# SEMI-AUTOMATIC DETECTION OF LAND USE CHANGE FROM DIGITAL AERIAL PHOTOS

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## ABSTRACT

It is necessary for map revision work to find out land use changed areas from aerial photos. Several attempts utilizing computer processing of digital aerial photo images have been made and examined aiming at increasing efficiency of change detection. Among them, three methods and their results are reported in the paper. One is to compare old and new DEMs derived from automated stereo matching. It was possible to detect new construction of houses. But further study is required to apply the method to various change patterns. Another method is to pick up roads by color classification of color aerial photos. By comparing the results of road extraction, new roads could be visualized. The third method is to use existing digital map data to mask out unnecessary area from aerial photo image and thus to enhance the efficiency of manual change detection. Some increase of efficiency was observed but with the slight increase of omissions of detection. Further elaboration is required for practical application of these methods. It is considered that combination of multiple data sources together with effective combination of multiple methods is necessary for improvement.

## 1. INTRODUCTION

Digital cartographic data corresponding to large scale maps such as 1:2,500 have been prepared in many municipalities in Japan nowadays. The wider the covering area grows, the more the needs to update digital maps are recognized. To increase the efficiency of revision work of digital cartographic data is one of the most important research target in mapping technology. On the other hand, digitized aerial photo image has become readily available owing to the development of digital photogrammetric instruments. This situation motivates us to develop techniques of automated digital map revision through computer processing using newly taken aerial photo images. However image understanding of aerial photos by computer is still challenging field of research and complete automation do not seem to be accomplished in near future. Therefore we set up our research target as change detection from aerial photo data to help works of human operators. Several attempts have been made in this research project. Some of the results are described in detail in the paper.

The methods so far tried can be classified as follows: (1) to limit possible candidates of changed areas by comparing the results of some kind of classification obtained through digital image processing of aerial photos of two different time; (2) to increase efficiency by limiting the area to be examined by human operator using existing digital cartographic data; (3) To enhance operator's visual recognition with various digital image processing to aerial photos. As for the class (1), we tried and examined many methods, such as a method to use height information obtained through automatic stereo matching, a method to classify possibility of change with correlation coefficient between aerial photo image of two different times, a classification method using color information of color aerial photos, comparison of power spectrum of land use patterns after Fourier transform and so on. Regarding the class (2), masks corresponding to roads and existing houses were made from digital cartographic data and were overlaid on new aerial photos so as to help to detect newly constructed houses. Various edge detection and edge enhancement methods including emboss filtering have been applied and compared in the class (3).

## 2. CHANGE DETECTION BY THE COMPARISON OF NEW AND OLD DEM FROM STEREO MATCHING

Digital photogrammetric instruments are nowadays becoming popular. They have capability to produce minute DEMs (digital elevation models) by automatic matching of stereo pair aerial photos. The difference of DEMs derived from old and new photos are used as the indication of change.

### 2.1 Method

**2.1.1 Test site and used materials and system:** The test site was chosen in Fukuyama city, Japan where aerial photos of 1987 (1:12,500 Color) and 1994 (1:25,000 B/W) are available as well as an old map of 1987 on a scale of 1:2,500. The test site is shown in Figure 1 (Map) and Figure 2 (Orthophoto). The digital photogrammetric system used here is named PyramidStereon (Oyama, 1996) which is composed of a personal computer, stereo viewing system, peripheral devices, and software.

**2.1.2 Method:** Aerial photos are scanned in 50 $\mu$m sampling interval for old photos and in 25 $\mu$m for new photos respectively, both corresponding to 0.625 m on the ground. DEMs with 2.5 m grid interval were generated from both the photos by stereo matching. DEM was also generated from contour lines of the 1:2,500 topographic map. Another DEM from old aerial photos was made by a human operator using an analytical stereo-plotter. The height on the roofs or tree tops

