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Application of Augmented Reality to Evaluate Invisible Height for Landscape Preservation

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1. Introduction

Landscape is the visible cognition of human environment, including natural objects such as mountains, rivers, the sea, forests and artificial objects such as buildings, bridges, and other structures. Landscape can be recognized and evaluated differently, depending on the viewer. However, people who share the same or similar local culture or aesthetics have the common recognition and evaluation of the landscape. A landscape can give a strong impact and make a socially, aesthetically, environmentally, or religiously desired outcome. On the other hand, if a mismatched object is laid out in the faborable landscape, people may feel that the good landscape is being destroyed. Recently, many good landscapes from viewpoint fields have been destroyed by constructing high rise buildings on the background area of the aesthetically pleasing structure. Figure 1 shows examples which singular landscapes of a Japanese historical Shinto shrine and a Buddhist temple are impaired by a modern tall glassy building and a tall broadcasting tower behind, respectively.

(a) (b)

Fig. 1. (a) A Japanese historical Shinto shrine and a new tall glassy building behind, (b) A Japanese historical Buddhist temple and a tall broadcasting tower behind

In order to prevent such landscape destruction, regulation of height of buildings and other structures must be enforced not only in the vicinity but also in considerably wide background area of the interested structure. To properly set the height regulation, it is necessary to compute the maximum height that does not disturb the landscape from the viewpoint fields for all the locations in the landscape preservation area. Such maximum height is called invisible height (Higuchi, 1988) and can be measured by drawing a vertical cross section as shown in Figure 2. However, it takes much cost and time to measure invisible height for all locations if we perform manually using a map or make a 3D computer graphics (CG) urban model, as described in the next section.

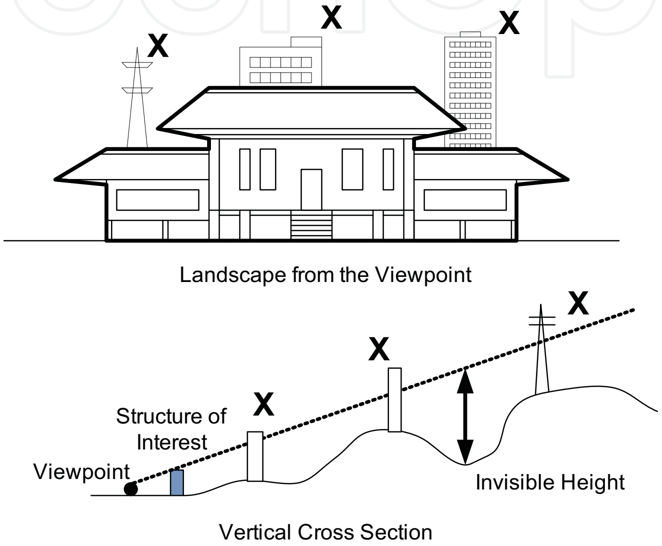


Fig. 2. Invisible height and regulation of height of structures for landscape preservation

Augmented Reality (AR) technology provides a facility to overlap real video images with virtual computer graphics images. The author perceived that invisible heights from multiple and moving points can be evaluated using AR technology without making an expensive and time-consuming 3D physical or numerical urban model. In this chapter, a new AR-based methodology for evaluating invisible height to support making regulations to preserve good landscapes is described.

2. Related work

2.1 Previous methods for measuring invisible height

In order to evaluate the invisible height for all the points behind the specific objects which make good landscape, the following four methods have been considered or employed in practice: (1) drawing sections from a map, (2) making a physical model of the area and buildings; (3) interpreting aerial photographs; and (4) making a numerical 3D terrain and building model. These methods require much time and cost.

As for the method (1), for each viewpoint, a large number of vertical cross sections must be drawn, and for each vertical cross section, invisible height must be measured at many points. Since there are a number of viewpoint fields for the interested structure, above mentioned work must be done iteratively. Furthermore, there may be other aesthetically pleasing structures nearby so that the above mentioned work must be done for all such structures and minimum invisible height must be selected for each location. Moreover, the height of the

interested structure is usually not uniform. The background terrain is usually not flat but uneven. As buildings and structures which already exist can make new hypothetical structure invisible, existing structures have to be drawn in the vertical cross section.
The method (2) is apparently expensive. The method (3) requires a special device called a stereophotogrammetry. The method (4) is also expensive and time-consuming.
Recently, Digital Terrain Model (DTM) (Lin et al., 2005), which represents elevations of terrain surface and Digital Surface Model (DSM), which represents elevations of surface of buildings, structures, trees, etc., may be available in some areas. If both of these data are obtained, the process of computing invisible height would be straightforward. However, such data are usually coarse and thus, not appropriate for this purpose. Even if the Laser imaging Detection and Ranging (LIDAR) method is used to make the 3D model, it takes much time and cost for processing the point cloud and making a surface model.

