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3D Data Visualization and Analysis Tools for AI Ready City: Space Syntax and Social Media Data

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ABSTRACT

Space syntax is now widely accepted as a set of techniques that can be used to efficiently analyze spatial morphological structure at the city or community level. Segment analysis, a type of space syntax that is typically rendered through two-dimensional vector lines, can show the effectiveness of pedestrian and vehicular accesses to parts of a city. However, analysis of a city's condition is far too diverse and complex for the use of space syntax alone. Other types of information, such as data from social media, can be integrated to determine and locate problems in the city, or to search for areas with potential for development. These types of data help in analyzing the quality of experience for those using the urban spaces, and they can be obtained by compiling the judgements of actual city dwellers, or by using advanced technologies to create a more realistic virtual reality and letting system users be the judges. The purpose of this research is to develop a 3D model and a virtual reality system capable of displaying the results of 3D urban morphological analysis, using space syntax segment analysis and social media data from urban space users to support the collaboration and communication among architects, designers, urban planners, city policy makers, or other city stakeholders. The virtual 3D model was created by using photogrammetry from aerial photographs, as well as a low polygon model built with referenced data from the photogrammetry model for faster rendering. The area of Thammasat University, Rangsit Center, was used as the prototype area for the AI Ready City.

Keywords: AI ready city, virtual reality, data visualization, data analysis

INTRODUCTION

In preparing to develop an AI Ready City, it is necessary to take various important factors into account. One aspect, for example, is managing and displaying the massive amounts of data that are generated at all times in every step of the procedure. These data are produced from diverse sources, and are standardized, stored, modified, presented and used as a guideline to support policy decisions made by city administrators. Nowadays, new data sources are playing an increasingly important role in the management of cities; such data is collected from various sensor devices, or even social media. This is big data, generated in real-time by a large number of users within the system. This type of data can be used in city management to analyze problems in a timely manner, sometimes even as they occur. Of course, new theories in urban analysis, such as space syntax analysis, are also being applied. Space syntax is now widely accepted as a set of techniques that can be used to efficiently analyze spatial morphological structure at the city or community level. Segment analysis, a type of space syntax that is typically rendered through two-dimensional vector lines, can show the effectiveness of pedestrian and vehicular accesses to parts of a city.

However, the analysis of a city’s condition is far too diverse and complex to be interpreted through the use of space syntax alone. Other types of information, such as data from social media, can be integrated to determine and locate problems in the city, or to search for areas with potential for development. These types of data help in analyzing the quality of experience for those using the urban spaces, and they can be obtained by compiling the judgements of actual city dwellers, or by using advanced technologies to create a more realistic virtual reality and letting system users be the judges. Making use of such complex layers of data relies on highly efficient data visualization. The advancement of 3D technologies, such as virtual reality, allows data presentation processes to transcend past boundaries in the capability to perceive and analyze city data.

The purpose of this research is to develop a 3D model and a virtual reality system capable of displaying the results of 3D urban morphological analysis, using space syntax segment analysis and social media data from urban space users to support the collaboration and communication among architects, designers, urban planners, city policy makers, or other city stakeholders. The area of Thammasat University, Rangsit Center, was used as the prototype area for the AI Ready City.

- To study the concepts and theories related to developing a 3D modeling and virtual reality system.
- To design and develop a 3D data analysis and virtual reality system for representing data from AI ready cities.

A Site for AI Ready City

Thammasat University, Rangsit Center, currently comprises an area of 2.81 sq.km., located in Khlong Luang District, Pathum Thani Province, Thailand. It is an area where people in the Thammasat community -- students and faculty members from various fields of art and science -- exchange knowledge. There are 25,000 students and 5,000 staff members. Thammasat University has developed a long-term master plan of Rangsit Center for 2034 (100 years Thammasat) with the Faculty of Architecture and Planning as the study operator. The objective is to solve problems involving the physical environment, which includes the lack of community centers and ambiguity in communicating Thammasat's identity, and to determine the direction of sustainable development, with a plan to support development with the principle of balance between development and conservation of the environment according to the concept of “Sustainable Campus Town”. In this regard, the Master Plan of Thammasat University, Rangsit Center, 2034, defines the usage characteristics of different areas within the Rangsit Center into 8 zones, namely central administration area, education areas, recreation areas, environmental conservation and learning areas, residential areas, academic and social service areas, creative economy promotion areas, and utility areas (Figure 1).

Figure 1

The Area Division of Thammasat University, Rangsit Center, 2034 (100 Years Thammasat)

Note. Adapted from "The Development of Thammasat University Rangsit Center 2034: Final Report" by Center of Innovative Design and Research, 2014, 10. https://planning.tu.ac.th/uploads/planning/pdf/Place/07092561/Re20180819_2.pdf. Copyright 2014 by CIDAR.

LITERATURE REVIEW

Data Acquisition and Architectural surveys with Aerial Photogrammetry

The current advancement of technology and techniques for architectural surveying and physical data collection have evolved considerably in terms of efficiency, convenience, speed, accuracy, and ability to represent realistic building conditions (Barber et al., 2001). One of the techniques widely used today is photogrammetry, which is the process of recording, measurement and interpretation of objects that appear on photographs through advanced geometric calculations. The photogrammetry process used in today digital photography is recognized as being able to collect valuable building information because the process works easily, quickly, and cost effectively. The photogrammetry processes consist of identifying the same elements in different photos (feature recognition), calculating the position and direction of the viewing angle in 3D space (camera calibration), (Debevec et al., 1996; Hartley & Zisserman, 2004), automatically modeling from reference points (image-based meshing), and modeling surfaces by projecting images from a calculated perspective into the model (Texture Projection) (Fitzner & Heinrichs, 2002).

