Create 3D Neighborhood model from 2D maps

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Abstract*—Urban planning and visualization are increasingly reliant on advanced technologies to provide comprehensive insights into the complexities of cityscapes. This research introduces an innovative approach to bridge the gap between conventional 2D maps and the intricate spatial realities of urban neighborhoods by creating detailed 3D models. The proposed methodology combines cutting-edge computer vision and 3D reconstruction techniques to extract essential features from 2D maps, including building footprints. By incorporating height information and architectural details, the method transforms flat representations into realistic 3D structures, offering a nuanced perspective on urban landscapes. The process encompasses the identification and classification of building types, the estimation of building heights, and the synthesis of intricate 3D geometry. This holistic approach enhances the visual fidelity of the resulting 3D neighborhoods, providing not only an immersive experience but also valuable insights into spatial layout and element distribution. Results from diverse datasets across various urban environments showcase the versatility and effectiveness of the proposed method. The generated 3D models serve as powerful aids in urban design, community engagement, and decision-making processes, ushering in a new era of spatial intelligence for urban planners and stakeholders.

***Keywords*— Urban Planning, 3D Reconstruction, Computer Vision, Edge Detection, Color Detection, Template Matching**

I. INTRODUCTION

Urban planning and analysis rely heavily on accurate information about the distribution, types, and characteristics of buildings within a city. The advent of digital mapping technologies has significantly advanced our ability to extract meaningful insights from urban landscapes. Sanborn maps, historically utilized for fire insurance purposes, provide detailed and comprehensive representations of urban areas, capturing building footprints and street layouts with high precision.

In this context, the research addresses the challenge of automating the recognition and analysis of buildings within Sanborn maps, aiming to contribute to the efficient extraction of urban information. The accurate identification of building types, estimation of stories, and understanding of spatial distribution play pivotal roles in urban planning, disaster response, and infrastructure development.

A. MOTIVATION

Sanborn maps, with their historical significance and detailed visual representation of urban areas, offer a wealth of information for urban planning professionals. However, the manual extraction of building-related information from these maps is labor-intensive and time-consuming. Automated methods are thus essential to streamline the process and provide timely, accurate, and actionable insights.

B. PROBLEM STATEMENT

The main challenge addressed in this paper is the automated recognition and analysis of buildings within Sanborn maps. The diverse architectural styles, varying scales, and intricate details depicted in these maps necessitate sophisticated computer vision techniques. The aim is to develop a robust methodology that not only identifies building footprints but also classifies building types, estimates the number of stories and provides a visual representation of the recognized structures.

C. OBJECTIVES

The primary objectives of our research are as follows:

1. Develop a template matching approach to identify building types (e.g., residential, commercial) and estimate the number of stories.
2. Incorporate color analysis to identify the dominant color of recognized buildings.
3. Generate 3D visualizations to enhance the interpretability of the results.

D. CONTRIBUTION

The proposed methodology contributes to the field of urban analysis by providing an automated and scalable solution for building recognition in Sanborn maps. By integrating computer vision techniques with color analysis and 3D visualization, the paper aims to facilitate urban planning, historical preservation, and disaster response efforts.

E. STRUCTURE OF THE PAPER

The remainder of this paper is organized as follows: Section II reviews related work in the fields of computer vision, urban analysis, and building recognition. Section III details the proposed methodology, outlining the steps taken to achieve automated building recognition. Section IV presents experimental results and discussions, while Section V concludes the paper and discusses future avenues for research.

II. RELATED WORK

A. A Novel Approach for Generation and Visualization of Virtual 3D City Model Using Open Source Libraries

The literary work under discussion presents an economical method for creating virtual three-dimensional city models from Indian remote sensing information. The authors created custom procedures and made use of open-source libraries in place of proprietary software. Preparing high-resolution satellite imagery and the DEM, resampling datasets, registering pictures and vector layers, and extracting height data are all steps in the workflow. By including virtual trees, taking into account the location of the sun, day and night effects, and ambient conditions, and adding textures to the buildings, realism is increased. A tiling-based method combined with the Open Scene Graph framework yields efficient visualization. Any region with access to imagery, OSM data, and a DEM may use this method. The merits of the suggested technique are emphasized in the research, along with its particular relevance to Indian remote sensing datasets and cost-effectiveness.

