

# WEB PHOTOGRAMMETRY : STEREOSCOPIC MEASUREMENT SYSTEM OVER WWW

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**ABSTRACT:**

As digital photogrammetric system developed, we became able to measure three-dimensional objects on a generic personal computer. And recently aerial photograph is easily obtained, for example we can get aerial photograph through internet at a low price in Japan. But three-dimensional measurement using by photogrammetry is not popular. One of this cause is that digital mapping system requires photogrammetric knowledge and experience for calculation of orientation parameters and construction of stereo pair models. So we developed a three-dimensional measurement system on network, Web Photogrammetry. This system consists of server and clients. Aerial photographs, these orientation parameters and three-dimensional feature data are stored on a server. Clients are connected with a server by a network and have stereoscopic display. When we access a server by WWW browser, we are able to browse aerial photographs stereoscopically that are retrieved from server. Stereoscopic image are shown on WWW browser and measure three-dimensional objects over there. If three-dimensional feature data are stored on this server, these are shown stereoscopically over the aerial photographs. We can store measured data on a server and share these data with other users. It is important to implement this system that stereo image are shown on WWW browser so quickly. So stereo image is generated at a client and server delivers stereo pair aerial photographs and these orientation parameters to clients. Then to realize enough response for measurement environment, clients communicate asynchronously with a server and parts of aerial photograph image data are cached at a client. We believe that anyone having stereoscopic display and network can measure three-dimensional objects without photogrammetric knowledge and experiences by using this system. As a result three-dimensional spatial data will be used in more variously field. In addition we can deliver aerial photograph quickly by this system for photo interpretation, for example when disaster happened.

**1. INTRODUCTION**

By the appearance of the digital photogrammetric system, we got possible to measure a three-dimensional objects in the general computer environment. We are able to perform all processes from orientation to making orthophoto.

Recently many digital photogrammetric systems have been developed (L. Coelho, 2004, A. Gómez-Molina, 2004).

However, we cannot use digital photogrammetric system without photogrammetric knowledge and experiences. So We developed a three-dimensional measurement system on WWW environment, Web Photogrammetry. Summary of this system is shown as **Figure 1**. On this system, we can browse stereoscopic images on WWW browser to measure three-dimensional features in the real world. In the system, stereo pair aerial photographs are derived by WWW servers. On WWW browser of a client stereoscopic view are generated to fast three-

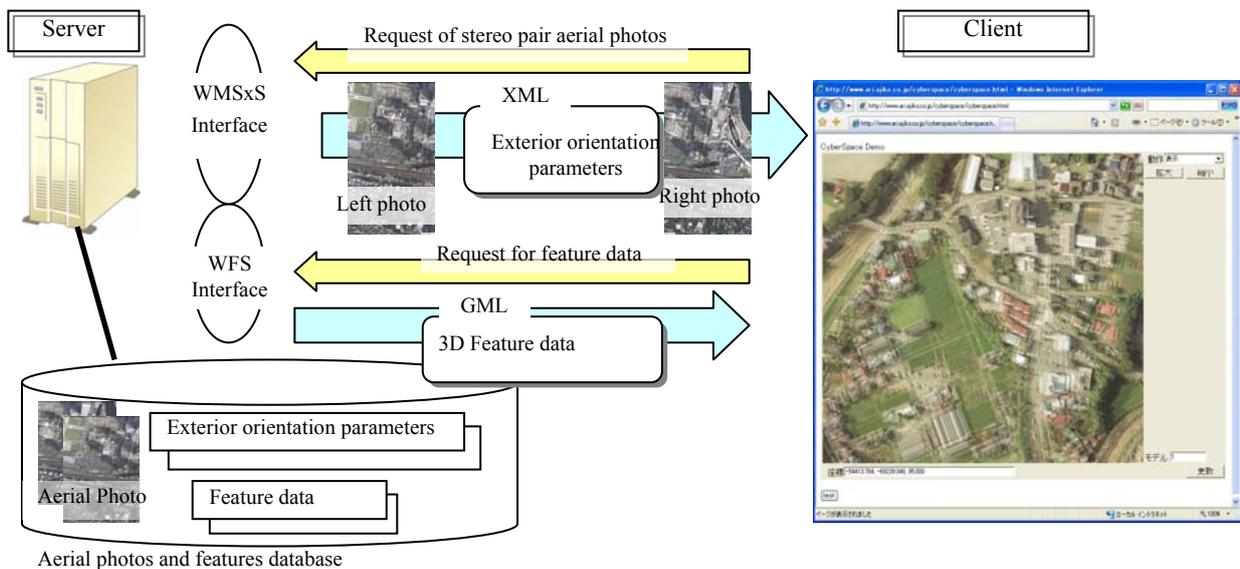


Figure 1. Summary of Web Photogrammetry

dimensional scroll operation. And also three-dimensional measurement is implemented and results of measurements are stored in the server side and/or a client side. The protocol of connection constructed between a server and a client is based on OGC WWW interfaces such as WMS and WFS. In the implementation to control stereoscopic images we enhanced WMS, as WMSxS (Web Map Service extended for Stereo). We believe that anyone having stereoscopic display and network can measure three-dimensional objects without photogrammetric knowledge and experiences.