Space Syntax

Space Syntax is a tool for studying the morphological structure of a city area, or urban morphology, including geographic features and changes in the shape and form of cities. Space Syntax applies theories to analyze the relationships between people and space (Hillier & Hanson, 1984) based on the structure of various types of buildings, cities, terrain and the connectivity between the area and circulation routes. People move and adapt to the condition of space, and each space has its pathways connecting to other areas; the study of the structure that comprises these spaces and their connections reveals underlying social implications within the city and community (Bafna, 2003). Analysis of the relationships in the continuous spatial network consists of:

- Axial analysis, which is a fundamental analysis of the traffic network. The parameters of the analysis include: total depth, indicating how many roads are connected to the other in the next sequence; connectivity, indicating how many roads are directly connected to another road; choice, indicating the ability to act as a passage to other routes, and integration, indicating the connectedness of the road lines or efficiency of access, etc.

- Segment analysis, which is developed by subjecting the results obtained from the axial analysis to further examination. The main parts of the analysis are NAIN (normalized angular integration), which is used to measure the value of being the city center, and NACH (normalized angular choice), which is used to show that the circulation routes are likely to be passed or have the potential to be easily accessible from other routes. These indicators can be read through color spectrum - warm tones representing high value, high accessibility, or connectivity to other routes, and the descending colors in cooler tones representing lower values, difficult levels of accessibility, or little connectivity to other routes.

Reality-based 3D Modeling

Reality-based 3D Modeling is a significant tool for collecting the present state of buildings for further analysis. It is also used as an important component of interesting media presentations to communicate with the general public, because three-dimensional data can represent clearer perspectives for better understanding of shape and space than two-dimensional images. It is also easy to edit or update the model, and it can be easily used for online collaboration. The point cloud-based 3D modeling process resulting from the use of 3D scanners and photogrammetry technology can be divided into 2 types.

1. Automated modeling from point clouds generate the model form by calculating neighborhood points and creating polygons from triangulation (Edelsbrunner, 2001). The point cloud can be obtained from either 3D scanners or from photogrammetry processes. The process should include point cloud sampling to eliminate unwanted points before proceeding further (Frey et al., 1994).

2. Modeling shapes and forms with a CAD (Computer-aided design) system by utilizing spatial data and the measurable data of a point cloud as reference. There are several ways to manage the point cloud before using it further as a reference, such as sampling for fewer points (Smith & Sritharan, 1988), or by filtering point clouds that are corners and edges of buildings by using an algorithm that calculates discontinuity on point surfaces or planes of points (García-Cortés et al., 2012). This modeling process can be done with most common 3D applications on the market by converting point cloud files into standard 3D files to be applicable in other 3D modeling programs.

3D Architectural Visualization Methods

Two-dimensional presentation media have limitations in representing the physical spaces of buildings, while three-dimensional presentations can enrich the perception of space. Nowadays, designers need a design tool or digital media that can effectively present 3D designs (Campbell & Wells, 1994). In addition to 3D animation in architectural presentations, virtual reality is another technology that plays an important role by creating a virtual environment that feels realistic to the users. The realistic perception occurs when the five senses are involved, especially visual and auditorial senses. The use of VR technology enhances the perceived experience of the architectural model by, for example, helping the users to better perceive the size of the space, better understand design details, and better see the design work from every point of view. In the past, the potential of VR technology was limited due to the requirement for powerful computer resources for real-time rendering and interaction. However, recent developments in information technology, both in software and hardware, are gradually reducing these limitations. Building 3D rendering via 5G systems allows designers to enjoy easier collaboration in the virtual environment.

