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Three-dimensional reconstruction of the landscape of Kobe, Japan from aerial photographs using photogrammetry

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Abstract:

In recent years, 3D technology has developed rapidly, and 3D data of various spatial scales have been created from small objects such as dolls and furniture to entire cities. In particular, 3D data at the city scale is being used to solve various problems using "digital twins" of cities, which are models of real places reproduced in virtual spaces (Seto et al., 2023).

There are two main techniques for creating 3D data of cities: laser surveying using LiDAR sensors and photogrammetry using multiple aerial photographs or satellite images. With the widespread use of drones, creating 3D data over a wide area has become easier. However, drones can obtain 3D data only for entities that currently exist. In contrast, the 3D restoration of urban landscapes that have been lost was conducted in the Virtual Kyoto Project (Yano et al., 2008). One method used by Yano et al. (2008) was to create 3D models of specific areas where landscape photographs have been preserved, and the other was to create 3D models of the exteriors of buildings that were common at the time, such as those from the *Heian* and *Edo* periods, and then place them throughout the city to recreate the landscape. These methods require considerable effort and can only be applied to specific cities such as Kyoto, which is a historic city with many preserved historical records. Aerial photographs are available for most of the 20th century and beyond. Therefore, it is possible to archive past landscapes in 3D data for cities other than Kyoto using photogrammetry to process aerial photographs from these past eras.

Restoring lost landscapes as 3D data from aerial photograph archives does not necessarily solve modern problems, but it does help us understand the historical context of the area. In particular, areas affected by large-scale disasters have changed their landscapes to such an extent that it is difficult to imagine in the current situation, and it is thought that restoring lost landscapes can be useful in urban planning and other activities.

Therefore, this study used photogrammetry to create 3D data for six points over 60 years from 1961 to 2021 and restored the landscape using the aerial photograph archive provided by the Geospatial Information Authority of Japan (GSI) for the urban area of Kobe City. The urban area of Kobe City was severely damaged by the Great Hanshin-Awaji Earthquake of January 17, 1995, with a magnitude of 7.3. The year 2025 is exactly 30 years after the disaster, and the landscape of heavily damaged areas has changed significantly due to redevelopment projects.

The aerial photographs used in the photogrammetry were obtained in 1961, 1975, 1985, 1995, 2009, and 2021. The 1961 aerial photograph is in black and white, and the other years are in color. An aerial photograph was taken in March 1995 after the earthquake. The GSI's aerial photo archive consists of 400 dpi images. Therefore, the aerial photos were selected from those with a scale of 1:10,000 or greater, resulting in the six aerial photos shown here. These aerial photographs were loaded into Agisoft Metashape, and point clouds and 3D model data were generated. The data were then output as a scene layer package so that they could be displayed in ArcGIS, and published on ArcGIS Online to create a web application called "KOBE 4D VIEW."

Figure 1 shows the changes in the landscape of the area around the JR Shin-Nagata Station, which was severely damaged by the January 1995 earthquake, as observed from 3D data for three points in time: 1985, 1995, and 2021. In 1985, a large building soared to the left of Shin-Nagata Station. It is a complex facility built in 1977, with a shopping center on the lower floors and residential apartments on the upper floors. The surrounding area is a mixture of densely packed low-rise houses, factories, and shops. The earthquake in January 1995 hit this area, which was full of low-rise buildings, and not only did many of the buildings collapse, but fires also broke out, destroying many buildings. Many of the buildings that did not collapse had blue tarpaulins on their roofs. Over 26 years until 2021, this area underwent large-scale redevelopment and land readjustment as part of a city-planning project for earthquake recovery. As a result, the landscape changed significantly at the block level, and there are areas where high-rise apartments were built in large

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numbers. However, the complex that was completed in 1977 remains unchanged at this point and continues to be a landmark of the area.

