SightSeeAR: Using BIM Segmentation to Enhance Visualization of Construction Worksites

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***Abstract*—Miscommunication on construction sites often stems from the complexity of 2D schematics and results in billions of dollars in rework annually. This issue disproportionately affects migrant trade workers with limited English proficiency and/or technical training. To address this challenge, we propose a segmentation pipeline for Building Information Models (BIM) that prepares complex models for task-specific augmented reality (AR) visualization. Our system, called SightSeeAR, is composed of two segmentation methods: keyword-based segmentation of BIM components and bounding-box segmentation. The resulting segmented models are converted into lightweight AR-compatible formats (GLB, USDZ) and delivered to workers through a mobile application interface. Segmentation uses Blender scripting and is deployed with AWS. Field evaluations in New York City construction sites highlight the pipeline's potential to enhance accessibility and comprehension. As well as establishing a foundation for further automation in AR construction workflows.**

Keywords: Augmented Reality, Building Information Models, visualization, usability.

I. Introduction

In New York City, the construction industry provides hundreds of thousands of jobs; it was the city's fastest-growing employment sector between 2011 and 2019, employing over 161,000 workers in 2019 alone. Taking a further look into the demographics of the industry, around 53 percent of construction jobs are held by immigrants, over 56 percent of whom do not have a formal education or college degree [1]. Moreover, the industry itself is very varied and encompasses approximately 130 different construction and non-construction occupations, the most common being trade workers, carpenters, construction managers, electricians, and plumbers.

The construction industry is an environment where efficiency and precision are essential. A significant portion of miscommunication and delays on construction sites stems from conflicting work done by trade workers. Of the total project's cost, approximately 9% is rework—considering both direct and indirect factors combined [2].

Building Information Modeling (BIM) has become a standard for digital representation of buildings. Allowing for representation of structural, mechanical, and design data to be unified in a 3D model. However, this utility is often inaccessible to field-level workers. Tools for interacting with BIMs tend to lean toward architects, engineers, and project managers.

In this work, we introduce a segmentation pipeline to prepare task-specific or region-specific BIM models for Nearabl's mobile-based AR visualization of MEP (Mechanical, Electrical and Plumbing) systems in construction sites. Our system, dubbed **SightSeeAR**, supports two forms of segmentation: (1) **semantic segmentation** based on keywords associated with BIM elements and (2) **spatial segmentation** using **bounding-boxes**. The resulting segments can be recursively segmented and converted into lightweight models optimized for visualization and interaction on web platforms or mobile applications. The system is implemented as an API using Python and Blender [6] scripting, integrated with AWS infrastructure for scalable processing and delivery.

The contributions of this paper are as follows:

- Develop a segmentation pipeline for BIM models supporting both keyword-based and bounding-box-based segmentation methods.
- Created an automated process to divide BIM models based on 2D floor plans.
- Adapted model file conversion to accommodate various formats required for web and mobile visualization.
- Conducted a usability evaluation with trade workers.

This paper is organized as follows: Section II presents related work in BIM segmentation and AR visualization.

Section III describes the system architecture and workflow. Section IV details the segmentation methodology. Section V presents an evaluation of the system. Finally, Section VI concludes the paper and outlines directions for future research.

II. Related Work

Recent efforts have focused primarily on the generation of BIMs from existing structures. There have been proposals for methods of reconstructing BIM models from 2D floor plans using geometric and semantic reasoning [3], while others describe a scan-to-BIM workflow that leverages photogrammetry and laser scanning to model existing environments [4]. These works highlight the importance of BIM in an increasingly digital world. To avoid post-construction BIM creation, our approach focuses on enabling model decomposition for more precise record keeping and facilitating trade workers with the same level of precision for model visualization. There has been growing interest in AR-based construction tools in the U.S., citing their potential to improve communication and productivity on job sites [5]. However, widespread adoption remains limited by the absence of streamlined pipelines.

Unlike prior work that focuses on generating BIMs from existing structures, our approach assumes the availability of BIM files during the design and construction phase and focuses on their preprocessing and decomposition for improved usability on active construction sites. This segmentation supports both semantic (keyword-based) and geometric (bounding-box) filters, enabling lightweight deployment on mobile AR interfaces and making model data more accessible to workers on site.