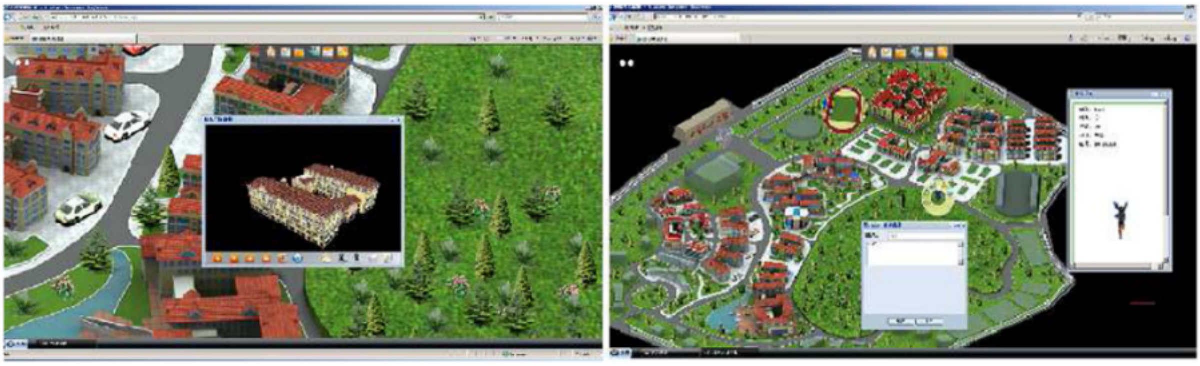
Data Visualization for Spatial Analysis

One of the most common tools being used for spatial morphological analysis is GIS (Geographic Information System), which is a computer-aided system for processing spatial-related data. Correlation of the data set is presented in table styles. All data correlation patterns can be analyzed to determine trends, or to predict future occurrences. Although studies that utilize GIS are widespread, it has been shown that two-dimensional map formats cannot accurately represent multidimensional spatial phenomena that are constantly changing. However, the representation of geodata or geographic information systems with VR technology offers a solution to these problems (Jiangfan, 2013). Numerous studies have focused on this process, such as a study by Bilke et al. (2014) that developed a system for analyzing disaster patterns using a back projection-based system in VR technology. The system can offer insight into disaster patterns ranging from analysis of floods to seismic data. Research by Cerfontaine et al. (2016) shows a system representing in-depth geospatial data through virtual reality space, with which users can interact in real-time. Another example from WebVRGIS developed by Lv et al. (2016) utilizes VR for data analysis in smart cities (Figure 2). Users can manage and interact with various databases. The system has been developed in several presentation formats such as WebVR (web virtual reality), 3D geographic information systems (3-DGIS), rendering with peer-to-peer (P2P) networks, etc.

Presently, unprecedented massive amounts of data are being produced continuously. One of the key factors prompting increases in the use and production of data is the popularity of social media. A number of researchers have focused on the development of information display systems for data from social media in conjunction with geographic information systems. For examples, research by Kádár and Gede (2013), studied tourist behavior using geolocation data from tourist photos uploaded on social media to measure the amount of tourist activity occurring in the city area. Research by Mao (2015) used YFCC100M (100m yahoo Flickr Creative Commons 2014) data to find the most visited places by observing the time and the location that the photos were taken to recognize the changing behaviors in photography trends. A study by Andrade and Schieck (2014) investigated the integration of social media data with space syntax analysis, with the goal of using it as a system to calculate traffic route options for vehicles.

Figure 2

An Example of WebVRGIS Interface Representing a Virtual Environment of a Smart City.



Note. From "Virtual Reality Smart City Based on WebVRGIS." by Lv, Z., Yin, T., Zhang, X., Song, H., and Chen, G., 2016, IEEE Internet of Things Journal, 3(6), 1021. https://doi.org/10.1109/JIOT.2016.2546307. Copyright 2016 by IEEE.

METHODOLOGY

Scope of research tools

The scope of research tools for representing all collected information and interactive media in 3D virtual reality environment consists of a set of personal computers for data processing and display via computer monitors and a head-mounted display (HMD) set.

Scope of research data

The scope of research consists of physical data from the area of Thammasat University, Rangsit Center, and data from space syntax analysis and datasets from 2 social media platforms as well as ten years of Flickr photo data and three months of Instagram posted data; these were used to generate the 3D visualized data of an AI ready city.

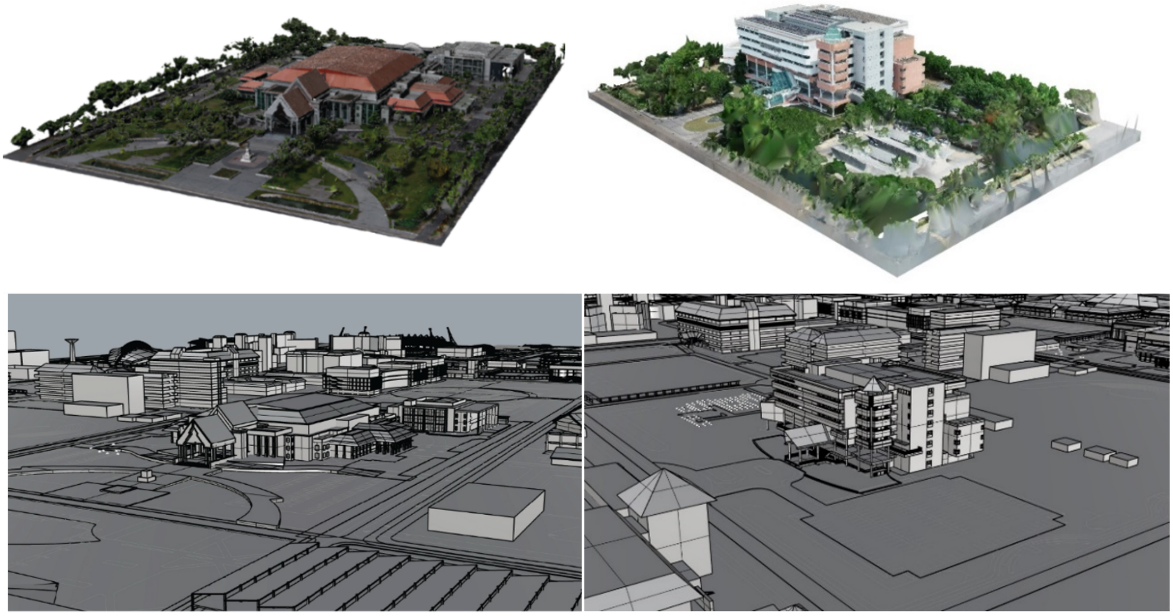
Data Collection Procedures

To create detailed 3D-computer-rendering models of buildings on the Rangsit Center, the collection of physical database data was mainly done by the aerial photogrammetric survey process, together with on-ground-survey photography (direct inspection) for exploring views that cannot be seen through aerial photogrammetric survey in areas covered or blocked by large trees. The data collection procedures are as follows: 1) flight planning, to define the boundaries and the areas to collect aerial photographs; 2) flight and capture, to use an aerial drone to capture high-resolution photographic data; 3) flight data management, to manipulate images suitable for the next procedure, and to screen out images that are irrelevant to the study area in order to reduce the processing time; 4) point cloud process, to manipulate point clouds by creating points in three-dimensional space; to inspect the inactive points and filtering out the point cloud noises by using Reality Capture software in conjunction with Bentley Pointools, and, finally, to send all point cloud data to the next modeling process.

