A Virtual Reality Environment (VRE) for Zoning Ordinance in Google Street View

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Abstract
Zoning ordinance plays an essential role in city planning and management. It sets rules that regulate land use based on geographical zones to protect the public welfare and the environment. Many stakeholders benefit from studies of zoning ordinances. However, zoning studies on a particular parcel could be specific, complex, and time-consuming. This paper develops an image-based virtual reality environment (VRE) on top of google street view to visualize zoning ordinance on the parcel level. The development process of VRE includes three main steps. First, zoning data are collected, analyzed, and preprocessed on the parcel level. Typical data sources include local zoning maps and zoning codes. Second, the zoning rules are examined on a parcel-by-parcel basis. Third, examined rules are visualized in Google Street View. In this step, Google Map JavaScript API is adopted. Codes for visualization are written in JavaScript in the online IDE JSFiddle. Throughout the process, 17 parcels are selected to demonstrate the visualization effects. They are located in the Residential and Commercial zoning district in the City of Columbus, Ohio, USA. The proposed VRE could serve as visual assistance for decision-makers in city planning and management.

Keywords: Zoning, Virtual Reality, Urban Planning, Smart City, Digital Twin

1 Introduction

1.1 Background

The zoning ordinance is a set of rules that defines the land use regulations. In the United States, every major city, except Houston, has established and adopted a comprehensive zoning ordinance since its first approval in New York City in 1916. In 1926, the U.S. Department of Commerce set a template guide, which boosted adoptions of the body of zoning ordinance ("Zoning and the Economic Geography of Cities (Book, 2016) [WorldCat.Org]," n.d.). Starting from its advent, zoning ordinance has experienced dynamic growth and has evolved with variations by jurisdictions and conditions. The regulations defined in the zoning ordinance take responsibility in responding to the social and economic needs and subject to up-to-date amendments based on local requirements (Swan, 1949).

The main purpose of zoning is to regulate land use and to prevent incompatibility as urban growth progresses. Commonly, local governments enact zoning codes to preserve and promote public health, safety, and welfare by determining land activities within the boundary of a particular property. Through these regulations, the objectives of establishing zoning ordinance could be achieved, such as to encourage orderly growth, to provide for agreeable natural resources such as light and air, to protect against natural hazards such as flood, and to increase

the value of buildings, etc. ("Chapter 3301 - PURPOSE AND SCOPE* | Code of Ordinances | Columbus, OH | Municode Library," n.d.). Land-related activities dictated by zoning code may include limit of building heights, building locations (building setback), minimum parking numbers, parking locations (parking setback), lot pervious ratio (acceptable percentage of open space on a lot), location of the entrance, etc. The details are subject to local municipality and relevant laws imposed on the property. In conclusion, zoning ordinance is a comprehensive city management tool in urban planning and development.

To ensure compliance with the zoning ordinance, due diligence regarding zoning and land use has become an important consideration for real estate transactions and development, especially the commercial sector. The reason is that zoning ordinance dictates how a property could be constructed and used. Thus, it determines the expected risk and reward of an investment within the scope of a legal framework ("Zoning Due Diligence and the Real Estate Industry," n.d.). In practice, Technical Due Diligence (TDD) is widely adopted for zoning analysis. A thorough TDD report is usually prepared and delivered to the client for decision-making purposes. The TDD report specifies the set of rules, requirements, and recommended practices of the property referring to both the constructed structure and the lot (Kutera & Anysz, 2016).

Many stakeholders in urban planning and real estate development would refer to the zoning ordinance to perform their work. They are identified as the owner, business consultants (lender, banker, finance officer, insurers, etc.), technical consultants (architect, design engineer, surveyor, etc.), construction manager, inspectors, city planners, government agencies, and land use lawyers, etc.

1.2 Challenges

Since TDD is very important in decision-making for many stakeholders, an accurate and in-time zoning study would bring great value to the industry. However, due to the complexity of the zoning ordinance, three (3) main challenges are identified below in conducting zoning research.