## 2. SYSTEM CONSTRUCTION

Web Photogrammetry system consists on clients and a server. On storages of a server, aerial photographs with exterior orientation parameter and feature data are stored. A client computer has a stereoscopic LCD, and we can view stereoscopic image with features. Stereoscopic image is created from two aerial photographs (left photo and right photo) that consist on a stereo model, and features are overlaid on this image. When a user specifies a three-dimensional coordinate of interested point, stereoscopic image and features are displayed so that this point may become central.

Stereoscopic image is created on not a server but a client. When that is created on client, two images must be transmitted from server to client and communication data volume becomes the double. But it is possible to efficiently control the cache data of images. In general, image data are cached on a client computer to realize smooth scroll of raster image in web based system. However it is impractical to cache stereoscopic images on a client. This is for following reason.

Stereoscopic image is determined by three-dimensional coordinate. To create this image, left and right photo images are rotated. Each angle of this rotation is determined by its exterior orientation parameter, and center of rotation is determined by that parameter and interested point coordinate. Stereoscopic images must be cached with interested point, but it is difficult. Therefore, when a stereo image is created, left and right photo images are retrieved form server or cache storage on client at the block unit of the fixed size.

A process displaying stereoscopic image is as followed.

- (1) A user specifies an interesting point on a client.
- (2) The client request a stereo model which is suitable to display this point from server.
- (3) The model which is suitable to display this point is searched in a database of the server, and identifiers and orientation parameters of left and right photograph of which this stereo model consists are sent to the client from the server.
- (4) Ranges required for creating stereo image are calculated in image coordinates of left and right photograph.
- (5) The client request image data in these range from server.
- (6) These image data are retrieved form database of the server, and are sent to the client.
- (7) A stereoscopic image are generated from these image data, and are shown to the user on WWW browser.

## 3. STEREOSCOPIC IMAGE

### 3.1 Stereoscopic device and image format

In this system, clients require a display on which we can browse stereoscopic image stereoscopically. A stereoscopic image is generated from two images (James, 1990), left and right images. There are two types as these display. One is micro-pol system, and the other one is parallax barrier system. **Figure 2** is a micro-pol system display and **Figure 3** is a parallax barrier system display. Micro-pol system forces users to wear polarizing glass, but users can browse stereoscopic image clearly and easily. On the other hand, users can browse image stereoscopically without glass at parallax barrier system. However it is difficult to browse stereoscopic image without experience, and we feel gloomy on this screen.



Figure 2. Micro-pol system display



Figure 3. Parallax barrier system display

Stereoscopic image is generated from left and right images which are adjusted to be able to be browsed stereoscopically, and these stereoscopic display require the formats supported by each device. For example, we can browse interlaced format of stereoscopic image stereoscopically. In interlaced format left image lines and right image lines appear alternately, such as odd lines are left image and even lines are right image (**Figure 4**).

Though we hope that this system provide a three-dimensional measurement environment to any users which do not have photogrammetric knowledge and experiences, it requires special device such as micro-pol system display (K. Matsuhiro, 2000) or parallax barrier system display. So it is important whether everyone can prepare for such a display unit so that many users use this system. However recently the price of display on which we can browse interlaced stereoscopic image stereoscopically became lower. In addition a stereoscopic broadcast using interlaced stereoscopic image has been started since December 2007 in Japan, so we hope that such as stereoscopic display becomes more popular.

### 3.2 Stereoscopic image creation

In the first step to create stereoscopic image, ranges of left and right images in each image coordinate system are calculated from a coordinate of interested point. These ranges are ranges in which image data is retrieved from a server. In the next step, image data of left and right images are zoomed in or out and rotated to be able to be browsed stereoscopically (Chester, 1980). That is to say, epipolar lines which are over this interested point on left and right images become parallel horizontal line of display device (or a stereoscopic image) by this operation. Finally stereoscopic image of which an image format is suitable to the stereoscopic display device are generated from these adjusted images.

helfert's transformation parameter. These parameters of left and right images are transmitted to a client from a server when the stereo model is determined to browse around the interested point.

The rotational angle  $\theta$  in formula (1) is given by formula (2) and (3). Then  $(x, y)$  is the coordinate of the interested point, and  $(x', y')$  is a photographic coordinate of any points that must be displayed on same point with the interested point in vertical axis of display device or stereoscopic image. In other words, these point and the interested point are in the same epipolar plane.