B. 3DPlanNet: Generating 3D Models from 2D Floor Plan Images Using Ensemble Method

The challenge of converting 2D raster graphics into 3D vector data, which has a long history in pattern recognition, is the main emphasis of the study reported. While deep learning has been included in modern methodologies, they have generally needed enormous datasets, in contrast to prior heuristic and rule-based methods. Using a limited dataset of 30-floor plan photos, the researchers in this work proposed 3DPlanNet Ensemble techniques, which combine rule-based heuristics to handle these issues. Similar to research using bigger datasets, the experimental findings showed great accuracy in wall and object detection. The technique also produced 110,000 examples with a wall accuracy of 95% or above, thereby converting 2D graphics into precise 3D vector data. This work provides a useful approach to 2D-to-3D conversion, demonstrating its efficacy even with a small amount of training data.

C. Creating building-level, three-dimensional digital models of historic urban neighborhoods from Sanborn Fire Insurance maps using machine learning

The paper addresses the challenge of extracting building-level information from Sanborn Fire Insurance maps. These maps offer in-depth perspectives on urban landscapes, which are essential for researching changes throughout time, including those brought about by 20th-century urban highway development and revitalization initiatives. The study presents a scalable methodology for the identification of building footprints and related features on Sanborn maps using machine learning. This enables efficient 3D visualization of ancient urban neighborhoods and provides insights into urban transformations. The study focuses on two neighborhoods in Columbus, Ohio, USA that were split in half during the 1960s due to highway construction. An F-1 score of 0.9 for building footprints and construction materials quantitatively indicates that the approach extracts building-level information with good accuracy. The mathematical results are complemented by visual analysis, and the authors demonstrate how their techniques have been applied to visualize neighborhoods, providing a thorough comprehension of past urban environments. The work advances computational techniques for deriving significant information from old maps, providing important new perspectives on the evolution of urban development.

D. Generation of 3D Building Models from City Area Maps

The work presents a unique pipeline that uses the CityGML LOD1 standard to translate building descriptions from city area maps into 3D models. The input data is made up of long-term, scanned city area maps that were given by the local government. The pipeline tackles issues including different handwriting, diverse layouts, poor contrast, damages, and artifacts from scanning. Its capacity to meet these obstacles with effectiveness is the main novelty. In this three-step process, text boxes on the maps are identified and analyzed to obtain building information. Based on this information, building forms are taken from an online city map API, and the resulting 3D models are created utilizing the height information and the derived shapes. This methodology has the potential to make a substantial contribution to the fields of urban modeling and analysis by offering a standardized 3D representation of historical and different city area maps.

III. PROPOSED METHOD

In this section, the author presents the proposed methodology for building recognition in urban environments utilizing template matching, color analysis, and 3D visualization techniques. The pipeline is shown in Figure 1.

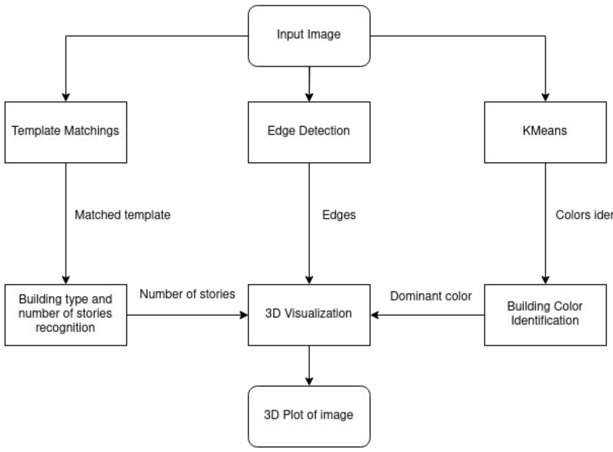

Figure 1: Proposed Pipeline

a) Template Matching for Building Type and Number of Stories Recognition

The approach incorporates template matching, a widely used computer vision technique, to identify buildings within an urban scene. Given a main image and a set of template images representing different building types, we employ the `cv2.matchTemplate` function from the OpenCV library. This technique allows us to detect regions in the main image that closely resemble the provided templates.

The matching threshold is carefully selected to ensure robust recognition and is set to 0.8 in the experiments. The output of this stage provides labeled regions corresponding to identified building types.