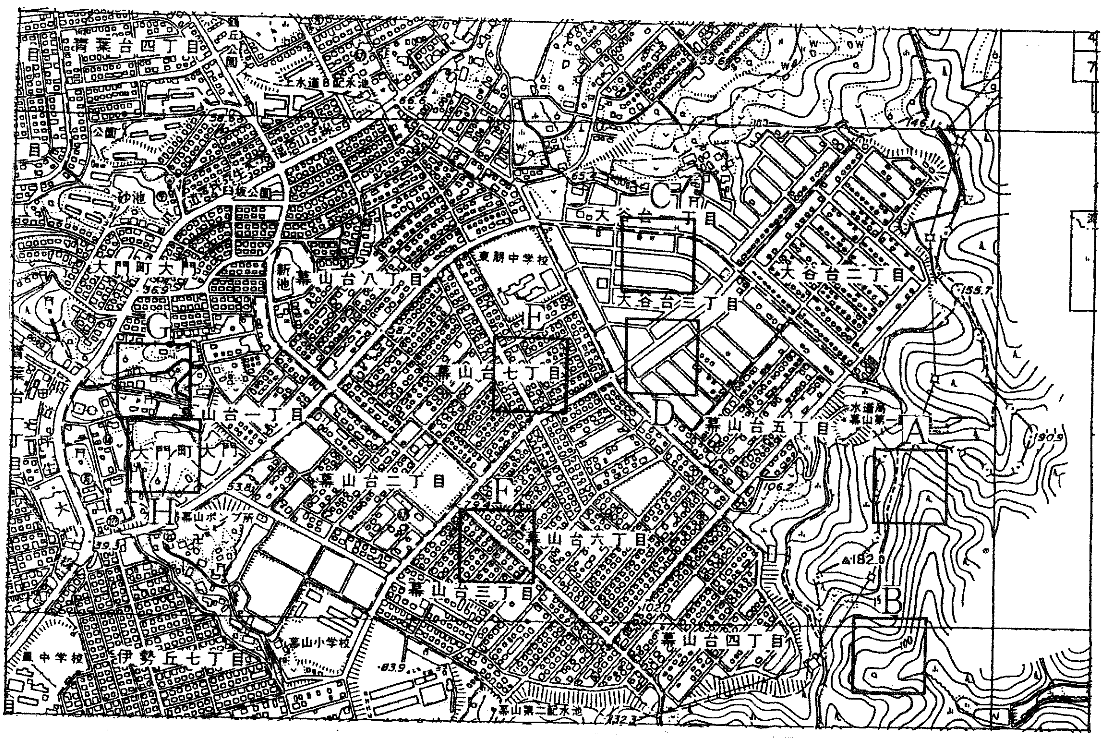


Figure 1 Test site of Section 2 (Map of 1987)

