RealScape Series Fixed Assets Change Judgment System

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Abstract

The Tokyo Metropolitan Government, which is the largest municipality conducting house change identification work in Japan, has terminated its visual identification work that has been in use for 20 years and shifted to a new systematization of the work in January 2006. Due to the very large area, covered, the Tokyo Metropolitan area is divided into four blocks and the required work in them is entrusted to different companies. Three of the four companies have adopted NEC's "Fixed Assets Change Judgment System" and are already involved in a full scale operation of this system. This paper is intended to introduce the Fixed Assets Change Judgment System, which performs stereo based comparative analyses of aerial photographs and detects changes in the shape and color of houses automatically.

Keywords

aerial photography, stereo processing, true orthorectification, house changes over time

1. Introduction

We have established a technology for the automatic detection of changes in the height and color of house buildings based on the 3D analysis of aerial photographs. This has enabled us to develop a fixed assets change judgment system by applying this technology in the house change detection. The system employs a method of stereo processing by pixel to calculate the height of each house based exclusively on its aerial photograph and thus enables a precise overlapping of the previous and current images. This makes it possible to judge any changes to the house by also considering height changes simply by using two aerial photographs and without any high-cost means such as an aerial survey. The system can also reduce the labor costs to less than 1/3 of the previous cost (compared with our system) and to thus reduce the required judgment period (to about two weeks per 100km^2). It has additionally solved the problems with traditional systems by enabling the detection of height changes that are hard to be distinguished visually and by replacing human error and prejudice by objective judgment based on computer processing.

2. House Change Detection

The Japanese fixed property tax is imposed by the municipalities on the owners of lands, houses and depreciation assets (hereinafter referred to as "fixed assets") on January 1st of every year (levy date) by calculating the tax sum according to current asset values. For this purpose, the municipalities take aerial photographs on January 1st every year and compare the photographs with those of the previous year in order to identify house change information (new construction, loss, enlargement, reform, reconstruction and work in progress).

The identification of changes is usually entrusted to survey companies who hire a large number of workers (**Fig. 1**). However, reliance on human labor has led to problems as described below.

1) Subject of Huge Costs

It takes about 10 hours to read and interpret a single photograph, and the average municipality must perform this work for hundreds of photographs.

2) Subject of Impossibility of Eliminating Human Judgment Errors

Errors are not acceptable from the viewpoint of fair taxation and, particularly, the "oversight" of houses subjected to ac-

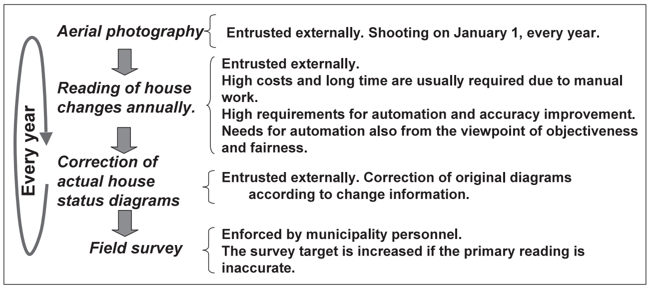

Fig. 1 Flow of house change detection in local municipalities.

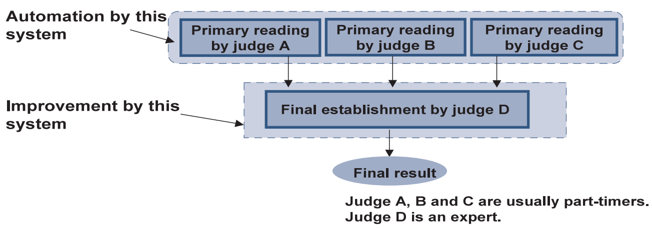

Fig. 2 Judgment procedure when improved accuracy is attempted by human visual identification.

tual change must be considered to be absolutely the worst of such errors. Nevertheless, the current work is dependent on the capabilities of individuals so errors are not avoidable with the traditional system.