III. System Architecture

The SightSeeAR system is composed of three components (Figure 1).

1. **Web Platform** – Enables user interaction for task- or region-specific model segmentation and validation.
2. **Segmentation Pipeline** – Handles the segmentation of large BIM models and manages data storage.
3. **Mobile App** – Provides AR visualization of the segmented model in the field.

A. Web Platform

Once uploaded, the BIM model can be selected for the following using a web-based application:

- **Keyword Segmentation**: BIM components are filtered based on semantic labels extracted from the model's naming conventions (Figure 2). For example, all elements tagged with "duct" are isolated and extracted. Blender scripting is used to parse, group, and export the relevant components from the model.
- **Bounding-Box Segmentation**: Select a bounding-box center and dimensions to encompass an area of the model (Figure 3). All the geometry within the box is grouped, segmented strictly at the boundaries, and exported.

In all workflows, the segmented components can be recursively subdivided and can be exported into mobile-compatible formats (GLB, USDZ).

B. Segmentation Pipeline

The segmentation pipeline operates through a Python-based API that manages the entire process, from segmentation and conversion to data integrity. The system is designed for scalability, supporting manual web-based processing and automated processing.

As part of the pipeline, the system supports **two segmentation methods**: keyword-based segmentation and bounding-box segmentation.

Part of the pipeline is **automatic bounding-box segmentation**; this part of the system assumes a given BIM model represents a single floor. Using a corresponding 2D floor plan, the system identifies distinct regions and computes bounding boxes around them. These 2D coordinates are then projected into the 3D space of the BIM model. The segmented regions are extracted programmatically, producing lightweight components that correspond to specific regions. These segments are then converted into formats compatible with web and mobile visualization.

