buildings and learn to control themselves adaptively and perform processes [4], (Fig. 1).

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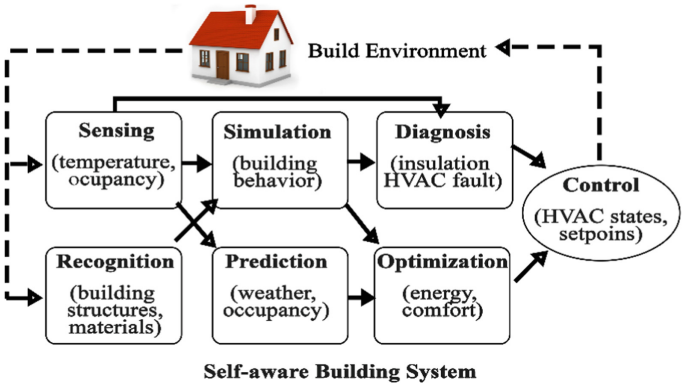

Fig. 1. A self-aware building system consists of several autonomous processes. Source: [5]

A specific need, among others, for well-being inside a building has led many studies, in recent years, on measurement and 3D representation of comfort conditions and / or important indoor spatial properties [2, 6]:

(1) building's energy design spatial properties, such as humidity, temperature, ventilation, thermal conditions, etc., and
(2) building's health design spatial properties, such as unhealthy emissions and pollutants, etc.

However, the combination of interdisciplinary techniques and technologies presents many advantages and limitations and must be adapted to the specific conditions and needs of each study.

2 Proposal Objectives and Challenges

The present research addresses the creation of an indoor pilot 3D representation of comfort conditions in a Mixed Reality environment with the use of interdisciplinary approaches and techniques. The proposed simulation system / methodology objectives are quite similar with previous studies of some of the same authors on nosocomial infections detection [7] and Air Quality emissions inside buildings [8] via biosensors particles spatial simulation in Mixed Reality environment. In this way, the proposed pilot 3D representation system will:

(1) describe in theoretical way a spatial modelling and simulation methodology of comfort conditions rates in order to contribute to a future implementation of a real-time 3D representation system,
(2) visualize temperature, humidity energy design and air pollution inside a building in 3D volumetric interactive 3d point cloud/voxel simulation with spatial reference inside either a virtual building or an AR building environment,
(3) test point cloud filtering algorithms for voxelization of a building,
(4) create a representative 3d models of objects in a minimum time by using scanning techniques,

(5) provide a framework for making a Post Occupancy Evaluation (POE) of energy efficiency (EE) in buildings' indoor environment with results visualization in 3d Virtual Environment.
(6) evaluate measurements rates in a simple graphical and ergonomic way for a non-expert user by comparing the measured rates with the optimal rates during the indoor walkthrough,
(7) contribute to create a wireless low-cost sensors grid system of comfort conditions measurement,
(8) define an adapted methodology of 3D effective indoor spatial modelling and mapping for MR with the use of low-cost system comfort conditions representation,
(9) contribute to understand the "problematic comfort areas" and implement a system by a statistic base knowledge to fix or improve these areas by sensing appropriate actions,
(10) visualize spatial phenomena with high degree of perception

3 State-of-the-Art and Innovation

3.1 Visualization Methods and Techniques

As this research is the extension of previous studies [7, 8], the state-of-the-art of this research proposal focuses on interdisciplinarity simulation & modelling approaches and techniques.

The Comfort conditions methods / techniques for volumetric visualization are based on several modern dynamic technologies, dealing, among others, with techniques in image overlay, OpenGL and VRML programming, special software kit [10], and with techniques in Wireless and telecommunication, VR, AR and MR technology, 3D spatial modelling [9], Building Information Modelling (BIM) integration, Voxel / points cloud representation, displays technology, energy visualization, etc.