The collection of information from shared photos and videos on social media was taken from Instagram posts (https://www.instagram.com) and Flickr photo data (https://www.flickr.com). By developing coding in PHP, the data were collected from the URL server; the data sets from Instagram are numbers of location-based posts of photos and videos that people have published on the media over a three-month period, and data sets from Flickr photos that show the geolocation of the places taken over a period of 10 years (Geotags). Both data sets are stored in the form of a JSON array, consisting of location name, latitude, longitude, post volume for Instagram, and number of visitors for Flickr, and will be presented in a 3D physical database format in the next process.

Figure 3

Examples of a 3D Photogrammetry Models Compared to (Upper Left and Upper Right) Examples of Manually Created 3D Physical Models. (Lower Left and Lower Right)



Creating databases of three-dimensional physical data

The goal of this research is to present various layers of collected information of the AI cities through a three-dimensional model of Thammasat University, Rangsit Center. The 3D point cloud models created from the photogrammetry processes, however, are in high resolution and in very large file sizes. Therefore, we created a 3D model of the Rangsit Center with three different resolutions to be suitably displayed on the real-time interactive media. These 3D models are stored in 3D databases, and users can choose an appropriate resolution of the model depending on the distance between the viewers and the model (Figure 3).

RESEARCH RESULTS

3D model database of the area of Thammasat University, Rangsit Center

We developed a 3D model of Thammasat University, Rangsit Center - a prototype of an AI Ready city - to exact scale with respect to the real physical condition (Figures 4 and 5).

Analysis of space syntax in three-dimensional computer model

One of the datasets to be displayed on the 3D database computer model is the analysis of space syntax of the entire area of the Rangsit Center, which consists of the traffic network, morphological analysis, and the results of using Geographic Information System QGIS together with the Space Syntax Toolkit. The traffic network was modeled with axial lines, which are the lines connecting the furthest point on the streets, and forming a network of circulations in reference to

OpenStreetMap (OSM) and Google Satellite (Figure 6).

After the traffic network has been completely generated on the model, the network lines need to be checked (verify layer) to confirm that all lines are connected. The axial analysis is performed to show the integration, connectivity, flow, choices, and total depth of each route. Segment analysis is the next process; it is used to calculate NACH value (Normalized Angular Choice), which distinguishes traffic routes with high and low accessibility to other traffic routes. The results from calculation of NACH values are in a vector format, with the analysis results shown in the parameter table format representing a two-dimensional traffic network. Finally, we used the QGIS2ThreeJS plugin to convert these two-dimensional data into a three-dimensional mode by referencing the X-axis and Y-axis positions from the existing data and adding Z-axis, or altitude data (Figure 7).