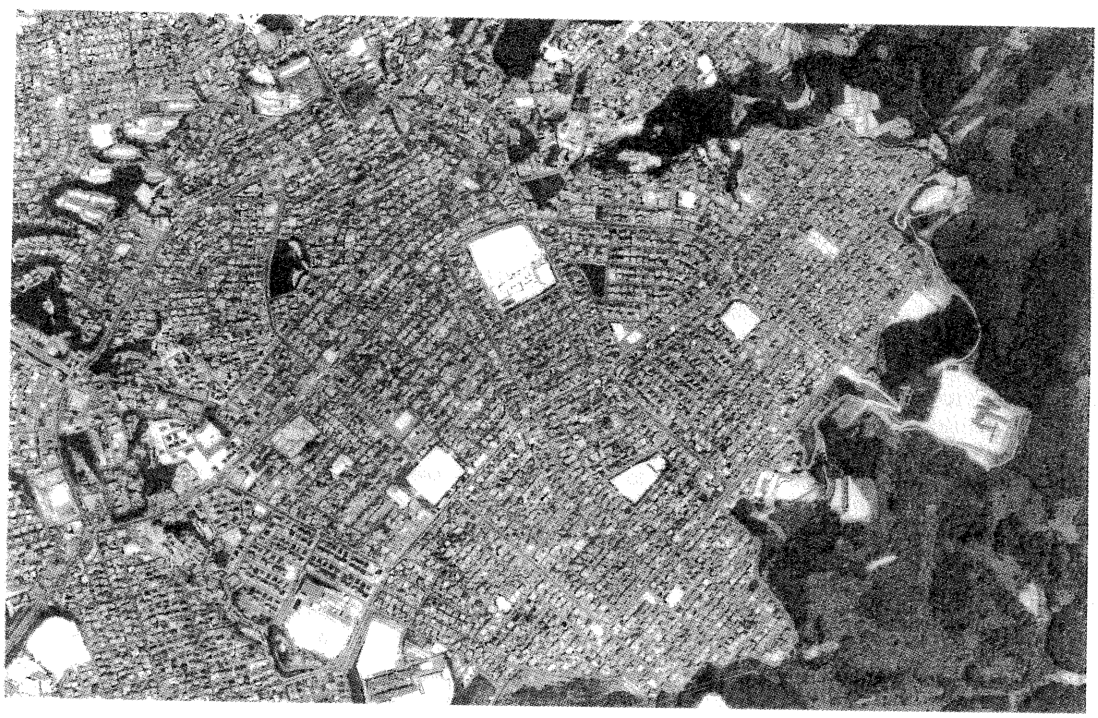

Figure 2 Test site of Section 2 (Orthophoto of 1994)

were measured in this measurement and this DEM was used to check the accuracy of automatic matching. Namely following four kinds of DEM were prepared, the posting interval of which is 2.5 m on the ground for every DEM.

(1) DEM made from old photos (1987) by stereo matching
(2) DEM made from new photos (1994) by stereo matching
(3) DEM made from contour lines of 1:2,500 map (1987)
(4) DEM made from old photos manually using a stereo-plotter

Five test area were chosen in the test site. Each test area is 150 m × 150 m in size and therefore has 61 × 61 grid elevation points. The land use and its change of test areas are shown in Table 1.

Statistical parameters of height in each test area were calculated and examined whether these can be used as the indication of land use change. Statistical parameters were also calculated for changed test area size by dividing the areas into four or nine in order to find out appropriate area size for this analysis.

Table 1 Test areas

| Test area name | Land use in 1987 | Land use in 1994 |
|---|---|---|
| C | Bare land | Houses |
| D | Bare land | Houses |
| E | Houses | Houses |
| G | Trees and houses | Houses |
| H | Trees | Bare land and houses |

### 2.2 Results

**2.2.1 Comparison of DEM (1) and (4) — Accuracy test:** DEM made by automatic stereo matching was compared with the DEM measured manually with a stereo-plotter. This result shows accuracy measures of automatic matching. The source material is old aerial photos. The results are shown in Table 2 for the test areas.

Table 2 Comparison of DEM (1) and (4) — Accuracy test

| Test area | Mean height of (1) (automatic) $H_1$ | Mean height of (4) (manual) $H_2$ | Difference of the mean $d$ | Standard deviation $\sigma$ |
|---|---|---|---|---|
| C | 78.66 | 78.49 | +0.17 | 1.00 |
| D | 87.47 | 87.57 | -0.10 | 0.92 |
| E | 78.57 | 78.81 | -0.24 | 2.06 |
| G | 31.35 | 31.68 | -0.33 | 2.35 |
| H | 43.84 | 46.55 | -2.71 | 4.49 |

unit: meter

Here $H_1$ and $H_2$ are the mean of height inside the test areas. These statistical parameters are defined as

$$n = 61 \times 61$$

$$H_1 = \sum_i h_{1,i} / n$$

$$H_2 = \sum_i h_{2,i} / n$$

$$d = H_1 - H_2$$

$$\sigma = \sqrt{\sum_i (h_{1,i} - h_{2,i} - d)^2 / (n-1)}$$

where $h_{1,i}$ and $h_{2,i}$ are height at grid point $i$.

It can be seen from the result that the differences of the mean height value are small and standard deviations which are the indication of accuracy of automatically derived height are within about two meters except for tree area. Therefore we consider the DEM of automatic stereo matching has enough accuracy for the purpose of change detection except for tree areas.

**2.2.2 Comparison of DEM (1) and (2) — Change detection by the difference of DEM from stereo matching:**
DEMs at two different time obtained from stereo matching were compared against each other in order to test the feasibility of the method. The results are shown in Table 3.