In actual work, attempts to prevent oversight errors are made by performing several read operations per area (**Fig. 2**) but this leads to a further increase in cost. Every photograph is taken to a scale that can cover an actual area of 800 × 600m or 500 × 600m (variable depending on the municipality), and every municipality has hundreds of photographs to be read. As a result, it is not rare that the man-hours required for the photograph reading operation exceeds 10,000.

Under these circumstances, the incentives among the municipalities to solve such problems by automating or systematizing the photograph reading work are now higher than ever. The criteria for the identification of changes are based on the law and the guidelines of the Research Center for the Property Assessment System and this procedure will continue even after systematization. Specifically, the criteria are required to detect the following types of changes without exception:

- horizontal or vertical changes of 2 meters or more.
- color changes in an area of about 2 × 2 m.

As these requirements set a high hurdle to be cleared for automatic processing, the attempts to automate have been limited to a partial use of certain tools and were far from a real systematization. The main judgment issues are the detection of height and color changes, the automation of which is accompanied by the following problems.

1) Height Change Detection

The height information may be obtained by means of aerial photography by using a laser profiler, but the costs of aerial surveys are very high if it is required to detect height changes of around 2 meters. Moreover, aerial survey devices are too expensive and their availability is limited for many municipalities.

2) Color Change Detection

Precise overlapping of previous and new photographs is required for detecting color changes, but two aerial photographs are difficult to overlap and be matched satisfactorily because the angles of the buildings are usually different due to a variance of the shooting conditions (shooting position, altitude, focal distance, etc.).

We have recently solved the two problems above by adopting the method of stereo processing by pixel that makes it possible to obtain the height information of all pixels in aerial photographs and correct their positional information.

3. Fixed Assets Change Judgment System

3.1 System Outline

This system is composed of two modules (**Fig. 3**).

(1) Stereo Processing Software

This inputs two aerial photographs into the computer, converts all pixels in them into 3D information and calculates the house height information (DSM: Digital Surface Model) with a resolution of 1 meter. At the same time, it applies precision true ortho processing in order to correct for the inclinations of houses in the photographs and to enable a precise overlapping of the previous and new photographs.

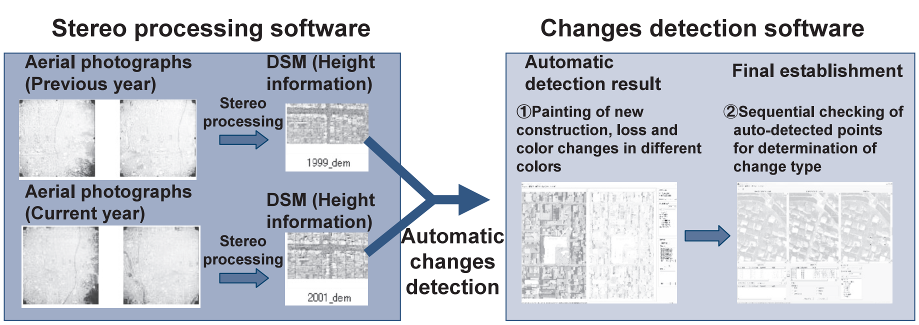

Fig. 3 System configuration.

RealScape Series Fixed Assets Change Judgment System

(2) Change Detection Software
This inputs the two, previous and new, orthorectification aerial photographs and the DSM information, and detects changes in the shapes and colors of houses and land.

3.2 Design Target

The target we set before designing this system was for compatibility between improvements in judgment performance and automation (prevention of human errors and detection of height changes that are difficult to detect visually). However, it is still difficult for the current technology level to achieve a perfectly error-free reading and judgment automatically. As a result, we decided to apply judgment using automated software in the primary reading and to provide the final reading only with the tools for accurate judgment (Fig. 2). According to actual data, the number of houses shot per photograph is between 3,000 and 4,000, the annual percentage of houses subjected to changes is 3% to 5%, so the average number of changed houses in a photograph is around 150. As the aim of primary reading in the traditional visual judgment work has been for example to select 500 to 600 candidate houses from 3,000 houses in a photograph, we set the target performance of our automatic judgment system for use in the primary reading at a similar judgment capability level to the traditional primary reading.