VR-AR-MR techniques: While VR techniques immerse the user inside a synthetic environment, AR superimposes the virtual objects into the real world, supplementing reality instead of replacing it [11]. If the real world can be augmented with virtual objects, consequently the virtual world can be augmented with real scenes (views, objects). Such an environment is called Augmented Virtuality (AV), while Mixed Reality (MR) occupies the space between Real and Virtual Environment [11] (Fig. 2).

The basic techniques in AR [10], deal with (a) Tracking, (b) Result Visualization, (c) Interaction & collaboration and (d) Client-Server Network Architecture.

Wireless techniques: especially in AR environment face three fundamental issues, such as (a) mixing real and virtual environment, (b) tracking [13] and (c) wireless communication between users and backbone computers (Fig. 3).

Voxel modeling techniques: Voxelization or point clouds techniques refers to the segmentation of space into cubes of specific dimensions and specific structure by using a 3D cube table, called voxel [15] that can represent a wide range of 3D objects and their related properties [8, 12], such as material type, density, position, etc., as well as, environmental parameters such as the heat transfer in a room through the segmentation of space by using sensors and voxel modelling techniques [16].

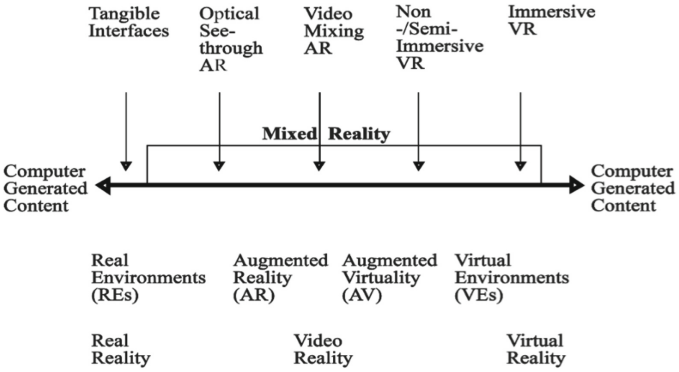

Fig. 2. Reality-Virtuality Continuum [11]

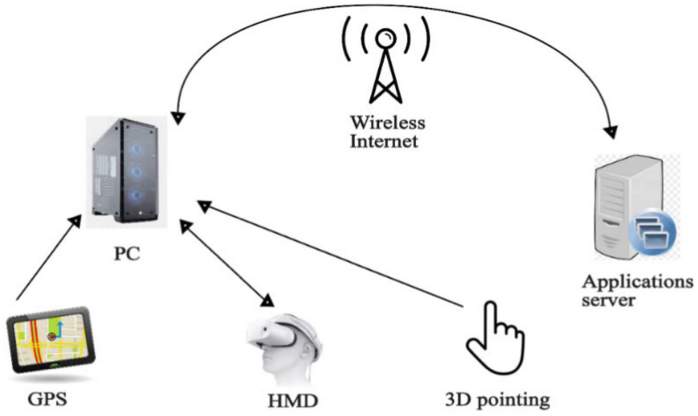

Fig. 3. Wireless AR application (M. Groves) [14]

Point clouds techniques to structure voxel grid space: The conversion of the geometry of a building starts from the stage of point cloud collection (Lidar technique) and later in their transformation through certain techniques and stages, into a voxel model. Classical plane segmentation algorithm is replaced by a voxel-based algorithm resulting from point clouds which proved to be more effective [17].

Lidar mapping: In order to achieve great detail and accuracy in indoor mapping of buildings, Lidar is the leader of all the techniques due to high density point clouds for the accurate representation of the geometry with the development of low-cost Lidar systems and sensors for collecting point clouds [18].

3D modelling techniques: Many relatively complex techniques of 3D modelling construction [8] have been implemented and used in comfort conditions volumetric visualization (Fig. 4). Indicative 3D modeling techniques [19], among others, are: (a) volume (Constructive Solid Geometry – CSG), (b) Occupancy Grid Mapping and voxels [20], (c) point clouds [21], (d) surfaces including polygons / NURBS splines [22], (d)

3D scanning, (e) Object's recognition [23], (f) 3D topology GIS features [24], (g) real-time remote 3D digital design and spatial simultaneous simulation [9, 25], (h) spatial interactive visualization and multimedia representation [3].