Table 3 Comparison of DEM from stereo matching

| Test area | Mean height of (2) $H_1$ (1994) | Mean height of (1) $H_2$ (1987) | Difference of the mean $d$ | Root mean square error $r$ |
|---|---|---|---|---|
| C | 79.89 | 78.66 | +1.23 | 2.23 |
| D | 88.72 | 87.47 | +1.25 | 2.05 |
| E | 79.05 | 78.58 | +0.47 | 1.90 |
| G | 33.42 | 31.35 | +2.07 | 3.49 |
| H | 40.38 | 43.84 | -3.46 | 6.40 |

$$r = \sqrt{\sum_i (h_{1,i} - h_{2,i})^2 / (n-1)}$$

Root mean square error $r$ is defined slightly different from the above "standard deviation" $\sigma$. This is because the difference itself has the meaning that height change occurred during the time interval in this case but in the former case the height should be the same and the difference is considered as an error.

It can be seen from the Table 3 that test areas C and D where bare lands turned to housing areas have average height increase due to newly constructed houses whereas change of average height is small in area E (+0.47 m) where no land use change occurred. Area G changed from trees and houses to housing area. Cutting trees decreases height and house construction increases height. It seems mixed effect of these appeared in area G. Trees are cut widely in area H and land is prepared for building houses. This situation results in different values in the mean height difference and the root mean square errors.

Therefore it can be said that change of average height or root mean square error in an area between two time may be used as the indication of land use change when height is measured by automatic matching of stereo pair photos. But there remains two mutually related problems. One is to determine the threshold value to judge change has occurred in the area. The other is to determine an appropriate area size. If the area where statistical parameters such as a mean and a root mean square error are calculated is large, then many kinds of land use and land use change patterns are included in one area and this method does not work well. On the other hand, if the area is small, errors in height measurement cause much erroneous detection of change. If the result of stereo matching become much reliable, then it will be possible to use height data at every grid point to detect changes.

**2.2.3 Effect of area size:** As mentioned above, it is desirable for this method of change detection that land use is as uniform as possible in a selected test area. When the area is smaller, the land use in the area is more uniform. Therefore the effect of area size is examined by dividing the test areas into four and nine. The difference of mean heights between two periods are shown below for the original and divided areas.

Table 4 Difference of the mean heights

From left to right: original area (150 m square), four division (75 m square), nine division (50 m square).

Area C (Bare land → Houses)

| | | | | | |
|---|---|---|---|---|---|
| 1.23 | 1.96 | 0.89 | 2.38 | 1.26 | 0.18 |
| | | | 2.12 | 0.98 | 0.79 |
| | 1.29 | 0.87 | 1.77 | 1.23 | 0.56 |

Area D (Bare land → Houses)

| | | | | | |
|---|---|---|---|---|---|
| 1.25 | 1.17 | 1.18 | 1.63 | 1.46 | 0.56 |
| | | | 0.69 | 1.18 | 1.51 |
| | 1.32 | 1.37 | 1.61 | 1.07 | 1.61 |

Area E (Houses → Houses)

| | | | | | |
|---|---|---|---|---|---|
| 0.47 | 0.62 | 0.46 | 0.46 | 0.48 | 0.31 |
| | | | 1.41 | 0.28 | 0.65 |
| | 0.73 | 0.17 | 0.80 | 0.09 | -0.04 |

(continued)

Area G (Trees and Houses → Houses)

| |
|---|
| 2.07 |

| | |
|---|---|
| 0.69 | 3.47 |
| 2.37 | 1.83 |

| | | |
|---|---|---|
| 0.15 | 0.07 | 3.99 |
| 2.36 | 2.20 | 4.07 |
| 2.64 | 1.48 | 1.84 |

Area H (Trees → Bare land and houses)

| |
|---|
| -3.46 |

| | |
|---|---|
| -2.71 | -4.93 |
| -1.18 | -5.17 |

| | | |
|---|---|---|
| -2.99 | -4.21 | -1.28 |
| -1.29 | -6.54 | -8.45 |
| -0.58 | -4.21 | -1.94 |

It can be seen from these results that in area C and D, difference values have positive value and vary larger among divided areas when the division become smaller. This can be attributed to the fact that the ratio of newly constructed houses is different within the small divided areas. On the other hand, area E has no land use change in the period but shows mean height changes of +0.17 to +0.73 m in four division and -0.04 to +1.41 m in nine division. These errors are considered to be some mis-matching in stereo matching and are compensated by taking the average. From this example, we temporarily drew a conclusion that appropriate area size is 75 m square and threshold of mean height is about 0.8 m for finding changes from bare land to houses.

