SIMPLE TOOL FOR COST ESTIMATION OF RECOVERY OF DAMAGED SITES

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ABSTRACT: Recently, Home use digital camera equipped with GPS and compass are available in the market. Some of them are equipped with accelerometer and perform positioning in places where receiving GPS signal is difficult. Using such digital cameras, we can record position and direction of cameras on EXIF information of pictures. When it is shown on maps using GIS, we can identify position of targets shown on pictures.

Since 2006, we have been developing a simple software tool for cost estimation of restoration of damaged sites. The tool is a combination of close range photogrammetry, CAD and spread sheet. The tool also provide simple digital surface model of the target site. So far, the out put of the tool does not have information of position. We had to plot the location of target site on digital map manually. Now the picture has information of position of camera and pointing direction. Thus we can report, damage and apply expense sharing by National treasury for recovery on more persuasive documents.

1. INTRODUCTION

Japanese territory lies in hazardous area. It is on the course of Typhoons, on the circum Pacific seismic belt and so on. Thus public civil engineering works in Japan are subject to damage caused by natural disaster. Public civil engineering works are essential for daily life of public and should be restored quickly. In Japan, Central government shares restoration expense born by local government and municipalities according to 'Act on National Treasury's Sharing of Expenses for Project to Recover Public Civil Engineering Works Damaged by Disaster' to ease burden of local government and municipalities so that restoration will be done quickly.

As is well known, smaller damage occurs more frequently than large ones. Restoration of small damages usually do not cost much. In such case, cost for requesting sharing of expense by central government will become large part of total cost. To efficiently use budget, Central government allows simplified procedure and unit price for typical restoration works. Then, we can apply simple CAD and spread sheet to make restoration work design document. The damaged sites need to be photographed as evidence. Recently, quality of home use digital cameras have enhanced very much so that they can be used for photogrammetric purpose. Then, it is wise way to use such photos for close range photogrammetry to obtain standard cross section of the site. Then the situation of those damaged sites and cost required for restoration will be plotted on GIS for presentation and statistics purpose. Recently, digital cameras equipped with GPS are available with reasonable price, and also free GIS engines, background maps provided on line free are available. We carried out demonstration of application of such free GIS systems and free maps to show Photog-CAD derived information effectively.

2. CONCEPTUAL DESIGN

As the purpose of developing this software is to ease human labor and total cost of restoration works, we tried our best effort to make the software simple, easy, stable, reasonably priced and fairly precise. To meet such request, it is preferable to design the software as integration of existing photogrammetry and CAD software. Precision required for inspection of necessity and adequacy of restoration work is about 10cm in relative position. 3D surface model building of a damaged site and design of restoration work are basically independent. Therefore, we can design the tool as sequential call of two independent

modules. Procedure for preparation of document for requirement of inspection is as follows.

Put (or find) reference marks
Put or select vertical object
Measure scale
Take photographs from 3 directions
Download photographs from a camera
Run Photogrammetry module
Estimate orientation parameters
Increase model points by automatic stereo matching
Select cross sections
Save cross section data
Run CAD module
Select work items from pull down menu
Design restoration work
Calculate volume of work
Estimate cost with spread sheet
Lay out document on spread sheet

The procedure should be simple and at the same time, the software should be reasonably priced. We need some compromise between automated processing and manual assistance. User will check reference marks on photos manually with assistance of software. Orientation and increase of model points are automatically done but increased points must be edited manually so that irregular points such as on the grass leaves are to be removed. Selection of work item is also done manually. Thus we can provide the software with reasonable price.