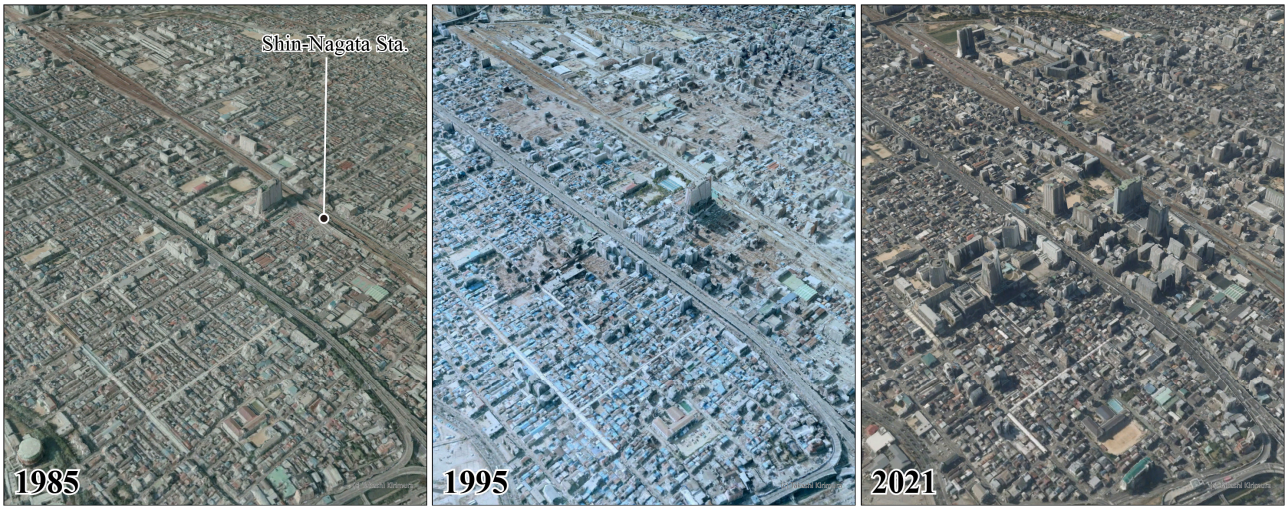

Figure 1. Changes in the landscape of the area around JR Shin-Nagata Station in 1985, 1995, and 2021.

With “KOBE 4D VIEW,” it is possible to observe these 3D data by switching between layers, and since its release in 2022, it has received approximately 2,800 views. The release and announcement of this application were carried out via Twitter (X), and over the past 12 months, since January 2024, it has received approximately 1,000 views, with an average of two to three views per day, indicating that it is being used. In addition, an app was created that combines data from the earthquake-related photo archive published by Kobe City as open data, based on 3D data from March 1995, with location information added by ESRI Japan.

Three-dimensional data can be used not only for the restoration of lost landscapes but also for geographical analysis. By classifying the point-cloud data generated by photogrammetry and identifying the point cloud on the ground, elevation data can be obtained, and by calculating the difference from the digital surface model, height data for buildings and trees can be obtained. Using these data, it is possible to conduct spatial analysis from a quantitative perspective, combining it with statistical data and other information to see how Kobe recovered after being hit by an earthquake. In addition, by superimposing 3D data from each point in time, the relationship between quantitative changes and changes in the landscape can be analyzed.

In this study, 3D data were created for the urban area of Kobe City from 1961 to 2021, using aerial photograph archives with photogrammetry. The 3D landscape data made it possible to visually observe the damage from the 1995 earthquake and the subsequent recovery. The 3D data created in this study do not have enough detail to be observed from the perspective of a pedestrian because of the limitations of aerial photography resolution; however, they are sufficiently accurate for use in a bird's-eye view. Aerial photographs of Japan from the past are available as open data at 400 dpi. If aerial photographs have been taken, it is possible to create 3D models from them for other cities and points in time. In future, 3D data for several cities and points in time will be created and released, and their utilization will be promoted.

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