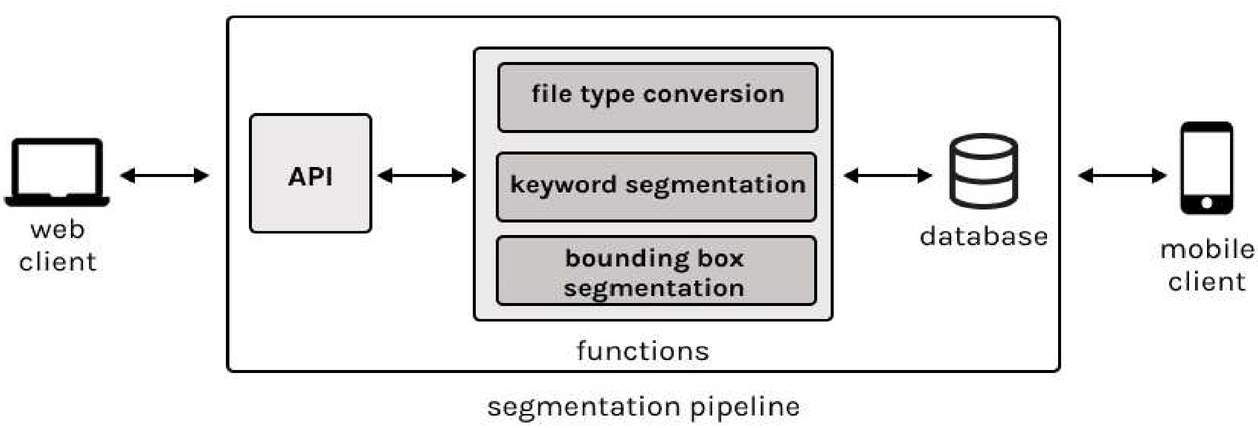

Figure 1. Diagram of the SightSeeAR system architecture

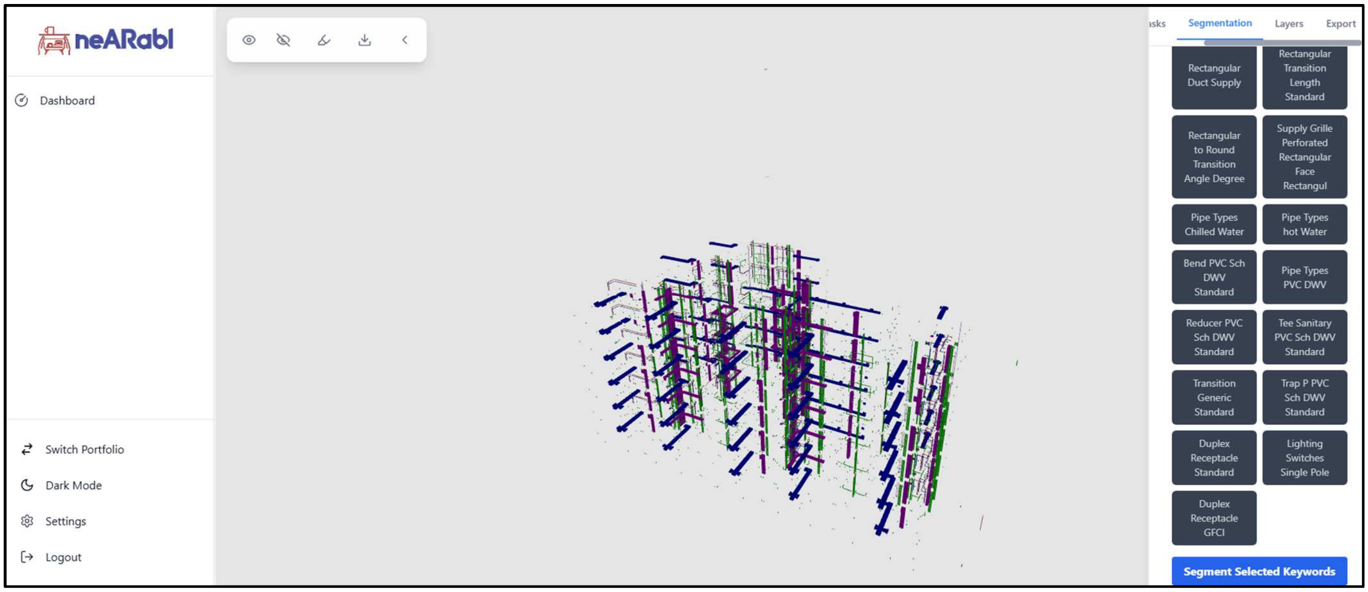

Figure 2. Segmentation via keyword in web platform.

C. Mobile AR Interface

For mobile, a Swift-based iOS application retrieves the segmented model files to render them in AR (Figure 4). Users can select from a list of segmented models and visualize it in real-world space using AR. Key features include:

- Tap to highlight individual components
- Real-world distance measurements
- Bilingual instructions and tooltips

This interface is designed to be intuitive for workers with limited experience and supports Spanish-language accessibility to accommodate the primary language spoken by many NYC construction trade workers.

D. Workflow Summary

To summarize, the system follows this pipeline:

1. **Upload**: Users upload BIM files via the web dashboard.
2. **Segment**: Keyword or bounding-box segmentation is performed via API.
3. **Export**: Mobile-compatible segmented models are saved and indexed into the cloud database.
4. **Visualize**: Trade workers access models through a mobile AR app.

IV. Segmentation Methodology

The segmentation component of the system is designed to decompose large BIM models into meaningful, more focused models. Our approach supports two complementary modes of segmentation: **semantic segmentation** via keywords and **spatial partitioning**. Both workflows are implemented as modular Python scripts using Blender's capabilities.

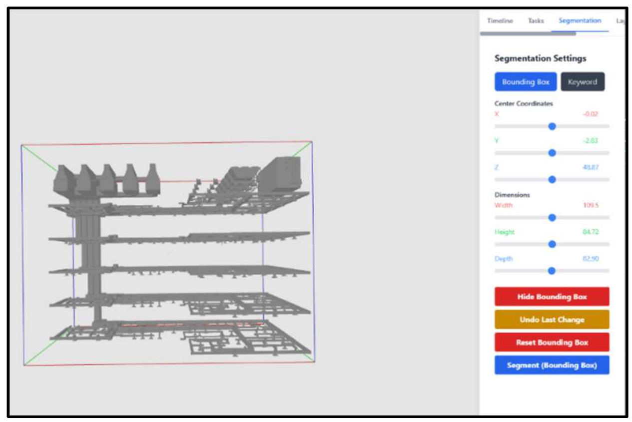

Figure 3. Segmentation via bounding box in web platform.