3. PHOTOGRAMMETRY

Most of home use compact digital cameras now in market have sufficiently good quality. They are equipped with optical lenses, high resolution photo-sensors. Theory of estimating exterior orientation parameters is well known as collinearity condition. It requires that object, optical center of lens system and image on optical sensor must be in a straight line. By rotating coordinate axis, we can transfer to coordinates fixed to a camera. Then, we can write down mathematical model through simple geometrical consideration (Fig.1).
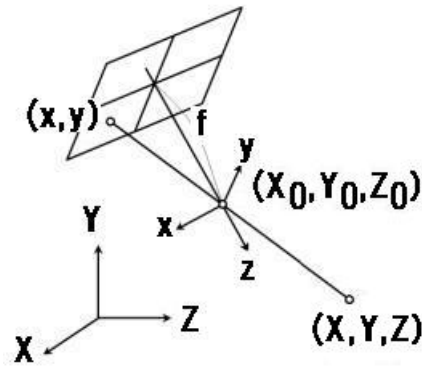

Figure1 Geometrical relationship

The coordinate axis here is a left hand system. We apply counter-clockwise rotation first around z-axis, then around y-axis, then around x-axis to make Local coordinate axis be parallel to camera coordinate axis. Derived mathematical model is as follows.

$$x = f \frac{a_{11}(X - X_0) + a_{12}(Y - Y_0) + a_{13}(Z - Z_0)}{a_{31}(X - X_0) + a_{32}(Y - Y_0) + a_{33}(Z - Z_0)}$$

$$y = f \frac{a_{21}(X - X_0) + a_{22}(Y - Y_0) + a_{23}(Z - Z_0)}{a_{31}(X - X_0) + a_{32}(Y - Y_0) + a_{33}(Z - Z_0)}$$

where

$$\begin{pmatrix} a_{11}, a_{12}, a_{13} \\ a_{21}, a_{22}, a_{23} \\ a_{31}, a_{32}, a_{33} \end{pmatrix} = R_x(\omega) R_y(\kappa) R_z(\phi)$$

$$R_x(\omega) = \begin{pmatrix} 1, & 0 & , & 0 \\ 0, & \cos(\omega), & \sin(\omega) \\ 0, & -\sin(\omega), & \cos(\omega) \end{pmatrix}$$

$$R_y(\kappa) = \begin{pmatrix} \cos(\kappa), & 0 & , -\sin(\kappa) \\ 0, & 1 & , 0 \\ \sin(\kappa), & 0 & , \cos(\kappa) \end{pmatrix}$$

$$R_z(\phi) = \begin{pmatrix} \cos(\phi), & \sin(\phi), & 0 \\ -\sin(\phi), & \cos(\phi), & 0 \\ 0, & 0, & 1 \end{pmatrix}$$

As interior orientation model, we apply 5th order radial distortion model

$$d = k_1 r^3 + k_2 r^5$$

These 2 parameters and focal distance are estimated using triplet method.

When we put more than 9 reference points on object site, and take photographs from 3 directions. we can estimate all necessary parameters by least squares estimation.

When orientation parameters are known, we can trace light path and find corresponding points roughly on images. Then we take correlation of images of photographs from 3 directions to find images of same point on each.. By doing so, we can increase nodes of TIN model of damaged site. Then cross sections are selected and stored in storage to be used in designing restoration work.

4. DESIGN AND COST ESTIMATION

When data of cross sections are exported as a file, we call CAD module for designing restoration work. The CAD module can refer built in database of standard work items and unit price of them for each prefecture. When we apply standard work items, we can simply select one from pull down menu and then, unit price and CAD parts are set automatically. When local work items are to be applied, we can draw CAD parts manually and register them manually. Once new items are registered, they can be used repeatedly on the PC.

5. APPLICATION OF GIS

Recently, some of compact digital cameras are equipped with GPS and digital compass. Those cameras record latitude, longitude and pointing direction as EXIF information together with photograph in JPEG format.

Figure 2. Example of EXIF data extracted with a free software

Figure 2 is an example of EXIF information. EXIF information can be easily extracted with free software. Fundamental information of the photograph recorded in EXIF is read by Photog-CAD to set initial value for interior orientation. So, it is straight forward to read GPS and compass information if available. When we can use a digital camera equipped with GPS and digital compass, we can easily plot camera positions and direction of damaged sites. A digital compass uses geomagnetic field as the reference of direction. It is well known that geomagnetic north is slightly different from true north (Geomagnetic Declination). In case of Tokyo for example, declination is about 7degree to west. Some camera record direction in reference to geomagnetism others correct declination using model to record true azimuth. The accuracy is not quite high but usually distance between the camera and the target will be several tens of meter and positional error due to direction will be to the order of one meter. Precision of point positioning using GPS will be 10meter or so. Some times worse. Therefore we can use recorded position and direction (corrected for declination if necessary) for identification of damaged site on a map. For reporting and statistic purpose, it will be desirable to use GIS. Because graphical presentation will help people understand the distribution, scale of damage and so on.