Zoning study is complicated, time-consuming, and tedious. Properties are located in various jurisdictions, subject to a different body of zoning ordinance, having unique natural conditions, development histories, or legal documents. As a result, no general solution exists for each property, even though they may share some common characters. Analysts have to conduct zoning study on a case-by-case basis.

Zoning study need inputs from various sources. Sources of information for zoning study may include zoning code, zoning map, legal adjustment like appeals and variance, detailed drawings of existing structures, development histories, land title documents, existing permits, etc. Due to the volume of available data sources, completing a thorough analysis can be difficult in a short time, which is often required by the client. Besides, information of heterogeneous format may lead to a high risk of mistakes, then cause project delays and financial loss.

Zoning Code is not straightforward for reading and communication. Stakeholders in zoning studies are spread in a wide variety of industries, occupations, and geolocations. They may have different terms and customs in communication, which may lead to misunderstandings or difficulties in communication of zoning requirements regarding a particular property (Qin, 2013). Consequently, the accuracy or timeline of the TDD process would be affected.

1.3 Needs and Significance of the Study

In response to the challenges above, a cinematic virtual reality environment is proposed to visualize zoning rules at parcel level. This study has selected 17 parcels from the City of Columbus in Ohio, among which 7 parcels are located in the commercial zoning district (C) and 10 parcels are from the residential zoning district (R). Specific zoning rules within the scope of the study include building setback, building height, parking setback, land use, etc. This study has investigated and summarized these rules on a parcel-by-parcel basis by referring to available zoning documents, then creating a visual assembly of the identified rules and the parcels in a virtual environment.

Through investigation and visualization of existing zoning rules, this study makes it possible for stakeholders to read zoning requirements at parcel level in a fast and straightforward way.

Instead of examining huge amounts of texts from zoning documents, it is time-saving and effort-saving for industry practitioners in obtaining and analyzing complex zoning information in a short period. For those who are lacking of a knowledge background of zoning, its visualized effects would facilitate understanding and communication. Also, smooth communication with visual aids would be helpful in the review process of zoning application.

2 Literature Review

2.1 Zoning Compliance Process in Practice

In empirical real estate development, zoning regulations are usually achieved through a permitting process. In the City of Columbus, the developer must prepare zoning compliance documents regarding their project to apply for a Certificate of Zoning Clearance before they are allowed to perform any exterior construction work. The Certificate of Zoning Clearance is issued by the Director of the Department of Building and Zoning Services or his/her designee. With the receipt of the application, the Director would review to determine its conformity of the Zoning Code, or as permitted of any variance, rezoning, waivers, or appeals. Once the certificate of zoning clearance is issued, any construction work outside of the scope would be deemed as a violation and subject to penalties or voidance of the certificate ("Chapter 3305 - ZONING ADMINISTRATION, ENFORCEMENT AND PENALTIES | Code of Ordinances | Columbus, OH | Municode Library," n.d.).

In response to the zoning enforcement process and ensure compliance, the developer would hire consulting agencies to do a thorough study of existing zoning documents. Afterwards, the design consultants would incorporate the study result to perform their responsibilities. The deliverable is usually to be a zoning compliance plan shared among all stakeholders, and be further referred to in the inspection phase when the construction is completed. In the City of Columbus, the workflow of zoning study in practice is summarized below:

- **Collect site information.** Site information is critical in deciding the applicable zoning rules. Typical site information includes address, geolocation, site geometry and dimensions, existing structures, adjacent property, adjacent road info, regional environmental conditions, etc.
- **Study zoning map and code.** With site information available, it is possible to enter into the general zoning code and follow the guidelines specified to determine applicable rules. Further information regarding the site in consideration could be decided at this stage, such as zoning district, building setback, parking setback, height limit, lot coverage, building areas, parking numbers, etc. Constraints identified at this stage are important to perform design works.
- **Investigate special documents.** Since zoning code is a general guidance for land use. Special documents regarding the characteristics and development history of a particular site may be issued. Details inside may dictate different zoning requirements other than the general code. Where there is a conflict, the special document is usually taking precedence. Therefore, it is a must to incorporate special documents into zoning studies.
- **Prepare design and application documents**. The applicant of the Certificate of zoning clearance must follow the required format and process to show that the proposed construction work is under zoning compliance.