Fig. 4. Different methods of 3D representation of the same building [26]

Displays techniques are used in VR and AR systems depending on the purpose of the application. Some of the most well-known visualization technologies are CAVE, Head Mounted Displays (HMD), See-through Displays (HMD clones for seeing virtual image superimposed over the real world).

VRML and X-VRML are scene description languages describing a 3D world construction and providing convenient access to databases, object-orientation, parameterization, and imperative programming techniques [27].

3.2 Related Systems – Discussions

Many simulation systems use voxels optimization techniques for 3D volumetric reconstruction, such as "Voxel Hashing" allowing the projection of 2D or 3D objects into a 1D hash table [28], merging voxels by OpenCL processing data allows [29] or classifying 3D triangle meshes [30] (Fig. 5).

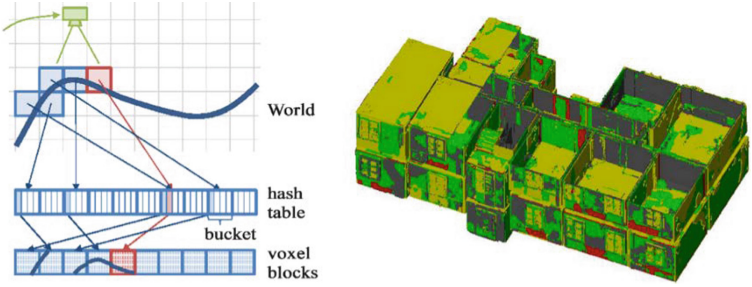

Fig. 5. Voxel-Hashing data structure. Source: [28], Voxel-based algorithm with 3D triangle meshes classification [30]

Other simulation systems incorporate AR into building management systems by using Tango Constructor app in order to capture spatial structures and texture information with a later processing of cloud dataset in MATLAB and a 2D temperature simulation in EnergyPlus software [5], (Fig. 6).

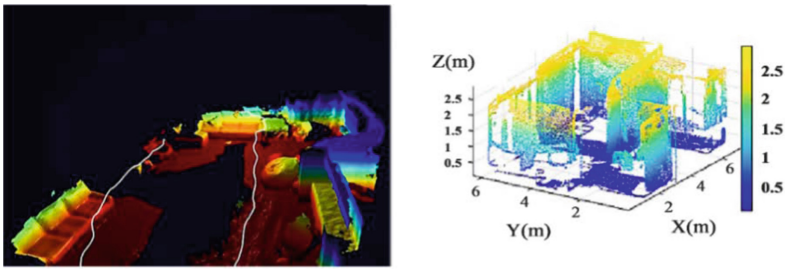

Fig. 6. Google's Project Tango technology maps the environment around it. Source: [31], Detected room 3D geometry. Source: [5]

Another system has been developed providing users with assistance for real-time monitoring of facilities' indoor thermal comfort conditions with VR [32] (Fig. 7) or AR technology with augmented virtual charts [2]. Other system integrates point cloud data and sensor data for visualization and analysis of a typical office building occupant comfort [6].



Fig. 7. Screenshot of the main interface of the prototype system with sensor outputs rates [32]

Finally, AR visualization systems of aerodynamics or fluid dynamic simulation use sensors and specific open-source software, such as Paraview in order to simulate an indoor air purification [33], or use sensors and library of speech and gesture recognition tasks in AR allowing 2D simulations [34] (Fig. 8).