Figure 4

3D Model of Thammasat University, Rangsit Center

Figure 5

Examples of Eye-Level Perspective Views

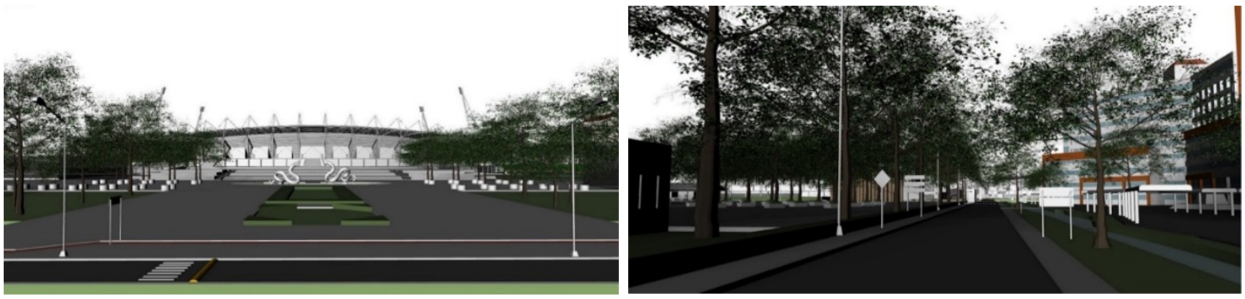


Figure 6

3D Model Showing the Traffic Network and the Results of NACH Analysis

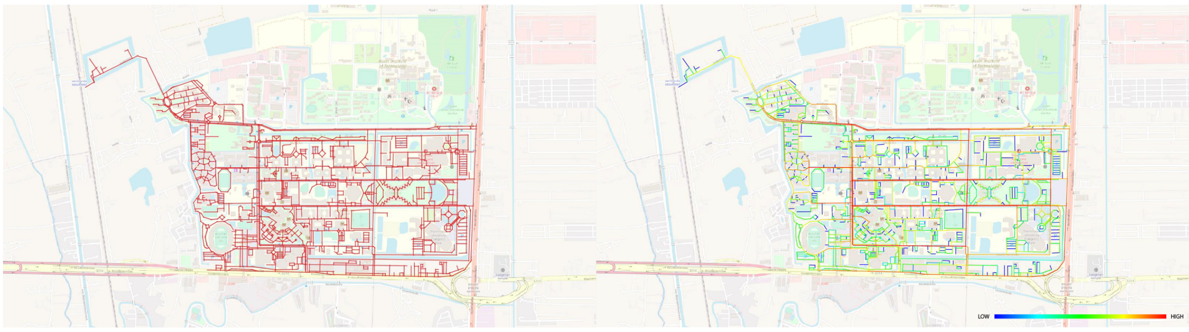
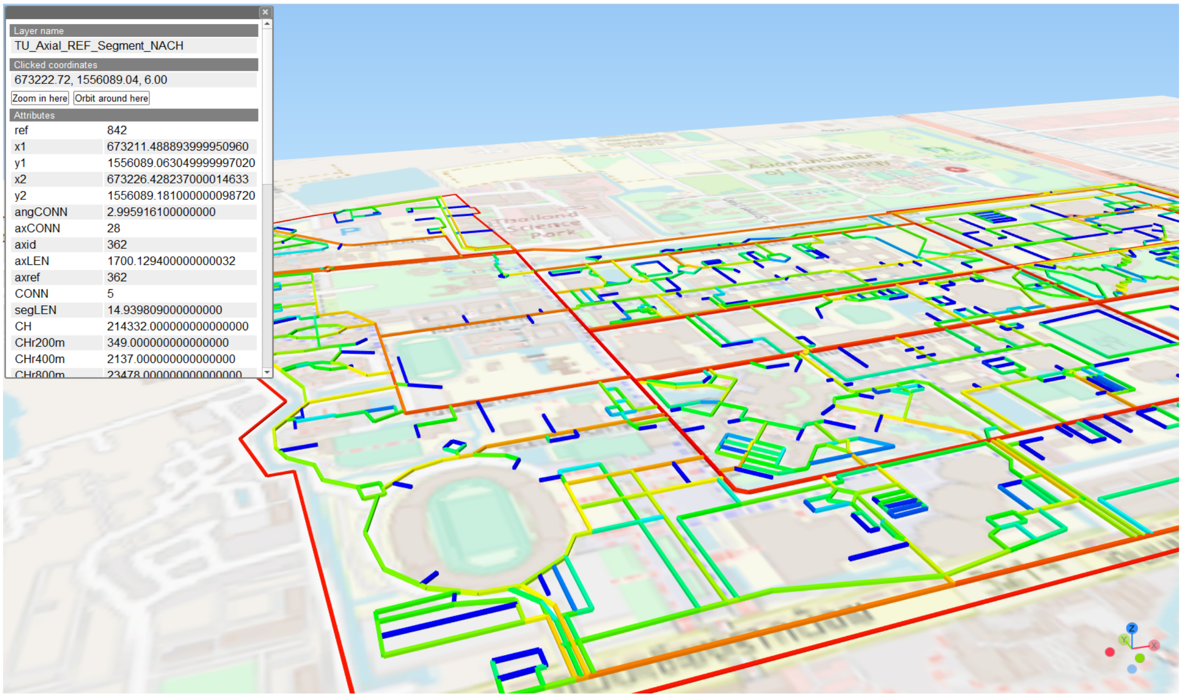


Figure 7

NACH Values Represented in 3D Model Using the QGIS2threejs Plugin



Representation of space syntax analysis results on three-dimensional database of Thammasat University, Rangsit Center

To develop the 3D visualization using virtual reality technology, the 3D model of Rangsit Center and the traffic network model from space syntax analysis were combined into one model by converting from 3DM file format and 3D space syntax analysis models imported through the QGIS2ThreeJS plugin from gLTF file extension to FBX format. The reason is that the FBX is a compatible 3D file format that can be used for further development in Unity software (Figure 8).

In the combined model, users can read the preliminary NACH analysis or accessibility values from the color spectrum. Warm tones represent highly accessible paths, while cool tones represent those with less potential to be reached. The model (Figure 9), moreover, shows that the overall potential of the traffic and accessibility in the Rangsit Center is good because the main traffic networks, highlighted in red, reach throughout all areas of the university. Nevertheless, due to the main thoroughfares being two-lane roads on a large grid system, the accessibility to any area via these main thoroughfares is occasionally impeded by traffic jams. Alternative mobility modes such as walking and cycling might offer better choices because most secondary thoroughfares are unreachable by car.

In addition, space syntax analysis on the 3D database model shows that the locations of many areas of the university, such as administration areas, education areas, academic and social service areas, and recreation areas correspond to the traffic system. These areas all are located on highly accessible main streets, while residential areas that require serenity, privacy, and safety are situated at a lower-access streets. However, some areas suggest an incompatible usage and a potential of accessibility, such as the creative economy promotion areas, which should be located on a well-accessed area, but are, instead, on a low-access thoroughfare. In conclusion, the 3D database created using space syntax analysis can be used in planning, developing, and/or improving the physical aspects of the university in the future, i.e., expanding the capacity of the traffic routes, and adding sub-routes to create smaller blocks of area, and with respect to facility management aspects, i.e., controlling access ways and planning to connect existing traffic routes to the new public transport system in the future.