**2.2.4 Comparison of DEM (1) and (3) — Trial to recognize land use by the difference of height data:**
By comparing DEMs of the old photo and of the map, houses and school buildings are visualized because height drawn on a map is ground height whereas height obtained by matching is the height on top of buildings. But it was difficult to get meaningful criteria to recognize land use from such statistical approach done in as sections 2.2.1 and 2.2.2. This comparison, however, should be useful to visualize large buildings and houses when normal ground height DEM is readily available. It may also suggest the extent of errors of DEM obtained by stereo matching.

### 2.3 Discussion

The comparison of DEMs at different time derived by automatic stereo matching gives information of land use change. It was found that about 75 meters square is appropriate for the area size of taking average for change detection from bare land to houses and the threshold is around 0.8 meter. It is still to be done to find out appropriate area sizes and threshold criteria of mean height change for various kinds of land use change patterns.

If height value at each grid point is much more accurate, we can proceed to check the change at each grid point instead of taking average of large area. Therefore it is an important issue for this research to examine the accuracy of automatic stereo matching. We consider the following topics should be studied in this regard: (1) to carry out stereo matching using other digital photogrammetric instruments or matching softwares and examine the accuracy of obtained height value, and (2) to check the effect of scanning pitch and scale of aerial photos; the height accuracy seems to be improved when sampling pitch on the ground is smaller, namely by using large scale aerial photos and minute scanning pitch.

Another issue is to combine every available data source with the height data from stereo matching. For example, if height data are combined with digital cartographic data with boundary line of buildings, then new construction and disappearance of houses might be detected one by one. These issues should be the research items in the next phase of the study.

## 3. CLASSIFICATION USING COLOR INFORMATION

The objective of this method is to utilize color information of color aerial photos whenever they are available, for reducing human work load in change detection. Change of roads could be visualized after several steps of image processing, including color reduction, applied to color aerial photo images.

### 3.1 Background

The basic idea was to use color aerial photos and to enhance the image by restricting number of colors into very small limited number such as 8, 16, 24, or 32. It was found that this color reduction can help recognition of change by human operator to some extent. It was also found that cubic close-pack algorithm was better than popularity algorithm or median cut algorithm as color reduction algorithm. But automatic change detection is still difficult because color or gradation of aerial photos varies by various photographing conditions such as season, time of a day and so on, and there is no easy way to establish correspondence between colors of photos at different time.

Based on this experience, we decided to restrict our target here to change detection of roads, important objects in a map. Roads are considered to have less color variation on image than any other objects. The method is to give knowledge by human operator to the result of color reduction.

### 3.2 Method

Change detection of roads from color reduction was done as follows. Color aerial photos taken in 1979, 1984 and 1992 on a scale of 1:10,000 were scanned at 400 dpi resolution. Test site was Kodaira city in Tokyo. Number of colors was reduced to 24 colors by cubic close-pack algorithm. Then the colors corresponding to roads were selected manually for image of each year. After eliminating salt-and-pepper noise by expanding-shrinking and smoothing processing, elimination of components other than roads, for example parking areas, was executed. This was done as follows. At first labeling was carried out according to color code of each pixel. Then label numbers of 4-neighbor of a pixel are examined and the number of pixels having the same label number was summed up for every pixel in a label. The sum was divided by the total number of pixels within the label. If this ratio exceeded some threshold value (value used were 6.25 - 7.25), the label component was regarded as lumps and non-road components.

Image data of roads was made through these processes for each year's photo. Changes of roads were visualized by comparing these data. Although there still remains some errors and noises, these images show change of roads clearly.