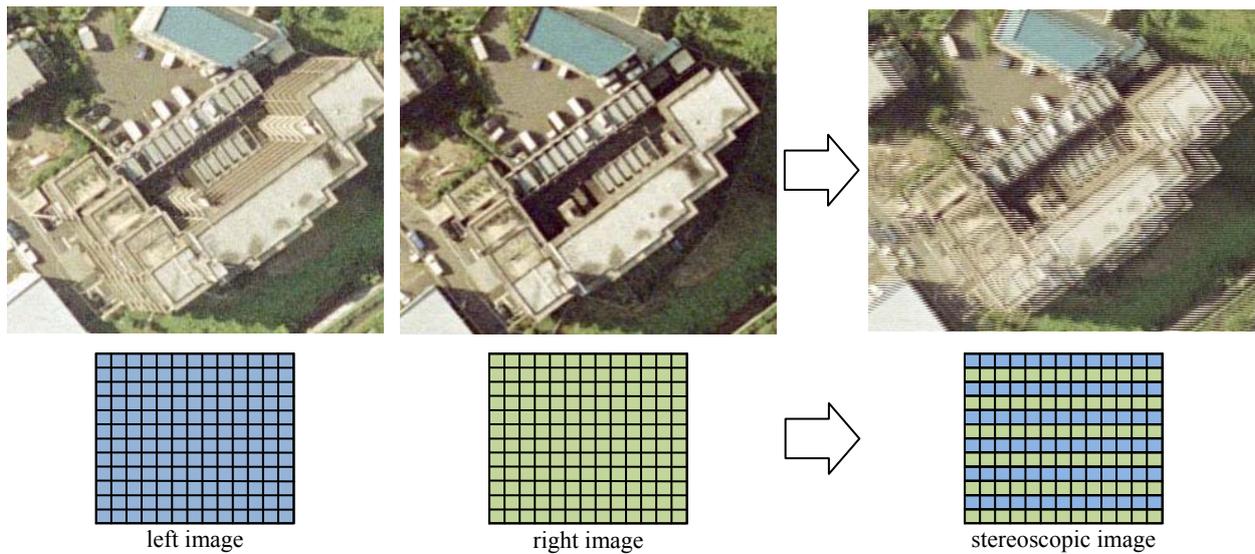


Figure 4. Interlaced stereoscopic image

Ranges required to generate a stereoscopic image are minimum bounding rectangles of image coordinates which are equivalent to corners of screen when an interested point is set to the centre of the screen. An image coordinate  $(x_{uv}, y_{uv})$  corresponding to a point  $(u, v)$  in screen coordinate is calculated by the formula (1). In this formula  $S'$  is a scale ratio of left image to an image of which range is calculating.  $W$  is a width of display area or stereoscopic image in pixel, and  $H$  is a height of them in pixel.  $(x, y)$  is a coordinate of an interesting point. Then the coordinate of upper left of display or stereoscopic image is  $(0, 0)$ , lower left is  $(0, H)$ , lower right is  $(W, H)$ , and upper right is  $(W, 0)$ .

$$\begin{pmatrix} x_{uv} \\ y_{uv} \end{pmatrix} = S' \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} u - 0.5W \\ v - 0.5H \end{pmatrix} + \begin{pmatrix} x \\ y \end{pmatrix} \quad (1)$$

An absolute coordinate  $(X, Y, Z)$  of an interested point  $(x, y)$  is calculated from orientation parameter of each photograph, focal length and transformation parameter from photographic coordinate to image coordinate. Orientation parameter consists of the absolute coordinate of projection centre and the three angles defining the view of photograph. Transformation parameter from the photographic coordinate to image coordinate is given as an affine transformation parameter or a

$$\sin \theta = \frac{y' - y}{\sqrt{(x' - x)^2 + (y' - y)^2}} \quad (2)$$

$$\cos \theta = \frac{x' - x}{\sqrt{(x' - x)^2 + (y' - y)^2}} \quad (3)$$

The three-dimensional coordinate (absolute coordinate) of such points are given by formula (4). Then  $(X_{l0}, Y_{l0}, Z_{l0})$  is the projection centre of the left image, and  $(X_{r0}, Y_{r0}, Z_{r0})$  is the projection centre of the right image.

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} X_{l0} - X_{r0} + X \\ Y_{l0} - Y_{r0} + Y \\ Z_{l0} - Z_{r0} + Z \end{pmatrix} \quad (4)$$

The value of scale ratio  $S'$  in formula (1) is 1 when the client calculates the range of left image. When it calculates the range of right image, scale ratio  $S'$  is given by (5). Then  $(x_l, y_l)$  is the image coordinate of the interested point,  $(x_r, y_r)$  is its image coordinate.  $(x'_l, y'_l)$  and  $(x'_r, y'_r)$  are the image coordinates of a point given by formula (4).

$$S' = \frac{\sqrt{(x'_l - x'_r)^2 + (y'_l - y'_r)^2}}{\sqrt{(x_l - x_r)^2 + (y_l - y_r)^2}} \quad (5)$$

### 3.3 Image data caching on a client

In many web mapping services, data retrieved from server are cached to a storage or a memory on client to show these data quickly. In this system, Web Photogrammetry, data retrieved from server must be cached on client.