Figure 8

The Process of Converting and Developing a 3D Model for Virtual Reality

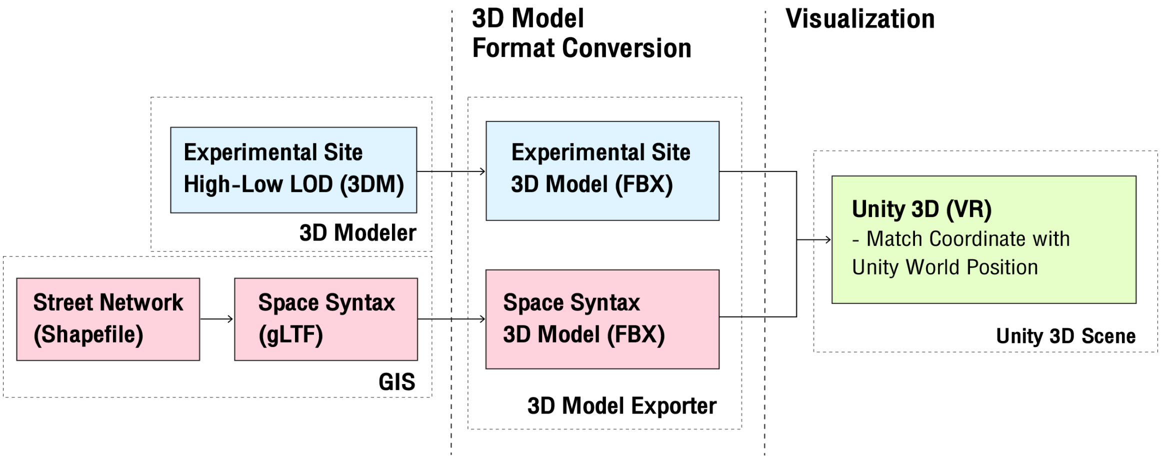
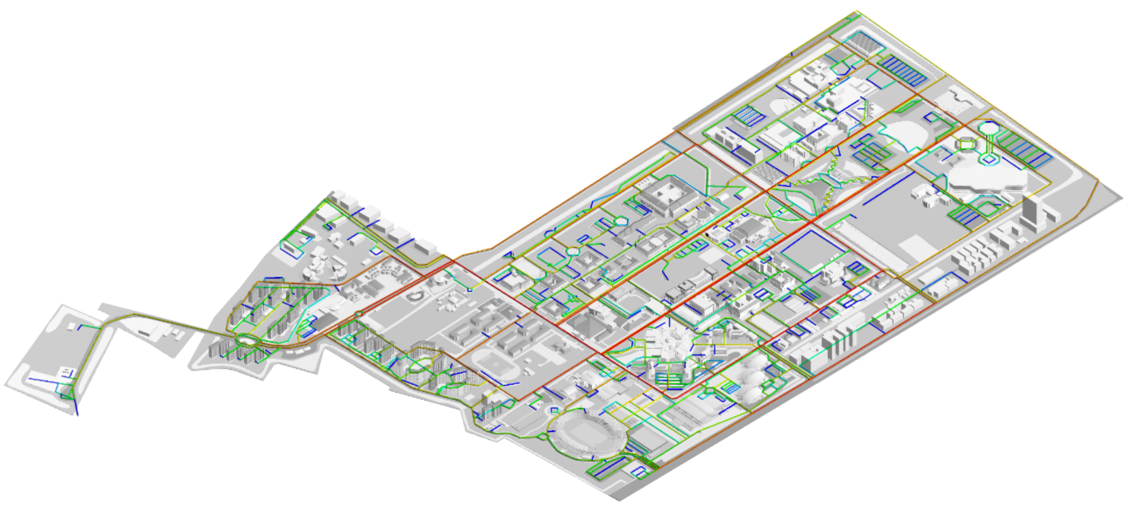


Figure 9

Space Syntax Analysis on 3D Model of Thammasat University, Rangsit Center



Developing a system for presenting data from social media on a three-dimensional database of Thammasat University, Rangsit Center

Data overlay is one of the most important steps, and also a common basic process in GIS. The principle is to bring together existing information from a variety of sources for use in decision making about various situations. This study attempts to present both two-dimensional and three-dimensional data gained from two social media platforms (Flickr and Instagram) on 3D database of Thammasat University, Rangsit Center. The two-dimensional browsing system was developed as a plug-in of QGIS, and the users are able to view the latest posted images, including image titles, descriptions, comments, geolocation, etc., on the 3D model with exact geographical locations (Figure 10).

Afterwards, the data, which are collected in JSON format, are developed in Unity software to render the 3D data in virtual reality mode. The process consists of three parts: reading JSON data, converting geolocation information, and displaying results with data visualization tool (Figure 11).

Figure 10

Data From Flickr and Instagram Shown on the Layout of Thammasat University, Rangsit Center