3.3 Innovation of the Research Proposal

The proposed research is innovative as it focuses on a differentiated approach to representing and evaluating energy values from sensors inside buildings. It is a practical,

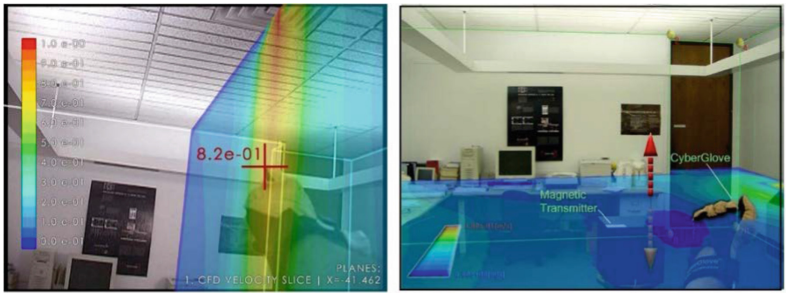

Fig. 8. Isoplane as seen by the user through the HMD and by the user using AR system [34]

pedagogical and immersive approach to understanding the interior structure of a building from an energy and health point of view. The innovation consists, among others, of an adapted method representing indoor energy values by sensors, adapted ways of building's modelling, values 3D representation, data processing and evaluation process, use and communication between new technologies and devices, and finally the social and scientific impact. In particular, the innovation of this proposal concerns:

(1) a simultaneous 3D building structure representation with an energy conditions values representation in 3D point clouds / voxels either in immersive VR of AR environment.
(2) a method to obtain accurate measurements by improving a grid installation of low-cost sensors system in adapted timing related to sensor rates evaluation for air temperature, humidity and pollution,
(3) an adapted methodology of volumetric building modelling based on BIM and energy information for MR comfort conditions representation
(4) provide future users / non-expert with the ability to real-time walk through and experience, through VR / AR environment the building's performance,
(5) a framework creation for making a Post Occupancy Evaluation (POE) of energy efficiency (EE) in buildings' indoor environment by comparing the measured results with optimal rates and offering an embedded interactive virtual 3D table-menu visualization in Virtual Environment during the indoor real-time walkthrough of a non-expert user,
(6) a significant contribution to a non-expert user for understanding "controversial comfort areas" and sensing appropriate actions based,
(7) a constantly re-feed base knowledge by the proposed representation system's use and experience of an expert or non-expert user,
(8) ensure an immersive pedagogical experience and awareness and of a non-expert user or an academic student on the appropriate comfort conditions through a volumetric interactivity virtual tour.

4 Scientific and Social Impact

4.1 Scientific Impact

The major scientific impact categorization of AR 3D representations concerns "Changes of proposed structures", "Design process", "Guiding visitors' experiences" and "Simulations of interdisciplinary information" [35].

The scientific impact of the proposed pilot system is significant because it allows the simultaneous representation of all elements with a real-time user's walkthrough inside the building's structure when the current simulation systems use 3D charts or 3D point clouds/voxel representations in a static virtual 3D building model inside a specific energy simulation software or 2D isoplane / 2D table simulation in a VR / AR building environment. The proposed system also creates special communication interfaces between point clouds/voxels techniques and Constructive Solid Geometry / BIM / GL Transmission / MR techniques and applications [35].

The proposed methodology provides very clear indications of the location, as well as the type of problems to be addressed by associating the classification building's interior geometry with its energy performance and air quality.

The contribution to the sustainability of energy efficiency in Buildings and the effective data manipulation with the octree structure of voxels for data mining and visualization of the measured values from the distributed sensors, play a crucial role since it can produce time-varying data.

Finally, the mobile low-cost system for extracting 3D building geometry and for measure environmental parameters such as (temperature, pressure, noise, air quality, etc) contributes to a cost-effective tool for innovative, more accurate and more understandable visualization, analysis and prediction of thermal comfort.

4.2 Social Impact

The proposed pilot system creates user awareness of the building's performance and air quality as until now assessing a building's EE and air quality was an activity for experts.

Association between internal geometric layouts and building energy performance and air quality will in turn provide designers with valuable knowledge with which they can fine tune their simulation tools.

Finally different partners target-groups can benefit from the proposed system [35], such as, Real estate market (high values to energy efficiency buildings), Engineers (simulations for energy demand of buildings), Customers (appropriate selection of apartment), Academic students (knowledge and evaluation), Public Authorities (contribution to a strategic plan for a social energy and health policy exertion / smart city platform's component for information, participation and deliberation).