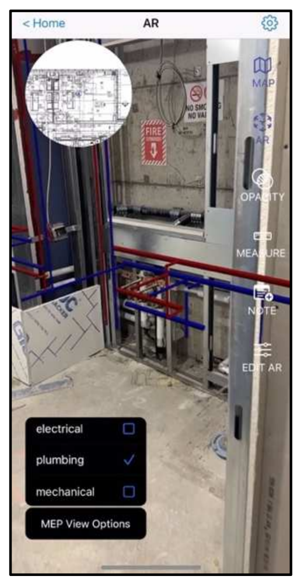

Figure 4. AR visualization of the segmented model in the Nearabl mobile application.

A. Keyword Segmentation

Keyword-based segmentation leverages metadata or naming conventions embedded in the BIM hierarchy (Figure 2). Most BIM authoring tools allow for component-level labels such as "pipe," "duct," or "column." Unfortunately, no two components can share a name; thus, you can have sets like {pipe-121, pipe-122}. There is no set standard for naming conventions, so we opt for a largest common string approach for grouping.

Once the model is imported into Blender, Python scripts recursively traverse the object tree. For each object, the script performs the following steps:

1. **Grouping**: Matching components are added to a logical collection.
2. **Isolation**: The grouped components are selected.
3. **Export**: The selected geometry is exported into a new file — either in the original format, a mobile-compatible format, or both — based on user selection.

This process enables users to visualize specific system layers relevant to their tasks, such as all electrical components or air ducts, without needing to visualize the entire building model, which often contains unnecessary information and adds to computational overhead.

B. Bounding-Box Segmentation

Bounding-box segmentation is used to extract spatial regions of the model, given a center and dimensions for the box. We developed an interface to guide through this 3D spatial segmentation (Figure 3). The workflow operates as follows:

1. **Dimension detection**: Upon selecting a BIM model, sliders controlling the model's center and dimensions are initialized to a size that encompasses the model. This allows users to adjust the bounding box content more effectively, providing a good starting point for a user-defined box. Additionally, box validation ensures that the selected box remains within the valid BIM model boundaries.
2. **Clipping Logic**: During segmentation, the bounding boxes of model objects are compared against the user-defined bounding box from Step 1. Objects whose bounding boxes intersect with this user-defined bounding box are bisected to create a new truncated version of the object with its parents' name.
3. **Export**: All fully encompassed and truncated objects are selected and exported into a new file, either in the original format, a visualization format, or both.

This approach allows users to single out any given area they need to focus on.

C. Automatic Region Segmentation Based on Floor Plans

Bounding-box segmentation via floor plan is used to extract 3D model representations of spatial regions given 2D floor plan regions. The workflow operates as follows:

1. **Floor Plan Input**: Obtain the 2D floor plan scale and region dimensions in the database.
2. **Coordinate Mapping**: Scaled and projected the regions' 2D coordinates into 3D space using known floor plan parameters. Since the translation from 2D to 3D is missing the height dimension, we determine the height dynamically based on the height of the BIM model.
3. **Clipping Logic**: Applies the same clipping logic as used in the bounding-box segmentation method.
4. **Export**: All fully encompassed and truncated objects are selected and are exported into a new file of a visualization format.

This approach allows entire floors to be subdivided into regions that can be visualized and manipulated independently, enabling smooth and efficient visualization.

D. Recursive and Multipass Segmentation

Our pipeline supports multi-pass segmentation. For example, a floor may first be divided into specific components (e.g., "plumbing") and then into regions using bounding boxes. This layered approach allows for specific task targeting, such as isolating only plumbing systems in a specific room.

V. EVALUATION

We evaluated our system both qualitatively, through feedback from workers, and quantitatively, by testing segmentation accuracy and analyzing model performance.

A. Qualitative Evaluation

To assess usability and potential impact, we conducted on-site testing with a construction manager and trade workers. Although the models used were not specific to their buildings, the segmented AR visualization was fully functional and representative of the system's capabilities. The sample size was 10, consisting of one construction manager and 9 trade workers.

We collected feedback via structured questions; workers responded favorably to the following prompts:

- *"How much would the AR visualization of individual parts/segmentation of the 3D model help you understand the construction plan/schematics?"* ***(4.5/5)***
- *"How much would it help resolve potential issues that may not have been noticeable in the full model?"* ***(4.4/5)***
- *"Do you think this app will help resolve miscommunication between site workers and managers?"* ***100% of respondents answered yes.***
- *"Would this save you time compared to using 2D schematics**?" 100% of respondents answered yes.***

Responses were overwhelmingly positive, with workers expressing the AR feature added an intuitive, spatial understanding that was not present in 2D plans.