### 3.3 Results and discussion

The extracted road components of color aerial photos of 1984 and 1992 are shown in Figure 3 and Figure 4. By overlaying these images, change of roads is visualized. As can be seen on these figures, there still remains non-road component. By comparing them with the original photos, it was found some road components disappeared in the final result. Therefore this method can be used for fast finding of change of roads but it cannot be used for automatic revision. Another problem is that it is not clear whether this method can improve efficiency of change detection because this method requires conversational operation of a human operator.

Figure 3 Extracted road components of 1984

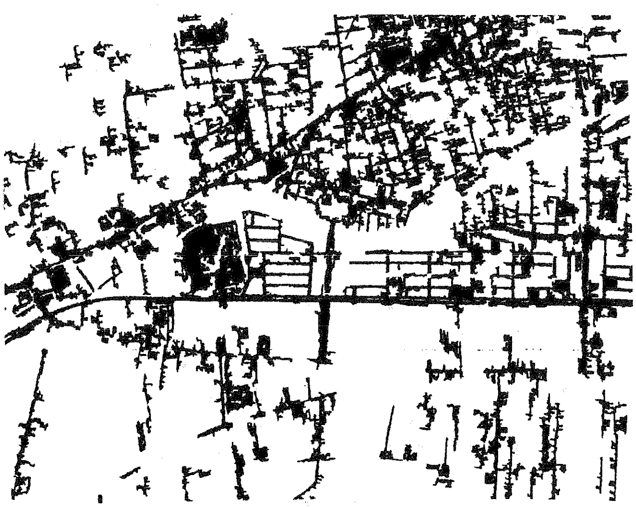

Figure 4 Extracted road components of 1992

## 4. ENHANCEMENT OF EFFICIENCY OF MANUAL CHANGE DETECTION WITH OLD MAP DATA AND NEW AERIAL PHOTOS

The objective is to make it easy to manually identify changed areas in updating work of digital cartographic data. In this situation, unrevised digital map data are available. Hence these old map data are used to mask out unnecessary part on the new aerial photos which are used to find out changed parts. Another idea is to apply an emboss filter onto aerial photo images to enhance visibility of images for change detection purpose. The efficiency was tested by measuring the time required for revision work.

### 4.1 Method

We set up here the target of detection to be the new construction of houses (disappearance of houses is ignored here). Then already existing houses and buildings need not be checked. It is unlikely that new buildings are constructed on existing roads. Therefore existing houses and road surfaces are masked using old map data and the remaining part on the photo was checked by operators on the CRT. Required time for revision work and its accuracy were tested. Single aerial photo is used and a mask made of digital map data is overlaid on it after projection transformation to locally register the position. Masks of existing houses are expanded with 5 m width in order to fill out unnecessary space between houses.

Emboss filter modifies an image like a relief picture and eliminates unnecessary details. This filter was applied together with the mask and the effect was examined.

Examples of masked aerial photo image and that with emboss filtering are shown in Figure 5 and Figure 6.

The following data are used for the test. These are the same data used in section 2.

- Old digital map: Fukuyama city, 1:2,500, 1987
- New aerial photo: ditto, 1:25,000 B/W, 1994
  scanned in 25 $\mu$m sampling pitch

Figure 5 Masked aerial photo image

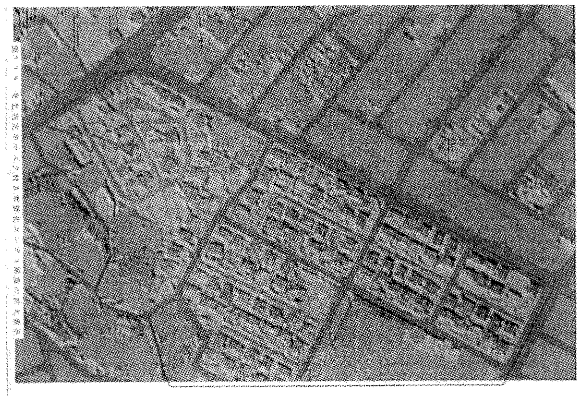

Figure 6 Masked aerial photo image with emboss filtering

### 4.2 Results

Four test areas are selected (These are different from those of section 2). Time of digital map revision work was measured for a non-experienced operator and an experienced operator. The results are shown in Table 5 and Table 6.