2.2 Review of VR techniques in City Planning and Land Use

Virtual Reality (VR) is a technique to allow users to interact with the environment by creating a virtual world with computers. Users can view and control virtual objects within the environment (Cruz-Neira, 1993). It could be used in the field of urban planning (Zhang & Moore, 2013). Traditional VR environment employs 3D models and rendering in a real-time manner. However, the 3D modeling process could be laborious and demands high-quality computer hardware to realize real-time renderings (Cai et al., 1998). Instead, image-based VR technique overcomes the limitations of the traditional heavy-duty 3D environment. Thus, it is adopted in this research.

Many products are providing image-based VR environments that are widely used in urban planning and land use. For example, Google Street View enables interactive panoramas from stitched VR photographs ("Google Street View," 2021). It serves as the first option for industry practitioners to solicit environmental information. For now, Google Earth VR has already incorporated Street View features of major streets in 85 countries around the world ("Google Earth VR Adds Street View Feature | Architect Magazine," n.d.). With the support of wearable headsets, users can experience an immersive virtual feeling of the built environment. Besides products from Google, there are many other providers that offer image-based virtual environments with advanced services. For instance, Esri has developed the ArcGIS 360 VR (3VR) format to publish available panoramas into the CityEngine scene. With the consumption of panoramic images, users can take a series of viewport snapshots of the city through browsers, mobile devices, and VR headsets ("ArcGIS 360 VR Experience—ArcGIS CityEngine Resources | Documentation," n.d.). This research would visualize zoning rules on top of Google Street View with consideration of its extensive use and easy access.

2.3 Review applicable services in Google Maps JavaScript API

Google Map JavaScript API allows users to get access and customize the map ("Overview | Maps JavaScript API | Google Developers," n.d.). Two services from it are used in this study, which is the Geocoding service and the Street View service. The Geocoding service can convert the address of property into geographic coordinates, such as longitude and latitude ("Overview | Geocoding API | Google Developers," n.d.). Through conversion, it enables the translation of human-readable addresses into geolocations of the property on google map. Thus, end-users can locate the property of interest in Google Maps by inputting an address. The Street View service offers a panoramic view of a position on the street. End-users could interact around with panorama from the browser at the address they input. ("Street View Service | Maps JavaScript API | Google Developers," n.d.). In conclusion, visualizing zoning rules could be achieved through services from Google Maps JavaScript API.

3 Methodology

There are three steps to achieve the goal of creating a VRE of zoning ordinance. First, zoning data are collected, analyzed, and preprocessed on the parcel level. Second, zoning rules are examined on a parcel-by-parcel basis. Third, visualize zoning rules in Google Street View. They are further explained below.

3.1 Data Source

A total of 17 parcels are selected along Bethel Rd. in the City of Columbus. Parcel information and their associated zoning requirements are further investigated by the author. Regarding data sources, parcel information is from the City of Columbus Online Zoning Map and the Franklin County Auditor's Website. Zoning requirements within scope are from Title 33 of the Code of Ordinance in Columbus, Ohio. Under Title 33, Chapter 3351 is visited to determine zoning rules for parcels in Commercial (C) district, and Chapter 3332 serves as the primary reference for parcels in a Residential (R) district. As guided by Title 33, road information is required to make decisions. Within the context of this study, road information is from Columbus Thoroughfare Plan (CTP) and Columbus Comprehensive Plan (Lashutka et al., n.d.).

3.2 Zoning Ordinance Analysis

Variables regarding zoning ordinance fall into two categories, which are parcel variables and associated zoning variables. Parcel variables include Parcel ID, address, lot location, lot dimensions (length and width), adjacent road information (road type and right-of-way), zoning district, etc. Zoning variables are further investigated from both parcel variables and the zoning codes. The variables include building setback, parking setback, building height limit, and land use type.

After analyzing zoning ordinance on a parcel-by-parcel basis, full variables and data are summarized in excel. Parcel variables and zoning variables are matched together. In order to be

readable in JavaScript, summarized data is further converted into a standalone txt file acting as the parcel dictionary. It would serve as input for the visualization process described in 3.3.