5 Research Methodology & Pilot 3D Spatial Representation

5.1 Introduction

The research methodology of the present study is based on previous studies of the same authors on nosocomial infections detection [7] and Air Quality emissions from biosensors inside buildings [8].

The present research includes interdisciplinary approaches and techniques as they develop independently taking into account specific communication specifications regarding other techniques, the connection between them affects the overall development of the entire research organization. The methodological steps consists in (1) energy design through the selection of buildings where the measurements will be implemented based on geometry criteria, (2) comfort conditions measurements, implementation and temporary storage, (3) 3D building geometry's modelling in a MR environment, (4) 3D modelling of the selected comfort conditions values adapted to the building's geometry model by using special 3D point clouds / voxels techniques, (5) adapted evaluation of comfort conditions values, and (6) final 3D spatial representation of all previous elements in a unique MR interactive environment (Fig. 9).

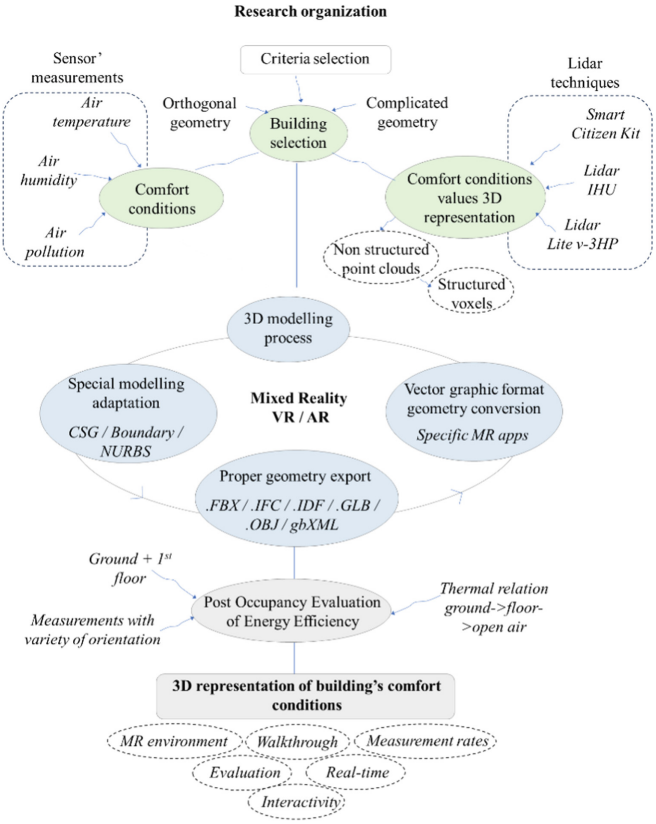

Fig. 9. Research schematic methodology

5.2 Buildings' Type Selection

Building use: the buildings to be measured are residences. They often represent the majority of the building sector that will very shortly need environmental certification in

order for users to proceed to any type of activity (renting, selling). It is also the type of building that has the least documentation on its envelope structure, energy efficiency and air quality, especially for those built before 1980. These buildings will require interventions in order to be certified that they comply with current energy efficiency regulations. Users will need to have awareness regarding both the energy efficiency as well as environmental factors that influence health issues.

Building geometry: in contrast with geometries from other building types (i.e. offices, schools) residences can display fairly complicated internal layouts. In order to examine the relation of internal geometry and indoor environmental factors, two buildings of varying interior geometry will be measured: one with simple orthogonal geometry and one with a complex configuration. This will establish our proposed method as suitable for any building types.

Relation with urban fabric: both buildings are free standing, consisting of a ground and first floor, thus providing measurements of spaces with a variety of orientations, as well as the thermal relation of ground-building, ground floor to first floor and first floor to open air.

Measurement conditions: the buildings will not be occupied, with systems of HVAC not in operation. Measurements will take place on a 24 h basis, in order to monitor value fluctuations. Measurements will take both place in winter (February) and summer (July), so as to test two opposite weather conditions. These will establish our proposed method for obtaining, visualizing and evaluating data for the actual building shell. Measurements can then take place after occupants move in and the building is in full use.