Table 5 Time required for revision work — Non-experienced

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 70 | 90 | 120 | 70 |
| with masks | 60 | 80 | 120 | 60 |
| with masks and emboss filtering | 40 | 70 | 90 | 45 |

unit: minute

Table 6 Time required for revision work — Experienced

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 30 | 35 | 54 | 30 |
| with masks | 31 | 30 | 55 | 32 |
| with masks and emboss filtering | 17 | 24 | 47 | 17 |

unit: minute

The houses to be added in the revised map were checked by stereoscopic observation of aerial photos and the number of them in each test area is shown in Table 7.

Table 7 Number of houses to be added

| Area A | Area B | Area C | Area D |
|---|---|---|---|
| 144 | 73 | 258 | 141 |

To see the accuracy of each method, number of omissions and erroneous inputs are summarized in Table 8-11 for each operator.

Table 8 Number of omissions — Non-experienced operator

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 2 | 13 | 2 | 4 |
| with masks | 6 | 9 | 5 | 1 |
| with masks and emboss filtering | 6 | 15 | 5 | 0 |

Table 9 Number of omissions — Experienced operator

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 0 | 5 | 0 | 0 |
| with masks | 1 | 15 | 0 | 0 |
| with masks and emboss filtering | 0 | 9 | 1 | 0 |

Table 10 Number of erroneous inputs — Non-experienced

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 1 | 4 | 6 | 1 |
| with masks | 0 | 8 | 1 | 2 |
| with masks and emboss filtering | 1 | 11 | 7 | 2 |

Table 11 Number of erroneous inputs — Experienced

| Aerial photo image | Area A | Area B | Area C | Area D |
|---|---|---|---|---|
| with digital map overlay (no other pre-processing) | 1 | 2 | 4 | 1 |
| with masks | 0 | 4 | 2 | 1 |
| with masks and emboss filtering | 1 | 17 | 9 | 2 |

The effectiveness of masking is not clear from the result (Table 5 and 6). Some speeding up was observed for a non-experienced operator but no effect was observed for an experienced operator. One of the problem of masking is that the number of omissions increased by the experienced operator in area B where many houses already existed. It was found that about 30 % of these omission was caused by being buried under expanded masks. Therefore the amount of expansion must be carefully chosen.

Emboss filtering has considerable effect of speeding up for both non-experienced and experienced operators. But the number of erroneous inputs increased. It is therefore hard to justify simply adopting the emboss filtering.

### 4.3 Discussion

In this method, human operators digitize the line of houses looking at CRT screen. It was felt by the operator that reference photo images should have higher resolution than 0.5 m on the ground. Otherwise the outline to be digitized is unclear and emboss filtering also do not generate clearly visible outline.

Emboss filter is effective for finding houses constructed newly on bare lands. But it is not much effective for finding houses in already developed area. Some other method should be developed for the case.

The experiment was for detection of new construction only. To apply inverse of the above masking image can be used to detect disappearance of houses.

## 5. CONCLUSION

Several methods have been tested to detect changes from image processing of aerial photos. Some of them are promising in view of reducing human work load. It seems that height data obtained by automatic stereo matching give useful information on land use change. Study in this direction should be further pursued aiming at adaptation to practical mapping process.

Image understanding of aerial photo is very difficult problem and it is impossible to get practical result only with this approach. Therefore it is important to combine every available data source in order to get practically useful result. This multi-data fusion approach, in particular effective utilization of existing digital cartographic data, should be the subject of the next phase.

## REFERENCES


Geographical Survey Institute, 1996. Study on semi-automatic analysis of aerial photos for land use change detection (The 2nd year). Geographical Survey Institute, Tsukuba. (in Japanese)

Geographical Survey Institute, 1995. Study on semi-automatic analysis of aerial photos for land use change detection (The 1st year). Geographical Survey Institute, Tsukuba. (in Japanese)

Oyama, Y., 1996. Semi-automatic digital photogrammetric system on PC. In: International Archives of Photogrammetry and Remote Sensing, Vienna, Austria, Vol.XXXI (to be published).