B. Segmentation Case Study

We tested our segmentation pipeline on real-world building BIM models provided by Nearabl. These models include detailed MEP (Mechanical, Electrical, and Plumbing) information and represent areas ranging from a single floor to six floors, with file sizes varying from 3MB to 32MB.

For smaller BIM models ranging from 3 MB to 7 MB (mean size: 5.09 MB), the average end-to-end processing time—including both segmentation and export—was **2.45 seconds (σ = 0.58 s) for bounding box segmentation** using user-defined regions via the web platform, and **2.33 seconds (σ = 0.30 s) for keyword-based segmentation** using user-selected keywords via web platform. The size of the resulting segmented models varied between 46 KB and 1.5 MB.

For larger BIM models ranging from 28 MB to 32 MB, the average end-to-end processing time was **9.56 seconds (σ = 4.75 s) for bounding box segmentation** and **10.13 seconds (σ = 4.65 s) for keyword-based segmentation**. Processing time for these larger models exhibited greater variability and was more sensitive to the segmentation criteria, as larger resulting segmented outputs tended to incur higher computational overhead. A detailed comparison of processing time versus resulting segmented model size—for both segmentation methods—is shown in Figure 5, specifically for original model sizes between 28 MB and 32 MB.

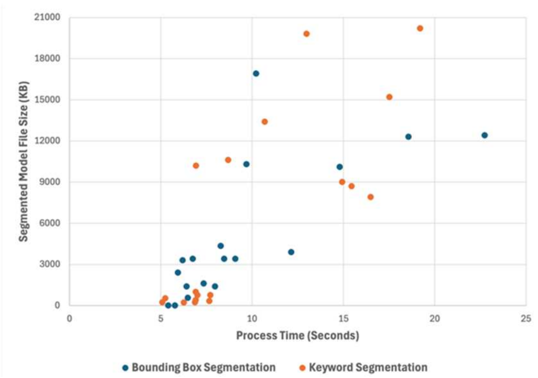

Figure 5. Processing time vs. segmented model size for bounding box and keyword-based segmentation on large BIM models.

TABLE I. COMPARISON OF ORIGINAL AND SEGMENTED MODEL SIZES

Model Type	Average Original Model Size (KB)	Average Segmented Model Size (KB)
Mechnical	334	22
Electrical	267	86
Plumbing	5166	2049

C. *Quantitative Performance*

While model segmentation varies based on user interaction and segmentation scope, we evaluated data reduction and portability by comparing the original model sizes with the segmented models generated through the automatic bounding-box segmentation workflow. For this experiment, we evaluated the workflow on six different floors, each containing separate mechanical, electrical and plumbing BIM models. Each floor was divided into four distinct regions. The system successfully segmented three separate models per region—corresponding to mechanical, electrical, and plumbing models—confirming the accuracy of region detection, mapping, and model export.

Our test validated the pipeline's ability to perform automated decomposition of BIM data based on floor plan geometry and produced visualization-ready segmentations.. The segmentation process reduced file sizes significantly, achieving a **93.5% reduction** in electrical models, **68% reduction** in mechanical models, and **60% reduction** in plumbing models. This corresponds to a weighted average compression ratio of **2.67x**, enabling faster loading and more efficient AR rendering on-site.

VI. CONCLUSIONS & FURTHER APPLICATIONS

This paper presents a segmentation and visualization pipeline designed to make BIMs more accessible for construction workers in mobile applications. By combining semantic (keyword) and spatial (bounding-box) segmentation methods, our system enables extraction of BIM components that can be visualized through a mobile AR.

Looking forward, we see several promising directions for future work:

- **Automated floor parsing**: Developing methods to automatically parse floors, not just regions within a floor.
- **Impact assessment**: Conducting user studies to measure improvements in task accuracy and error reduction.

This pipeline brings technical BIM models to practical usage. The system serves as a foundation for improving communication, productivity, and safety on construction sites. While also laying the groundwork for more adaptive and sophisticated AR workflows in the construction environment.

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