As one of aims of developing this software is to supply a useful tool with reasonable price, we are going to use FOS (Free or Open Software) as a GIS engine. Here, we will pick up Cyber Japan provided by Geospatial Information Authority of Japan (GSI) and Quantum GIS as examples.

5.1 CYBER JAPAN

Cyber Japan is a simple GIS service provided by GSI. AS the Japanese National Mapping Organization, GSI maintains 1/25,000 national base map and 1/2,500 Fundamental Geospatial Data (FGD) in urban area. GSI opens those maps on line together with simple GIS engine. They call the total system Cyber Japan. Because maps and an engine are provided by GSI free of charge, what users must prepare are just data in XML files to be plotted on the map. GSI also provides CSV to XML converting service.

Therefore users are requested to prepare coordinates of the sites, icons if necessary and URL of HTML document with detailed information of the site. In figure 3, map displayed using Cyber Japan web system is shown.

Figure 3 map displayed using Cyber Japan

Background maps used in this system are in default 1/25,000 topographic map. If viewed in the same scale, topographic maps are more informative than FGD which have only 13 layers. When URL of linked file or site is included in prepared XML document, the document or site will be shown in new window on click of the icon.

Cyber Japan Web System is equipped with a function of selecting object by rectangle.

Figure 4 Link to HTML on click of icon

There are some tools provided by GSI available on line. For efficiency, we coded small tool to read EXIF data and

URL and then output two XML files. As this is an experiment the tool is external. This can easily be built in Photog-CAD.

To use this system, we must be on broad band line. And GSI requires the created site be visible from general public. It is quite understandable requirement. Sometimes however, users may be reluctant to open up sensitive information. Even so, Cyber Japan will be one of the easiest platform open to public and all the necessary technical information are also open on line.

5.2 QUANTUM GIS

Quantum GIS is an open source GIS engine by Open sours Geospatial Foundation. This software is basically stand alone system (easy to export maps as Map Server data). It means we need maps. Fortunately in Japan, according to NSDI Act, GSI provides 1/25,000 FGD all over Japan and 1/2,500 FGD in urban area free of charge. So, we can use FGD as back ground map and plot Photog-CAD data on it. To prepare data, we can again use free software. CSV to Shape converter is available. FGD are originally in JPGIS (Japanese profile for TC/211 standard format). JPGIS to Shape converter is again available as free software from GSI. Figure 5 shows positions and pointing directions of camera.
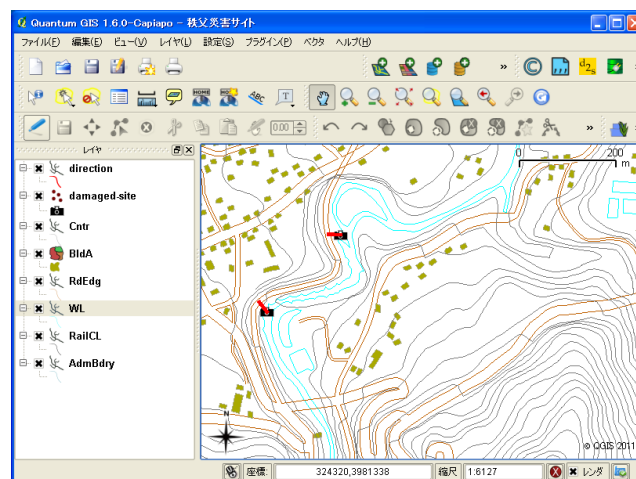