3.3 Stereo Processing

Fig. 4 shows the flow of stereo processing.
(1) Input Data
The input images can be similar analog or digital aerial photographs to those used in traditional change judgments. Each of these photographs consists of a series of picture frames taken by overlapping an area of about 60% between frames. This system executes stereo processing by assigning two adjacent picture frames as the left and right images and obtains the height information on all of the pixels in the overlapped area.
(2) Relative Orientation
Unlike cases in which images are taken using a stereo camera that can be calibrated every time before use, aerial photographs are taken using various camera attitudes. This procedure makes it necessary to perform paralleling work to align the orientations of the input images. For this purpose, the system applies an aerial survey spotting calculation technique in order to calculate relationships between camera positions based on the coordinates of a few sets of corresponding points in the images. We call this process “relative orientation.”
(3) All-Pixel Stereo Matching
The main task in stereo matching is to identify the corresponding points in the left and right images. When the left and right images are paralleled with relative orientation, all of the subjects are located on the same scanning line number in the left and right images. So the search for corresponding points can be limited in a single dimension. We adopted the DP (Dynamic Programming) matching method for the search, which uses the cross-correlation value as the evaluation value and outputs the DSM information resulting from the processing. In order to obtain high-quality DSM information, it is necessary to select the image correlation parameters such as the window sizes and threshold values optimally according to the scales and types of input images. As their selection necessitates experience, we provided the system with param-

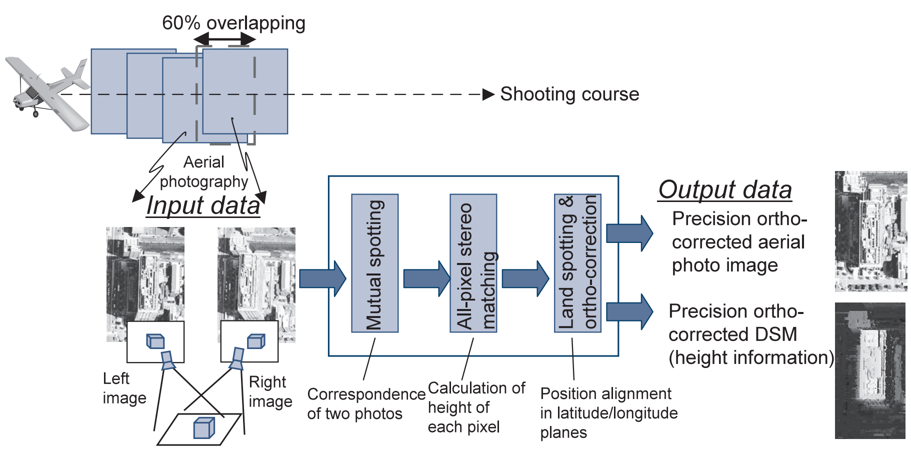

Fig. 4 Outline of stereo processing.

eter settings that are optimized according to the types of processed images, so that the user can perform optimum processing simply by selecting one of the parameter settings.

(4) Absolute Orientation

Since processing for the above is performed in the image coordinate space, it eventually becomes necessary to compare the correspondence of the photograph and the DSM information with the latitude and longitude of the land location, or absolute orientation technique. At the same time, a conversion of the parallax values obtained by the stereo matching of the altitude value (m) is also performed.