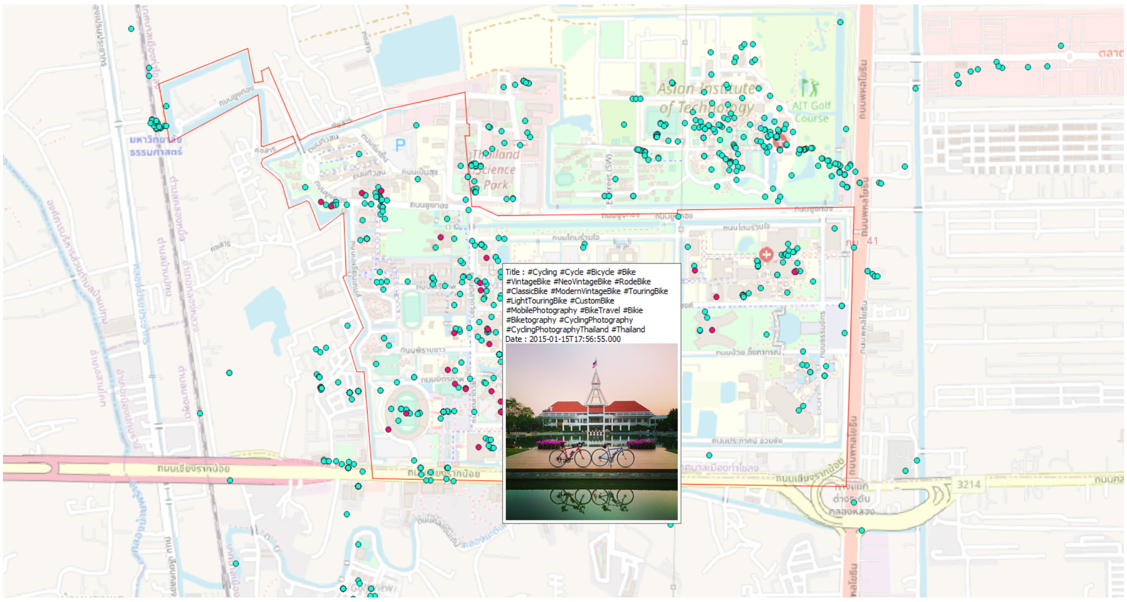
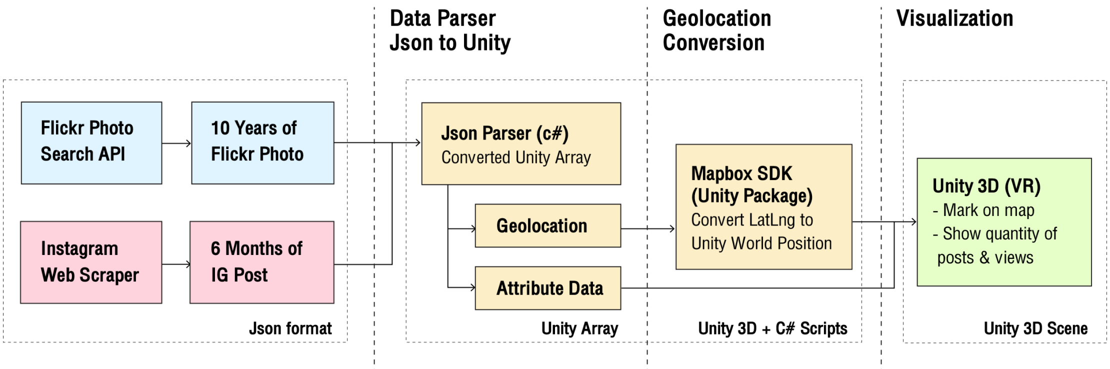


Figure 11

The Process of Displaying Social Media Data on a 3D Model by Using Unity Software



The first step is to read the JSON data by importing data from both social media sites in JSON format to read the JSON Array values, and then passing the values from the datasets (Parsing) to a Unity array that controls the display of 3D data in virtual reality. This data manipulation in Unity is developed with C# language. The second step is conversion of geolocation data, which is an important step in bringing geolocation datasets to display in virtual reality by using Mapbox SDK to render world map data. The process also converts latitude and longitude coordination data into Unity World Position to ascertain that the data display in the 3D model will match the actual world geographic location. The third step is to display all data in 3D bar charts in order to show the volume (quantitative data) of Instagram posts and Flickr photo views with actual locations based on Instagram pins and Flickr photo locations. The red bar graphs show Instagram data, and the blue ones show Flickr data. The 3D visualization shows that many areas of the university have a similar amount of information from Instagram and Flickr. For example, recreational areas receive the most attention from both datasets since they are significant places for people to engage in activities. Some educational building blocks have two different datasets, which possibly implies users' different interests in the activities on different social media platforms. The 3D database of both social media platforms will be useful for facility management, controlling the quantity of people in the area, and creating an understanding of the importance of the area to the activities of people (Figure 12).

By integrating results from all space syntax analysis and the two social media data visualizations, both similarity and contradiction are manifested (Figure 13). For instance, the recreational areas are in moderate-to-low-accessibility potential condition, but have a high volume of Instagram posts and Flickr photo views. This suggests that the areas receive interest for activities, but, due to an unsupportive traffic network, there is greater likelihood of traffic jams. (Figure 14 left). Therefore, traffic routes should be improved to facilitate better access to the area, and pedestrian traffic, rather than car traffic, should be promoted. Another example is the academic and social service area, which receives a high volume of posts and photos, demonstrating the importance of and interest in activities in this area. Although this area is located on a route with relatively high traffic potential, the access is through the main path only, so it lacks alternative traffic routes (Figure 14 right). This area may need more development to accommodate people's interest as well as further enhancing the identity of Thammasat University in the future.

However, the 3D visualization of these data on the 3D database model represents a sample of a data set at a particular time only, and can be developed further based on real-time datasets from other social media, or from big data derived from intelligent systems installed in a smart city. When a dataset changes in quantity or location, the model can immediately present such changes. In a 3D Virtual Reality system, users can view the 3D data in the virtual environment in two modes of perception: overall view and walkthrough (Figure 15). This VR system helps support collaboration and communication among architects, designers, urban planners, city policy makers, and other city stakeholders, and helps in investigating problems in various situations, as well as allowing the exploration of areas with high potential in real-time.

Moreover, in the VR mode, users are able to select the views from two types of 3D models. The low polygon model offers views suitable for general information, with compact file size and fast interactions. This model is also developed in multiple levels of detail (LOD) that automatically utilize the appropriate level of detail by referring to the distance between the navigation camera of the user and the subject building. The second type is the photogrammetry-based 3D model which offers a more realistic quality and views of textured surfaces and shapes of the buildings that are close to the real buildings (Figure 16).

