Evaluating walkability in Tsukuba using remote sensing and GIS

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Abstract: Enhancing community environments to support walking and bicycling is a promising approach to increase health levels based on physical activity. This paper examines walkability (walking or bicycling) areas in Tsukuba and presents the usefulness of creating Walkability WebGIS. ALOS image, Zenrin, and road maps were used for the study. Based on spectra recorded in the satellite data, greenness index was computed to highlight urban greeneries in the walkable area. An extensive fieldwork was also conducted to verify the results and record photographs. From well settled to tranquil areas are also identified to effectively inform the walkers or bicyclists. Walkable routes were further graded into five levels of suitability ranging from very low to very high for walkability. A practical Walkability WebGIS including easy-to-use help system was developed in ArcGIS Server to disseminate the degree of walkable feasibility to the Tsukuba residents. In this system, the residents can freely explore the maps and use spatial functions to understand their surrounding walkability environments and print maps for their daily usage.

Keywords: Walkability, WebGIS, Health GIS, Tsukuba

1. Introduction

Recently, walkability (walking or bicycling) is an emerging and hot topic in the study of urban form. In Europe, Canada, US, and Japan, numerous jurisdictions are starting to consider impacts of walkability in health and urban planning. Moreover, in recent years, many urban residents from different age groups are getting self consciousness about their health. Some people like walking, jogging, cycling, and soft physical exercising routinely in public spaces.

Walkability, generally referred to as walking or cycling, is being measured from a variety of angles. A rapidly growing area of urban form research concerns how to measure the level of walkability of neighborhoods and make aware of it to residents in the area. Many scholars and planning practitioners have already examined the many components of the land use-transportation connection and built environment-physical activity link. However, very few have examined walkability at street level using GIS and delivered the results in WebGIS platform. This article aims at examining walkability areas in Tsukuba and presents the outcomes by creating WebGIS. Furthermore, walkability assessment was performed in Tsukuba using remote sensing and GIS techniques. We created an interactive website in ArcGIS Server 9.3 to deliver the derived information from our research to Tsukuba residents as a practical scenario.

2. Database and methodology

In this research, our focus is for Tsukuba city which is located in the northeast of Tokyo (Thapa and
Murayama, 2008). This is a well planned science city having a significant number of educated population rather than the industrial population. The population in the business core of Tsukuba and its vicinity is growing with a density of 730 persons per square kilometer as of 2008. Population composition of Tsukuba is much diversified in-fluxing the residents around the globe due to study and research opportunities in higher academic and research institutions.

Several databases were incorporated while developing the Walkability GIS (Table 1). QuickBird and ALOS (Advanced Land Observation Satellite) satellites image are geometrically corrected for maintaining the geographic consistency with other geographic layers, i.e. Zenrin, road, and fieldwork data. We used QuickBird image in the densely populated areas to visualize the walkability areas more clearly. High resolution image (QuickBird) consists of high level of details creating a large amount of data that alter the server performance. Therefore, it is further optimized to light weight version for the WebGIS without losing suitable information for the walkability purpose.

### Table 1: Data used in Walkability GIS

<table>
<thead>
<tr>
<th>Data source</th>
<th>Year</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuickBird</td>
<td>2006.10.5</td>
<td>0.6m</td>
</tr>
<tr>
<td>ALOS</td>
<td>2006.8.4</td>
<td>10m</td>
</tr>
<tr>
<td>- Band 3: Red [0.61–0.69 μm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Band 4: Infrared [0.76–0.89 μm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zenrin</td>
<td>2008</td>
<td>-</td>
</tr>
<tr>
<td>Road data</td>
<td>2006</td>
<td>-</td>
</tr>
<tr>
<td>Fieldwork</td>
<td>2007</td>
<td>-</td>
</tr>
</tbody>
</table>

To determine the density of green on a patch of land, we must observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants. The pigment in plant leaves, chlorophyll, strongly absorbs visible light especially in red region (from 0.6 to 0.7 μm). The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves a plant has, the more these wavelengths of light are affected, respectively. The AVNIR2 sensor onboard in ALOS records the spectral reflectance in three visible bands and one infrared band (Thapa and Murayama, 2009) where two bands 3rd and 4th refer to Red and Infrared, respectively. Therefore, a numerical ratio between these red and infrared region provides a clearer picture of green density in the study area. A greenness index (eq. 1) widely known as a normalized differential vegetation index (NDVI) is computed to highlight the density of urban greeneries in the walkable area.