(5) True Orthorectification

Since stereo processing requires a large amount of calculations, traditional aerial survey software generally obtains the altitude information only for the topographically characteristic points and for the houses and the contour lines, and applies interpolation to other points. This has resulted in problems such as dealing with houses that lack contours and are undistinguishable from the ground and consequently remain inclined in the images. On the other hand, our system can determine the absolute positions of all pixels because the stereo processing applied by it offers the height information of all pixels without a need for contour information. We call this processing method the “true orthorectification” method. True ortho images show the roof surfaces of all houses and buildings in their real positions without tilting (**Fig. 5**). This makes it possible to overlap a photograph precisely onto a map or to overlap two photographs taken under different shooting conditions.

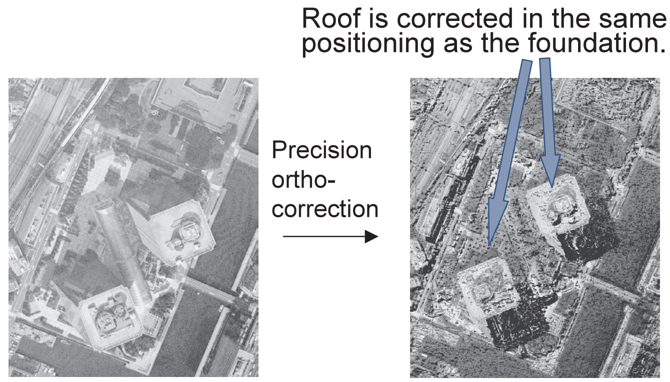

Fig. 5 True orthorectification.

(6) System Configuration

We developed stereo processing software that is capable of executing the above processing in a concurrent processing environment composed of multiple PCs (**Fig. 6**). The software includes a server & client system for concurrent execution of stereo processing using a grid computing method, and software for use in a series of operations such as the corresponding point input tool for use in spotting, and which can perform work for the generation of DSM information based on aerial photographs. The clients are composed of 1 to 48 PCs and can join or leave the stereo processing dynamically, enabling a flexible system configuration according to its purpose.

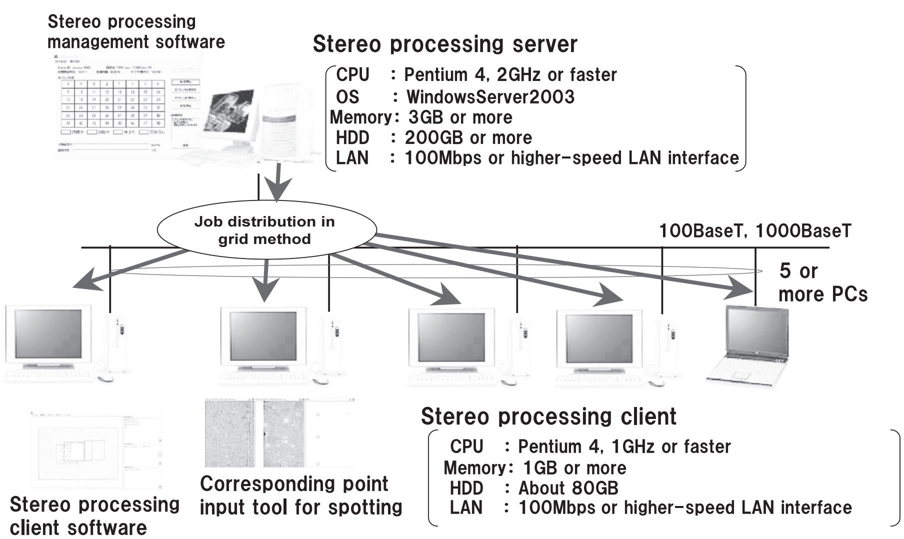

Fig. 6 System configuration.