5.3 Sensors Implementation & Comfort Conditions Measurements

The current proposal will explore the above methods for extracting the geometry of buildings as well as collecting point clouds through the Lidar technique. The non-structured information provided by the point clouds will be transformed into structured voxels [36], which will be the framework for visualizing the various parameters such as temperature, humidity, air quality, noise, etc. that will be measured with low cost but high added value sensors. The sensors to be used in the research fall into two categories: (a) distance measuring sensors and (b) sensors for measuring environmental parameters. For the first category as mentioned, there will be used a low-cost lidar sensor (Fig. 10) suitable for indoor applications. For the efficient and effective use of such a sensor, a small platform will be constructed. For the collection of the geometric information (point clouds) of buildings, an effort will be made to develop and use a low-cost Lidar system [37], which will test the low-cost sensor LIDAR-Lite v3HP of Garmin company.

For measuring the environmental parameters, low-cost sensor such as the Smart Citizen Kit (smartcitizen.me), will be used, which has been developed as part of the iSCAPE project under the European Community's H2020 Program under Grant Agreement No. 689954 [38] (Fig. 10).



Fig. 10. Low-cost sensors: LIDAR sensor - Lite v3HP of Garmin company. Source: [32], and environmental sensor Smart Citizen Kit [33]

5.4 3D Building Geometry Modelling Process

Creating 3D spatial models for representation with 3D energy clouds points in an interactive MR environment is a quite complicated process. This is due, among others, to:

(a) the specific requirements of the MR representation regarding the communication protocols of the 3D objects,
(b) the plethora of 3D modeling and representation applications creating different formats and techniques,
(c) the involvement of energy values representation, special connected devices such as sensors, specific glasses, wireless technology, creating technical difficulties in their communication,
(d) the technology that governs the entire MR environment constantly evolving and creating new experimental communication standards.

The methods of creating 3D models vary in relation to the needs of each study and to the involvement and use of specific tools. The method of objects modelling photos is the process of creating a 3D object from scratch using dedicated specific 3D software. The photogrammetry method uses compilation of photos of the object from multiple angles (approximately 80–200) extracting 3D geometry and texture data by using 3D dedicated software. The Constructive Solid Geometry – CSG (CSG), Boundary and NURBS polylines method creates solid CAD models that must be converted by specific software into universally supported formats such as VRML [39], BIM file format, Collada, OBJect, etc. [40] within many cases specific model elaboration in order to optimize the converted models to comply with web/device standards [8]. To do so, these model formats are converted in proper format used across most platforms such as websites, Android and iOS. Indicative formats are GL Transmission Format (gLTF) or the accompanying gLB format which are royalty-free specification and common publishing open format for the efficient transmission and loading of 3D scenes and models by applications, including support for PBR (Physically Based Rendering) materials for realistic rendering and USDZ format which is Apple's optimized 3D file format for mobile devices using Universal Scene Description (USD) [41] format build in collaboration with Pixar. Finally, some MR applications (VR / AR) visualize 3D scenes after proper vector graphic formats transformation supported by specific 3D models creation software while specific

visualization equipment such as Tablet, smartphone, specific MR glasses (Hololens, Head Mounted Display - HMD), etc. [14] is needed for the final interactive 3D visualization. The selection of 3D modelling process and the corresponding techniques to be implemented in this work will be estimated and adapted to the research progress and the specifications needs of all element's integration such as sensors, clouds points 3D representation, etc.

5.5 Comfort Conditions Values 3D Representation

To generate building models directly from point cloud data (e.g. for engineering simulation) there are 3 dominant methods [42]: (a) Constructive Solid Geometry (CSG), (b) Boundary Representations (B-Reps) and (c) Spatial sub-division representations where an object domain is decomposed into cells with simple topological and geometry structure, such as regular grids and octrees.