Following template matching, we extract labels from the matched regions. These labels are then analyzed to determine the specific instances of building types present in the scene. We employ a label parsing mechanism to extract relevant information about each instance.

The instances extracted from labels are further processed to identify the building type and estimate the number of stories. This information is crucial for urban planning and analysis. The method classifies buildings into types such as residential (D), commercial (F), and automotive structures.

b) Building Color Identification

Color analysis is integrated into our methodology to identify the dominant color of the buildings in the main image. Utilizing the LAB color space and KMeans clustering, we identify the cluster center closest to pure yellow, assuming it is the dominant color of the building.

c) 3D Visualization

To enhance the interpretability of our results, we generate a 3D visualization of the identified buildings. This includes top and diagonal views, providing spatial context and emphasizing the recognized building type and color. The resulting visualizations aid urban planners and researchers in understanding the distribution and characteristics of buildings within the scene.

The proposed methodology integrates these components to provide a comprehensive and interpretable solution for building recognition in urban environments.

IV. RESULTS

In this section, we present the results obtained through the application of our proposed methodology to Sanborn maps. The evaluation encompasses building recognition accuracy, classification performance, and the visual representation of the recognized structures.

a) Dataset

Our experiments utilized a diverse dataset of Sanborn maps collected from https://www.loc.gov/collections/sanborn-maps/about-this-collection/. The dataset includes maps from various urban areas, capturing a wide range of architectural styles, building sizes, and environmental conditions. The templates of building attributes like building type, and number of stories are extracted from various maps. These templates are used during template matching. The sample templates and input neighborhood are shown Figure 2 and Figure 3

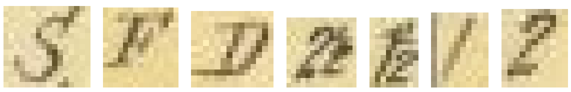

Figure 2: Sample Templates

Figure 3: Sample map of the neighborhood

b) Building Type and Stories Estimation

The methodology aimed to estimate the number of stories for each recognized building. Here the templates from the dataset are iterated over the main image using the template matching function presented by the OpenCV library. A match is found only when the identification is above the threshold of 80%. The sample output of extracted values is the bounding box as shown in the Figure.

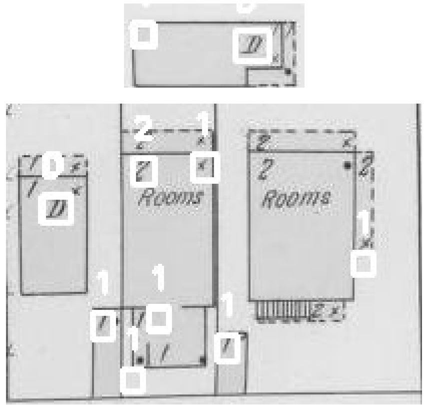

Figure 4: Building Type and Stories estimated by using Template Matching

c) Color Identification

The color analysis component of our methodology identified the dominant color of recognized buildings. The color palette is generated after running the Kmeans clustering algorithm. The identified color is only passed in the next step of 3D visualization. As shown in the figure, the Kmeans algorithm takes the 3 dominant colors present based on the assumption that the most dominant color is yellow as shown in the sample map of the neighborhood.

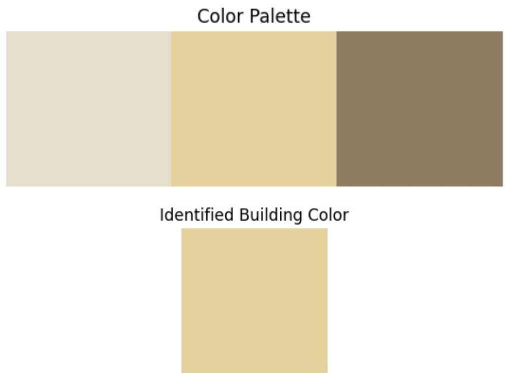

Figure 5: Color recognized using Kmeans classifier

d) 3D Visualization

To enhance the interpretability of the results, we generated 3D visualizations of the recognized buildings. The visualization is achieved by using the mpl_toolkits library from matplotlib. The mplot3d toolkit adds simple 3D plotting capabilities (scatter, surface, line, mesh, etc.) to Matplotlib by supplying an Axes object that can create a 2D projection of a 3D scene.