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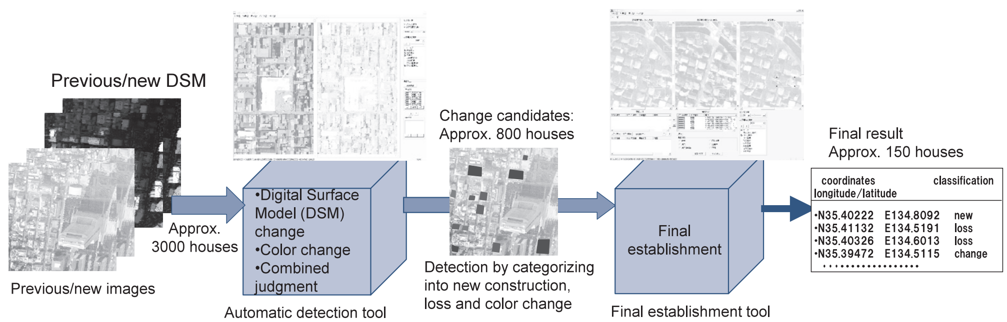

Fig. 7 Outline of the change detection system.

3.4 Changes Detection Software

The changes detection software inputs both previous and new color images and the DSM information obtained as a result of stereo processing and detects any changes in them. It is composed of an automatic detection tool for automatic execution of the processing corresponding to the primary reading operation, and the final establishment tool for supporting the final judgments by experts (**Fig. 7**). The following paragraphs describe these tools separately.

(1) Auto Detection Tool

For automatic detection, we developed a method that can specifically analyze and detect changes in houses such as new construction, loss or color changes. For the altitude changes, it refers to both previous and new DSM information and detects increases in height as new construction and decreases in height as loss. For the color changes, it refers to the true ortho color images and detects changes above threshold values as color changes. Since it is difficult for users to specify the color change judgment criteria in numerical terms, we have adopted a method with which the system recommends the threshold value. Here, all of the detected color changes cannot be interpreted as actual changes because the detection of changes in an area of 1 × 2m means that objects of a certain size such as automobiles would be detected as color changes. Therefore, our system refers also to the DSM information in order to eliminate color changes in areas with a height of below 2 meters from the ground.

The results obtained with this tool are output as a csv file containing a map image showing new constructions, losses and color changes by painting each pixel and the center coordinates (latitude and longitude) of each change area detected as a mass by means of labeling.

(2) Final Establishment Tool

The final establishment tool is designed to assist experts performing the final judgments, and inputs the colored map and center coordinate list obtained with the automatic detection tool. While the results of automatic detection indicate three types of changes including new construction, loss and color change, the final establishment tool is also capable of more detailed categorization of change types (new construction after loss, works in progress, etc.) according to the requirements of municipalities.

4. Comparison Evaluation

In fiscal 2005, we tested stereo processing by creating the DSM information of 2,800 photographs (on-ground resolution 12.5cm) of the Tokyo Metropolitan area, and obtained approval by Japan Association Surveyors that the results were within the standard error tolerance of 50cm horizontal accuracy and 1.0m vertical accuracy. For the change detection, we conducted comparisons for 10 photographed districts in the Shinagawa District and confirmed that the following changes were detected without exception by comparing the results with separately conducted visual judgment operations.

- Height changes: Horizontal or vertical change by 2 meters or more, in areas of 1× 2m or wider.
- Color changes: In areas of 2 × 2m or wider.

As it is estimated that the time taken for the manual final establishment operation is 2 to 3 hours per pair of images our system can offer an operation time reduction effect of about 60% compared to the time taken for the traditional judgment process by one person as shown in **Fig. 8**. The time saving effect may be even larger if our system is compared to a multi-operator system as shown in Fig. 2.

5. Conclusion

In the future, we will promote our system for house change detection operations for use by more municipalities as well as encouraging its application in other fields, such as for the de-

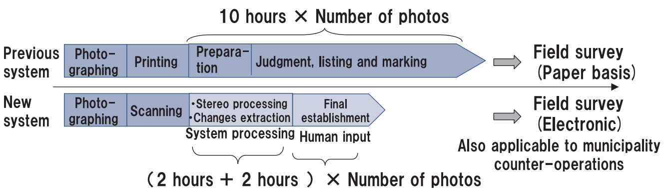

Fig. 8 Time reduction effect of automation.

tection of ground profile changes after a disaster.

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