Figure 12

The Interface Presenting 3D Data From Instagram on 3D Model of Thammasat University, Rangsit Center

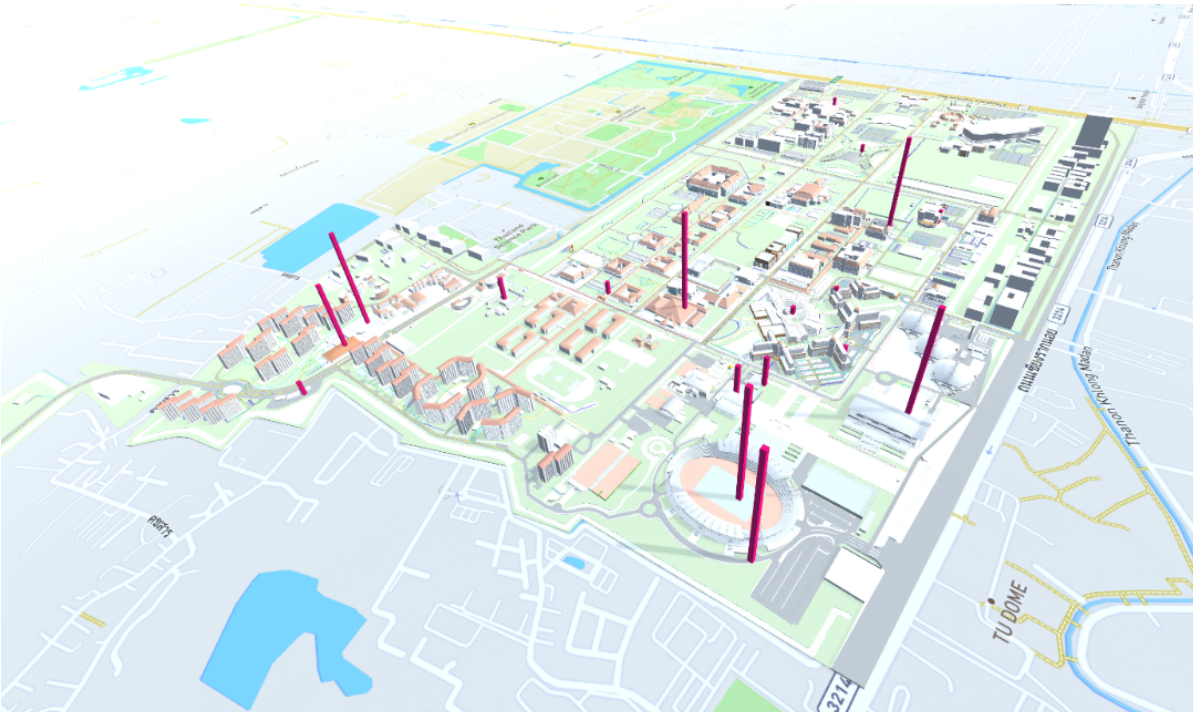


Figure 13

The Interface Presenting 2D and 3D Data From Instagram and Flickr on 3D Model of Thammasat University, Rangsit Center

Figure 14

An Example of System Usage to Identify Two Areas Where Accessibility Conflicts with the Number of Social Media Posts

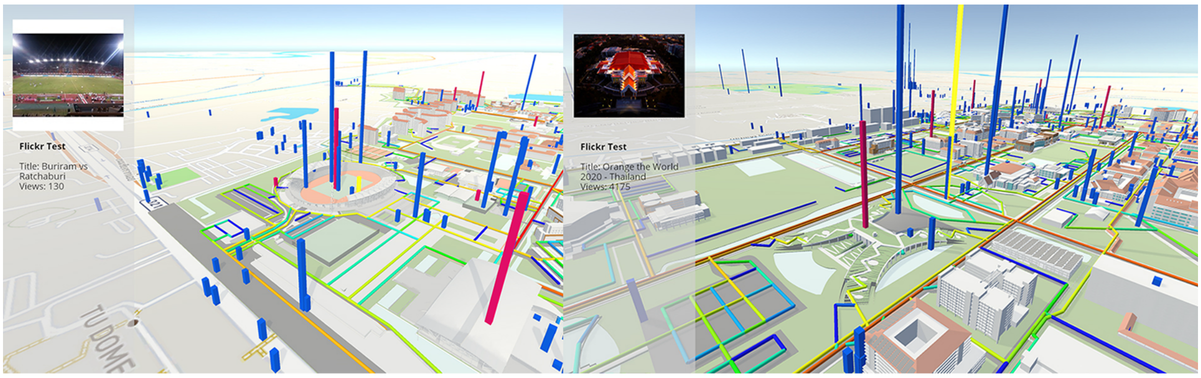


Figure 15

(Top) Multi-User VR Data Visualization Supporting Multiple Users Simultaneously. (Below) Two Modes of VR Display - (Left) Aerial View and (Right) Walkthrough Mode

Figure 16

(Left) A Low-Polygon 3D Model and (Right) a Photogrammetry Model

CONCLUSION

This research shows the design and development of tools for analyzing and visualizing three-dimensional data of AI Ready cities by using Thammasat University, Rangsit Center, Thailand, as a prototype area of study. The two data sets – a static dataset from space syntax analysis indicating the potential of space and traffic in the university, and a dynamic dataset from social media (Instagram and Flickr) showing volume of use and activities in different areas -- are displayed in a Virtual Reality 3D model. The VR system was designed to support collaboration and communication among architects, designers, urban planners, city policy makers, and other city stakeholders. This digital model can be further developed to support 3D visualization for various types of data obtained from city dwellers and smart cities, such as traffic, electric power, public bus information, and data from other social media platforms to help in creating, enhancing and developing a better AI city.

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