In this system, cached data are image data of left and right photographs. It is important to cache stereoscopic image, because the stereoscopic image are generated from left and right images which are rotated, and these rotational angles are changed by an interested point. So in this system, cached data are used to create a stereoscopic image.

When an interested point are specified by user, a stereoscopic image are once generated by using left and right cached image data, and image data which are required to generate stereoscopic image and which are not cached on client are requested to a server. When the image data which are requested are received, stereoscopic image are generated again, and these image data are cached on client.

## 4. RETRIEVING AND OVERLAYING FEATURES

Feature data having three-dimensional coordinates are retrieved from server. These data are overlaid on stereoscopic image and we are able to view these data in three-dimension. Before stereoscopic image is generated, client retrieves from features from server. In this time the range in which feature data are retrieved is determined by interested point coordinate, exterior orientation parameters and stereoscopic image size. Next feature data are projected on left and right photo images.

## 5. COMMUNICATION PROTOCOL BETWEEN CLIENTS AND SERVER

In this system, clients send three kinds of data request to server. These requests are transmitted over the protocol based on OGC (Open Geospatial Consortium) web service common implementation specification. One of the requests is to retrieve photo id of left and right and these exterior orientation parameters. Another one is retrieving photo image of specified range. The protocol of this operation is WMSxS. The other one is retrieving features that have three-dimensional coordinate. This request is send to a server over WFS.

## 6. EXPERIMENTAL SYSTEM

We constructed to the experimental system of Web Photogrammetry. To construct its server, we used apache HTTP server, PostgreSQL and PHP. The client is implemented as a common language runtime object by using C#. This control referred by object tag in HTML with parameter tag that describes a coordinate value of interested point. The client control is displayed on the browser, when a user displays this page by the Web browser, and the stereoscopic image mainly on the designated coordinate is displayed.

In this system, users can select an interested point from address list (Figure 5). After the interested point is selected, aerial photographs around this point are displayed stereoscopically on WWW browser. On the stereoscopic image, users can measure the features in aerial photographs, for example houses, buildings, and roads. It is possible that feature data measured by a user save a xml file, and this is stored on server as feature.

Figure 6 (a) shows operation example of this system on stereoscopic LCD, and (b) shows a screen shot of measurement result. A polygon of white line on stereoscopic image is a measurement result of a road, and the area of its polygon and length of this polygon are shown in the dialog box.



Figure 5. Selection of the interested point from address list

## 7. CONCLUSION

In this paper, we described a three-dimensional measurement system, Web Photogrammetry. In this system, we are able to view stereoscopically aerial photo retrieved from a server over internet, measure features on aerial photographs which are browsed stereoscopically, and measured feature data are stored to the server. In addition, it is possible to share three-dimensional data and to distribute the stereoscopic image by this system. Web Photogrammetry make possible to derive stereoscopic aerial photo quickly, for example when disaster occurrence, offer remote work environment of digital mapping, and manage three dimensional data over stereoscopic aerial photo such as facilities data and disaster prevention information.

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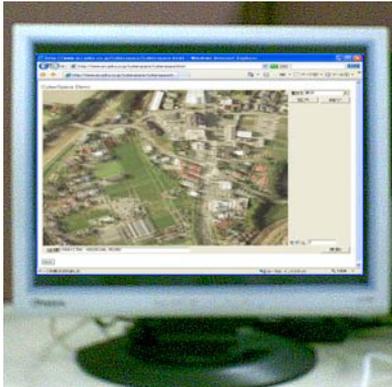
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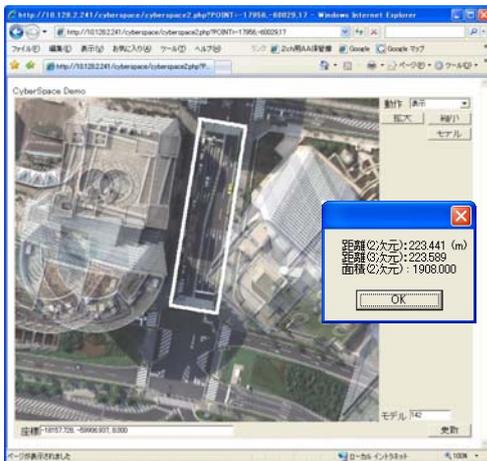
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(a) Stereoscopic LCD



(b) Screenshot of measurement result

Figure 6. Example of stereoscopic image on web browser