2.2 Virtual reality and augmented reality

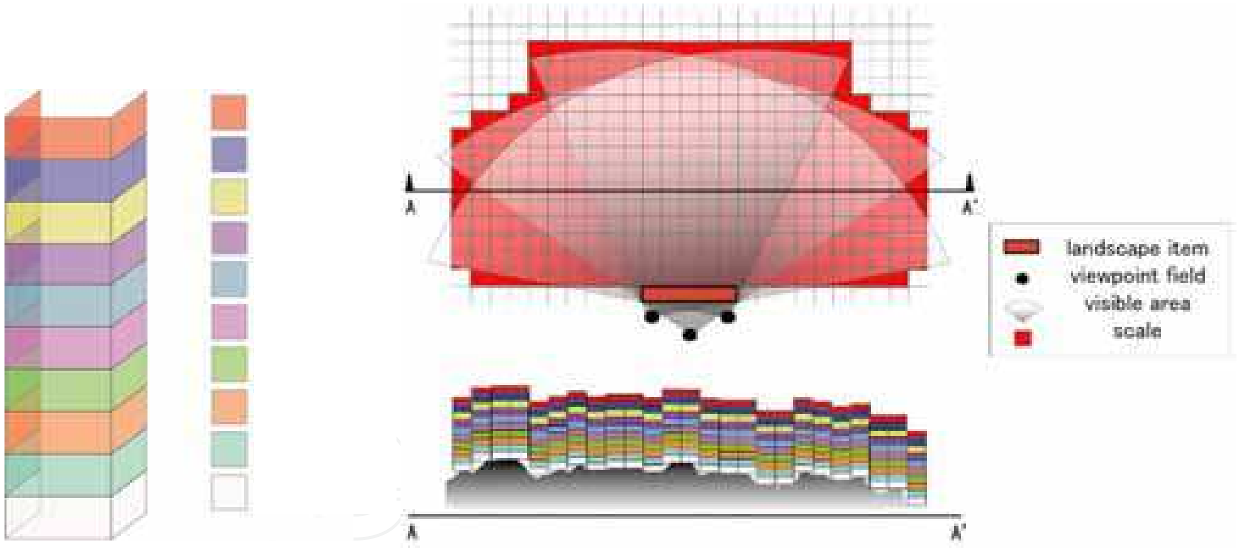
VR technology is often used for observation and evaluation of landscape by city planners, designers, engineers, developers, and administrators (Yabuki et al., 2009). VR and 3D urban and natural models allow the user to explore various landscape scenes from multiple and moving viewpoints (Soubra, 2008; Dawood et al., 2009). However, if VR is employed in order to evaluate the invisible height for wide area behind the historical or valuable buildings or structures, one must develop a detailed and precise 3D city model with existing buildings, trees, and other objects. This could take a long time and high cost. If such a city model has already been built for other reasons, it can be used without additional cost. Unless otherwise, making a large 3D VR model may not be a suitable choice just for obtaining the invisible height alone in terms of cost-benefit performance.
On the other hand, AR has attracted attention as a technology similar to but different from VR (Wang & Wang, 2009). AR technology provides a facility to overlap real video images with virtual computer graphics images. According to Azuma (Azuma, 1997), AR has three characteristics, i.e., AR combines the real and virtual worlds, has real-time interaction with the user, and is registered in a 3D space. There are three types of displays for AR: Head Mounted Displays (HMDs), hand-held displays, and spatial displays (projection to the real world). The advantage of HMDs is that they provide the immersive effect to multiple moving users. There are two types of HMDs, i.e., video see-through type and optical see-through type. The HMD must be tracked with six degree of freedom (6DOF) sensors for registering the virtual images to the real world. The sensors can be either 1) position/ posture sensors consisting Ground Positioning System (GPS) and gyroscope sensors (Feiner et al., 1997; Thomas et al., 1998) image sensors such as charge coupled device (CCD) cameras with markers (Kato & Billinghurst, 1999), or 3) feature point detection software (Jiang & Neumann, 2001; Golparvas-Fard et al., 2009). So far, the marker-based AR seems to be most popular because a free open source AR software package called ARToolKit (Kato & Billinghurst, 1999) is available. With ARToolKit, all you have to do is to make markers and purchase a web camera in order to start experiments of AR. Thus, ARToolKit has been used in this research. The marker in ARToolKit is a square with a black frame and some letter or shape inside the frame. ARToolKit can detect a marker from a video image and register the viewer's location by measuring the size and distorted shape of the marker on the video display image. The marker is linked with a virtual CG object and the system shows the object image on the video screen.