The resulting graph will have the same look and feel as regular 2D plots. These visualizations provide insights into the spatial distribution, building types, and dominant colors within the urban landscape.

Figure 6: Sample building layout

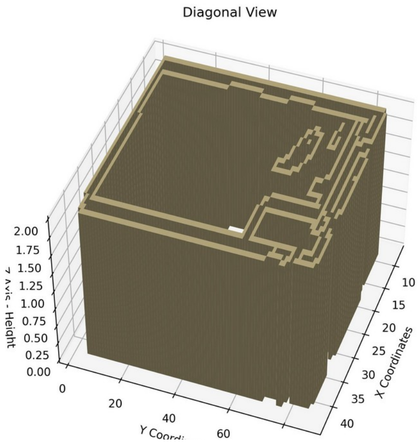

Figure 7: Building representation in 3D

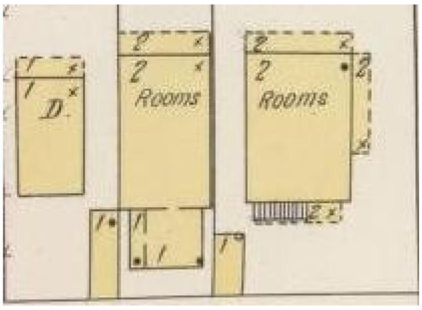

Figure 8: Small neighborhood in 2D map

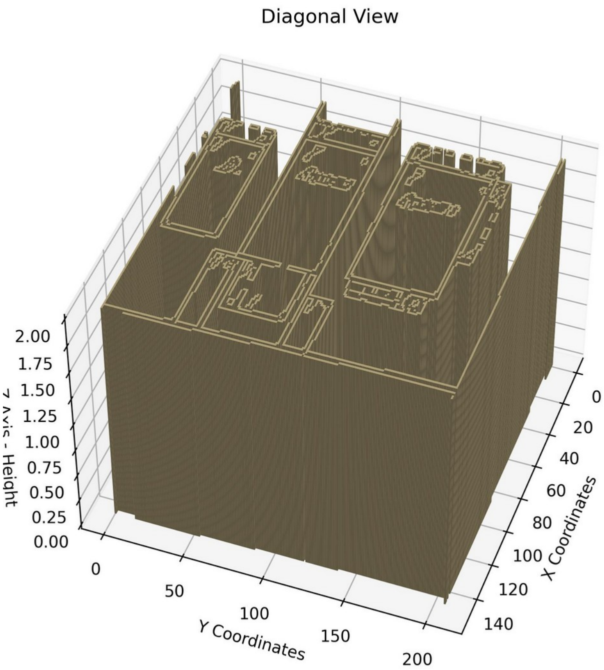

Figure 9: Small neighborhood representation in 3D

V. FUTURE WORK

The research provided an innovative methodology, that can be implemented to generate 3D models of buildings and neighborhoods from a given 2D Sanborn map. However, there are some limitations when using the approach:

1. The building level footprint identification has not been achieved, as the edges detected included lines of the plot containing the building.
2. The templates used during the matching operation were very small and the accuracy dropped as the size of the neighborhood map increased.
3. The color analysis only identified the dominant color present throughout the neighborhood. This method suppressed any other color present on the building when plotting in 3D
4. The height estimation was applied uniformly throughout the 3D model after extraction.

These limitations would be addressed with better image processing and computer vision algorithms. Overall, the method uses simple image processing and computer vision techniques to achieve a precise 3D model of the given 2D Sanborn map.

CONCLUSION

In conclusion, the research introduces an innovative methodology that leverages cutting-edge computer vision and 3D reconstruction techniques to bridge the gap between traditional 2D maps and the intricate spatial realities of urban neighborhoods. By transforming flat representations into detailed 3D models, we enhance the visual fidelity of urban landscapes, offering a nuanced perspective crucial for urban planning and analysis. The proposed approach not only identifies building footprints but also classifies building types, estimates the number of stories, and incorporates color analysis for a comprehensive understanding of the built environment.

The results obtained from diverse datasets demonstrate the versatility and effectiveness of our method across various urban environments. The 3D neighborhood models generated not only provide an immersive experience but also offer valuable insights into spatial layout and element distribution. This research significantly contributes to the advancement of urban visualization tools, providing a transformative solution for informed decision-making in urban design, environmental analysis, and virtual city exploration.

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