The choice of one method than another depends on things like the nature of the application, the demanding processing power, the complexity of the object and others. The current study deals with the third dominant method, which is based on voxel segmentation. Voxels can represent complex objects in reducible, discrete units (like particles), they can be incredibly powerful for simulating real world behavior of complex objects. The main advantages of voxels are:

(a) They are a more "accurate" 3D building block than any other modeling type, as they mimic particles,

(b) They unlock new simulation techniques that would be impossible with other modeling methods,

(c) Voxels are the quickest way to quickly model and visualize volumetric data (especially in natural or organic formations).

The 3D representation procedure to be followed is: (1) Lidar scans of a room or building, (2) Registration of different scenes, (3) Cleaning process of unwanted points, (4) Rendering, (5) Export of unstructured point clouds (.las files), (6) Filtering of point clouds through voxel-based sampling filters (e.g. Voxel Center Nearest Neighbor filter), (7) Import of structure point cloud (voxel) in open source visualization software, (8) Visualization of the model with different voxel methods (slice etc), (9) Integrate the sensors values (temperature, humidity, etc) into the voxel model and visualize the interpolation values and (10) Export of the visualized model for use in AR, VR etc. applications.

5.6 Comfort Conditions Values Evaluation

Our proposal seeks to establish a method for visualizing indoor environmental data as well as air quality. The methodology will initially be established for primary data such as air temperature, relative humidity, noise pollution, PM (air pollution), as they are environmental factors that are of primary importance to users' health. This methodology can further be expanded to include more factors, such as MRT, thermal comfort, EMR radiation. After measurements are taken and 3D representations are constructed, our proposal presents users with an evaluation mode. In order to choose the best type of

evaluation visualization, a pilot study with questionnaires for users can be performed, investigating their preferred evaluation type. A radar chart (if chosen) will be assigned to each of the parameters measured, providing instantly to the user, while walking through the space, with the value requested, located in the chart in relation to the ideal comfort zone.

Air temperature is the primary environmental factor that users can easily perceive. Also, the percentage of relative humidity on a daily basis, throughout the year is a decisive factor in indoor air quality, as high percentages indicate environments potentially dangerous for occupants' health, facilitating the existence of airborne allergens and bacteria, among others.

Noise pollution is another crucial factor contributing to occupants' health. Anxiety, poor sleep and performance and hearing impairment have been registered as possible negative effects of continuous exposure to high levels of noise in the building envelope [43]. Measurements will be taken with windows and doors closed. A clear picture of the building's performance is formed with measurements on a daily and weekly basis, while the building is not occupied and while in full operation.

Air quality is monitored, among others, through the measurement of particle matter (PM). In particular particles with an aerodynamic diameter of 2.5 μm or smaller (PM2.5) pose a significant threat to human health, as they can penetrate deeply into the lungs and cause serious damage that triggers potentially lethal diseases [44]. The WHO have set standards for PM2.5 concentration: 25 μg m–3 (24-h mean) and 10 μg m–3 (annual average) [45]. The air pollution index for PM2.5 is divided into six levels: 0–50, 51–100, 101–150, 151–200, 201–300, and greater than 300. Based on these the severity of air pollution in an environment can be specified [46]. Indoor PM concentration is a combination of factors related to outdoor environment as well as occupants' activities indoors. PM2.5 concentration visualization can provide occupants with a clear understanding of the surrounding outdoor air quality, as well as the effects of their own actions, when measurements are taken when the building is in use. Comparison of measurements from buildings that have a different internal geometric layout can further reveal if a complex geometry can work in favor or against PM concentration in a residence.