Figure 5. Camera position and pointing direction plotted on a FGD

As this is an experiment, we used existing free-software to extract GPS and compass data and convert it to Shape file

together with link information. Again, it is rather straight forward to build this procedure into Photog-CAD.
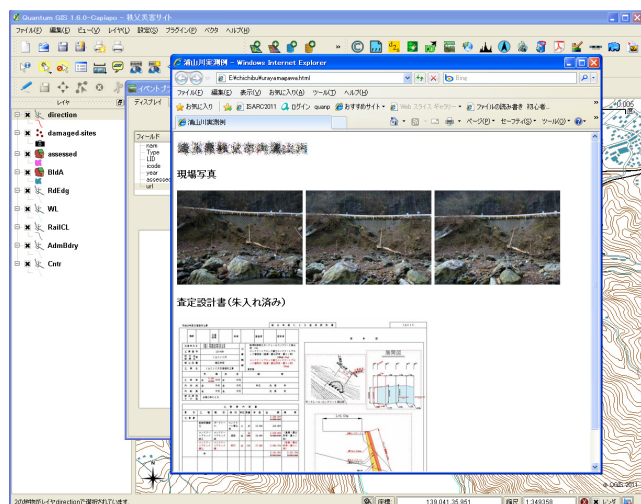

Figure 6. Detail is shown as linked HTML document

There are many useful plug-in's for Q-GIS. Here, we used event visualization plug-in eVis plug-in distributed together with the engine. The plug-in allows us to jump to linked object on crick the URL in pop-up window. We can prepare full information in HTML document for each site and distribution of damaged sites on map. To make a statistic, we can use buffering function of core plug-in for Q-GIS. In case of Q-GIS, we can generate buffer and then simplify it and use 'Select object by polygon' function to select object (Figure 7). After selection, we can display attributes as is shown in Figure7. Then, for example, we can sum up necessary expenditure along one branch of river.
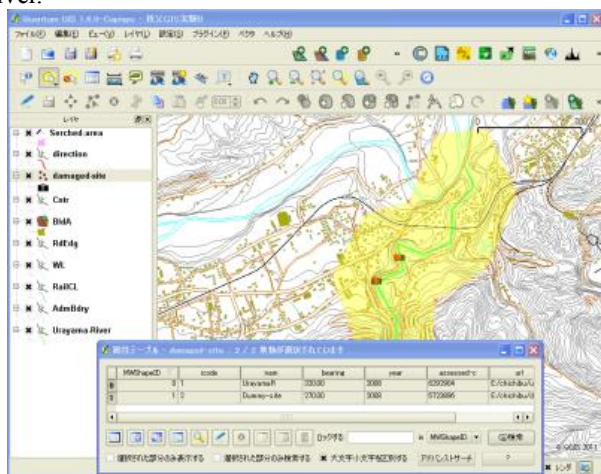
Figure 7 Select sites

Thus, even small municipalities that can not spend too much for just requirement of expenditure support from national treasury for restoration can efficiently carryout survey, design, cost estimation and presentation.

6. CONCLUSION

Simple, easy to handle and reasonably priced software named Photog-CAD for efficient preparation for requirement of expenditure support from national treasury for restoration was developed. The software can handle each damaged sites one by one. For presentation and statistic purpose, we must handle data within certain area. For such purpose, application of GIS is desirable. For experiment, we coded small tools and also applied existing free software and demonstrated easiness of realization of those function as part of Photog-CAD's function.

As GIS there are definitely many other tools or platforms available for free or quite small cost. Important thing is to find suitable platform and code small tools if necessary and use them together with Photog-CAD. It will ease and speed up recovery from disaster.

Application of GIS for statistics and presentation purpose is easily possible even now with existing free software. For efficiency, we coded small tools. Those tools are just simple and small and easy to be built into Photog-CAD.

7. ACKNOWLEDGEMENT

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ADDITIONAL NOTE

On March 11, Paciffic coast of Northern Japan was hit by M9.0 earthquake and accompanied Tsunami.   Quite wide area was demolished.   To support preparation for restoration work, we decided to distribute Photog-CAD to stricken municipalities free of charge and started distribution on March 22nd.   We hope this action will be of some help. We sincerely hope people of northern Japan will overcome this disaster.

We also want to extend our sincere thanks to ISARC 2011 organizing committee and other related people for expressing their sympathy and encouragement.