AR seems to be more often used indoors rather than outdoors because of the difficulty in registration of the user in the 3D world. A number of outdoor AR research projects have been reported (You et al., 1999; Kameda et al., 2004; Reitmayr & Drummond, 2006; Steinbis et al., 2008; Abawi et al., 2004; Ota et al., 2010). AR has been used for inspection of constructed objects such as steel columns (Shin & Dunston, 2009) and reinforcing bars (Yabuki & Li, 2007) in their research.

3. Proposed method for evaluation of invisible height

3.1 Overview of the proposed method

The main idea of the proposed method is when the user observes the landscape object under consideration from the viewpoint fields, wearing a HMD and a video camera connected to a PC, the AR system displays gridded virtual vertical scales (Figure 3(a)) that show elevations from the ground level and that are located behind the landscape object, on the HMD with overlapped real video images (Figure 3(b)). The user, then, captures the image and observes the maximum height that does not disturb the landscape for each virtual vertical scale. This process is iterated for various viewpoints, and appropriate maximum height for each location behind the landscape object is determined. Then, virtual vertical, maximum height scale models that should not disturb the landscape are generated and the user confirms whether the virtual objects are surely invisible, while walking around the viewpoint fields and wearing the AR system.



(a) (b)

Fig. 3. (a) A color-coded CG scale and (b) Placement of scales

The first step of the proposed method of this research is to set multiple viewpoints of the interested structure. Viewpoints are usually determined by the advisory panel of academic experts in architecture, arts, landscapes, history, religions, etc., and representatives of the citizens. The panel members walk around the interested structure and decide multiple viewpoints making good landscapes.

Then, the area of the background region of the structure from the viewpoints is determined on the map. The area is then gridded with a certain interval such as 10m, 50m, 100m. For each grid point, the elevation of the terrain is measured. The terrain data can be borrowed from DTM provided by public agencies if available. Otherwise, the user can obtain it by scanning the contour map, converting it to vector data, interpolating the elevation data from the Triangulated Irregular Network (TIN) data. In the AR system, a translucent color-coded vertical computer graphics (CG) scale is placed on each grid point of the background area. Note that the terrain is usually uneven so that the scales are placed as shown in Figure 3(b). For each viewpoint, the location of the marker is determined.

Now, the user visits the site and sets the marker at the designated location using surveying equipment. Then, the user wears a HMD with a video camera and starts the AR system. On the screen of the HMD, the marker, real video image, and a number of CG scales are shown. The user can select one row of CG scales for displaying at a time because overlapping scales may not be readable. For each row, the user captures a screen image and this process is iterated at all viewpoints.

After returning to the laboratory, the user reads the invisible height for all scales from the captured images. Then, for each grid point, the minimum invisible height from the data of multiple viewpoints is determined. Then, upper portions of all the vertical CG scales are cut out so that the height of each scale is equal to the minimum invisible height. The user visits the site again and checks whether all the CG scales of invisible height are shorter than the visible structures at all the viewpoints. The confirmed data is the baseline for making the height regulation for preserving good landscape.

3.2 Implementation of the proposed method

A prototype system was developed for validating the methodology proposed in this research. As for the AR, ARToolKit was used because it is commonly and widely used for AR research in the world. The author used a standard spec laptop PC, SONY VGN-SZ94PS with RAM of 2.0 GB, VRAM of 256MB, a 1280x800 display, OS of Microsoft Windows XP. A HMD of eMagin, Z800, 3D Visor and a web camera of Logicool QCam Pro for Notebooks with 1600x1200 pixels were used. The web camera was attached with the HMD, as shown in Figure 4. Although the PC and the web camera have high resolutions, the screen size of 800x600 pixels were used for AR due to the limitation of ARToolKit.