5.7 Pilot 3D Spatial Representation of Building's Comfort Conditions in MR Environment

Technical approach: The modeling as well as the representation of the building's geometry types will be implemented either in VR and / or AR environment. The technical approach of 3D modeling as well as the Level of Details (LOD) will be adapted in relation to the integration of the other elements, the communication with them, the technical limitations and the detection of the respective ideal way of elements and information revelation. The 3D building's geometry may be accompanied by a different type and level of customized rendering in relation to the representation environment, the memory and speed of the output devices equipment and the representation of the selected elements. The representation of the application in VR environment will need special VR head glasses and corresponding hand sensors, while the representation in AR environment will need a special smartphone / tablet with integrated tracking movements sensors. In

VR environment, 3D building's modelling is necessary as it is the "shell" (spatial reference) in which comfort conditions values and their evaluation will be simulated. In AR environment, building's 3D modelling is an additional but not necessary information for the 3D representation of comfort conditions values since the user can navigate the real space of the building (Real Reality) by seeing the space through a special AR device (smartphone / tablet) and at the same time simulate through the same device these values and their evaluation inside the existing building (Augmented Reality). The 3D representation of these, almost transparent due to their sparse density, values will be in the form of 3D points clouds / voxels that will allow their visual adjustment in space and the corresponding spatial perception of the user.

By using a point-based distance sensor (such as the LiDAR Lite v3HP) together with two servos for both the azimuth and elevation axes, a point cloud data is collected and can be exported to a comma separated value (CSV) file and geometry definition file (OBJ) [47]. This system will be used for the extraction of the 3D geometry (point clouds) of the room/building. Regarding the sensors for measuring the environmental parameters, the smart citizen kit is designed with the ability to expand, with a central data recorder and the ability to connect to the Internet. All of the above is based on open-source hardware and code.

Visualization results: The indoor pilot 3D representation of comfort conditions in MR environment will be implemented in VR and / or AR environment. In VR environment, 3D building's modelling process is necessary to integrate comfort conditions clouds 3D representation with the corresponding rates simulation and evaluation. Special VR head glasses and hand sensors will be needed for real-time walkthrough. In AR environment, 3D building's modelling is not necessary and it be replaced by the building's Real Reality (RR). Special AR devices (smartphone / tablet) with integrated trackers / sensors simulate augmented comfort conditions clouds in superimposed transparent representation with augmented objects of rates charts and evaluation. In both cases, 3D representation of spatial and environmental phenomena presents a high degree of spatial perception (Fig. 11).



Fig. 11. Visualization results of the proposed pilot representation system in MR environment

6 Conclusions

This research attempts a 3D spatial representation and ergonomic assessment of energy and health design inside a building. The final specific interactive 3D architectural representation of energy and health conditions rates, in relation to the building's 3D spatial

simulation in a virtual environment of mixed Reality (Real + Virtual + Augmented Reality), occasionally adapts different representation techniques so that the final representation becomes perceived by an average habitant, through an architectural, spatial representative, ergonomic and communicative approach.

The research methodology involves, among other, buildings' energy design based on geometry criteria, comfort conditions measurements, 3D building geometries and comfort conditions modelling and adaptation in a MR environment and final 3D spatial representation of all previous elements in a unique MR interactive environment.

The scientific and the social impacts are very significands because on one hand all sensors can be combined via the internet and with in situ measurements, to transfer the results of the measurements to a virtual environment and on the other hand the contribution to a strategic plan for a social energy and health policy exertion by public authorities via implementation of the proposed visualization / evaluation system to selected buildings' local network.

The integrated technical approach of the proposed system allows the use of special VR head glasses and the corresponding hand and point-based distance sensors and the comfort conditions values in the form of 3D points clouds / voxels. The visualization results allow the integration of comfort conditions clouds 3D representation with the corresponding simulation and evaluation rates and the use of special AR devices (smartphone / tablet) with integrated trackers / sensors that simulate augmented comfort conditions clouds in superimposed transparent representation with augmented objects of rates charts and evaluation.

Ensuring an immersive pedagogical experience, awareness and information of a non-expert user or an academic student on the appropriate comfort conditions through a volumetric interactivity virtual real-time walkthrough, the perspectives of the proposed system are very promising. This is due to, inter alia, the dissemination of methodology and evaluation methods, through assessment of users' reception of the visualization and evaluation of indoor environmental data with surveys and questionnaires and finally to an adjustment of the proposed system to an accessible online platform as a component of a smart city platform for public awareness, information, participation and deliberation.

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