3.3 Visualization process

With readable parcel and zoning data available, the visualization of zoning ordinance at parcel level can be achieved with four main steps (Figure 1).

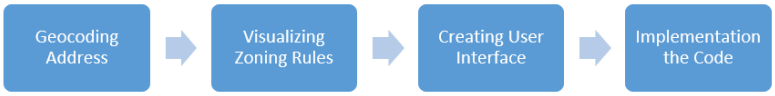

Figure 1. Four steps to realize visualization of zoning ordinance

- **Step 1: Geocoding addresses.** The purpose of this step is to convert addresses to geological coordinates, including longitudes and latitudes. With coordinates available, it is possible to locate the parcel in Street View. This process needs a Geocode API Key and the input of addresses. The output would be coordinates saved in JSON or XML format.
- **Step 2: Visualizing zoning rules.** With the online IDE JSFiddle, visualized could be achieved by creating a zoning overlay on top of Google Street View. Coordinates from the first step are used to locate parcels. Variables identified in 3.2 serve as the data source on the display of visualization effects and a zoning information dashboard.
- **Step 3: Creating a user interface.** Create a textbox to receive the user's input. The input is expected to be addresses that are captured in the database.
- **Step 4: Implementing the code.** Test the code by inputting the address of the parcel. The output would take the user to the street view of the parcel with an overlay of its zoning rules. Figure 2 is a demonstration of the visualization result in JSFiddle.

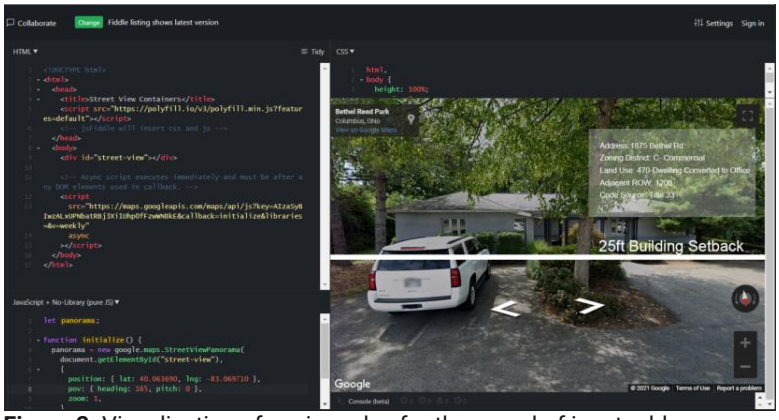

Figure 2. Visualization of zoning rules for the parcel of input address

4 Discussion

The VRE presented in this article has visualized the common variables in zoning regulations at the parcel level. The interface has provided virtual access to locate the parcel of interest with the display of associated zoning rules. It allows users to interact with the virtual environment to obtain zoning information. The tool could shorten the TDD process and with integrated data and increased accuracy. In addition, stakeholders with different knowledge backgrounds could have better communication experiences with visual aids.

However, there are a few limitations observed from this study. First of all, visualization of zoning rules in Panorama does not reflect accurate dimensions. Second, sampled parcels in this

study are limited, rather than full coverage of all types of zoning districts. Third, the zoning rule in this study only reflects general zoning codes, not including zoning variance, rezoning, zoning waiver, or other legal documents.

5 Conclusion

This study has explored the use of image-based VR technology to visualize zoning rules. With 17 parcels in the City of Columbus as examples, the study has examined the zoning compliance process, developed database conversion, and investigated visualization of zoning rules in Google Street View. A workflow with applicable tools in creating the VRE has been demonstrated. It has the potentials to be scaled up to extensive properties besides the variables within the scope. Also, the workflow could serve as a basis to be further adjusted for other municipalities.

Inputting forward the application of VRE in zoning studies, possible future works are recommended below.

- Development of 3D VRE.
- Auto-extraction of zoning rules.
- Auto-checking of zoning compliance and violations.
- connecting into smart city platforms.
- Scalability of use in other municipalities.
- Connection to smart city platforms

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