$$ NDVI = \frac{\lambda_{NIR} - \lambda_R}{\lambda_{NIR} + \lambda_R} + 1 \quad \text{(eq. 1)} $$

Note: $\lambda = \text{wavelength}, \quad NIR = \text{near infra red} \quad R = \text{red}$

The equation produces a gradient score between 1 and 2 which represents higher the value in a patch of land, greater the greenness density in the land. The score of greenness index is further aggregated to the street level. Based on the index value, the streets are further classified into five levels of greenery from very high to very low. As an walkable area awareness, the city core area is presented in four categories of walkability area, i.e., well settled walking area, easy access to shopping malls, mixed landscape area, and tranquil area based on the fieldwork data (Asai, 2008).

A complete suite of Walkability WebGIS in ArcGIS Server 9.3 (ESRI, 2008) is developed. It includes the results of the research and map exploration functions with well guided help system. The website can be accessed at: http://sae.sk.tsukuba.ac.jp/TsukubaWalkability/default.aspx

### 3. Results and discussion

The Figure 1 shows Walkability WebGIS for Tsukuba.
Figure 1: Tsukuba Walkability WebGIS

The WebGIS system provides a basic GIS through web which is useful to the Tsukuba residents to understand the walking environment in their surrounding vicinity.

The greenery map layer, a result of greenness index, in the system provides a gradient indication of greenery levels ranging from very low to very high at the street levels. While the walkable area map layer provides insight on walkability qualities of landscape such as location of tranquil area, easy access to shopping area, etc. which helps to the walkers and bicyclists make decision for walking route upon their interests.

The system stores most updated data and free to all user through its designated system for peaceful usage. However, the base data are not downloadable but user can print map of their desired locations including desired map layers selection.

The WebGIS system is well designed that requires no prior knowledge of GIS. It consists of basic geographic data exploration tools, navigation, advanced functions including a small separate window for map contents, map overview, results, wide map area, and well guided help (Figure 2) on the system. The help system provides full details of WebGIS and its functions usage.

In this WebGIS system, the residents of Tsukuba can explore their local living environment visually, calculate distances, geographic coordinates, and area,
search their area of interest, such as walking routes, business offices, shopping malls, restaurants, schools, banks, etc., identify spatial proximity of their interest, and print a map of desired location without having any GIS software in their personal computer.

Currently, general basic tools for exploring the map, for example, zoom in/out, panning, viewing map in full extent (whole city at once), object identifier, distance measurement, magnifier, and scale are available. User can choose their desired map contents to be viewed in map. However, an advanced function is also available at this moment, i.e. Proximity Analysis allowing user to calculate the spatial proximity of their interested area in a certain radius which is very useful to know what kinds of facilities or environment exist within the desired distances.

The targeted users are the residents (Internationals as well as Japanese) in Tsukuba. Due to availability content in English including well explained help system of know-how about the WebGIS, many international residents are expected to use.

4. Concluding remarks

Linking remote sensing technique with GIS has enabled us to examine situation of walkability in Tsukuba City which provided a cost effective environmental application to be used in residents’ daily life. As we could see from the results; there is a disparity of spatial distribution for walkability. The whole system provided many choices to the residents in Tsukuba. Some areas in the city core have higher greenery in the walkable routes while some have not. Similarly, variability on landscape qualities in the walking areas is also existed which can be connected with personal choice of the residents. For example, some residents like to combine walking with shopping so they can choose the areas that have easy access to shopping areas. The WebGIS provides full phase to explore the environment and help to the residents to make decision on their choice.

As a future prospect, adding more spatial functions can provide better understanding to the walkable environment exploration for the Tsukuba residents. In this research, we computed only one greenness index to show an application of remote sensing and ALOS data potential. However, seasonal factor should be added to the index as density of greenery varied by season.

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References