(a) (b) (c)

Fig. 4. (a) Head Mounted Display, (b) Web camera, (c) Wearing HMD with Web camera

A marker of the AR system was made for identifying the location and viewing direction of the user. Markers are usually small, for example, 50x50 mm, for the use of tabletop or desktop AR. However, as the landscape objects are buildings in this research, the typical size of the virtual, vertical scale is about 300m, and the distance of the scale from the viewpoint can be up to 5 km, small markers such as 50x50mm may not be visible from the viewpoints and the numerical errors due to the small size of the marker can be very large. Thus, a marker of which size is 900x900mm was made (Figure 5). The reason the edge size was 900mm is that the maximum width of wood plates typically available in Japan is 900mm. Although a larger marker such as 1.8m x 1.8m can be made by bonding four panels, handling would be very difficult and it could be extremely heavy in order to make it rigid.

Virtual vertical scale was developed as an OpenGL computer graphics (CG) object (Figure 3(a)). The shape of each scale is a rectangular solid which consists of multiple 5m-depth colored layers. Each layer has different color so that the user can read the height of the scale. In addition, the scale object must be see-through or very thin. Otherwise the scales would cover the target buildings and the user could not read the maximum invisible elevation for each scale.

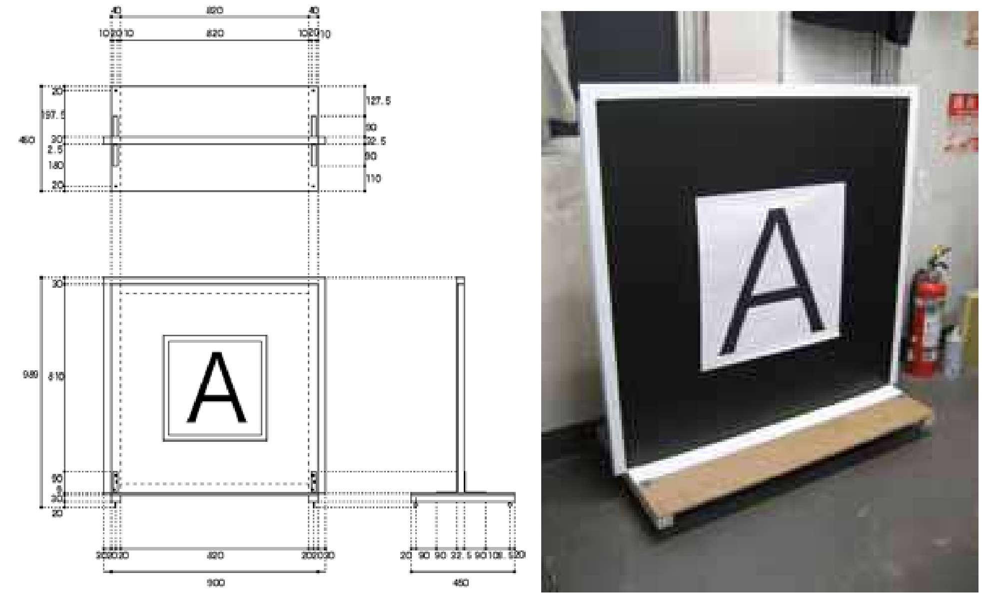


Fig. 5. Drawings and a photograph of the marker

4. Demonstration experiment and result

To demonstrate the proposed methodology and the developed prototype system, an experiment was executed. First, Convention Center and adjacent Gymnastic Hall of Osaka University (Figure 6) were selected as an experimental landscape preservation target because these buildings have highly evaluated property of aesthetic design and no permission was necessary to perform the experiment. Then, the horizontally flat and open square in front of the center and the hall was selected as a viewpoint field. The marker was installed at the square.

Then, 50m grid was drawn on the map of Suita Campus, Osaka University (Figure 7). The horizontal axis was named alphabetically, i.e., a, b, c, etc., and the vertical axis was named in number order, i.e., 1, 2, 3, etc. Each grid cell was named according to the horizontal and vertical number, e.g., d12, k16, m9, etc. The highest elevation in each grid cell was measured on the map and was assumed to represent the elevation of the cell. The virtual vertical scale of rectangular solid was placed so that its bottom elevation is the same as the ground elevation of the cell. This can be done by measuring the location, including the elevation, of the marker, computing the elevation difference for each cell, and linking the marker and all the scale objects. Table 1 shows the elevation difference between the marker and all the cells. Figure 8 shows all the scales on the gridded area. If all the virtual scales are displayed on the screen, the scale would be invisible or illegible. Thus, for each time, one row is selected and shown on the screen, and then, the next row is selected and shown, and so forth.

Fig. 6. Convention Center (left) and Gymnastic Hall (right) of Osaka University

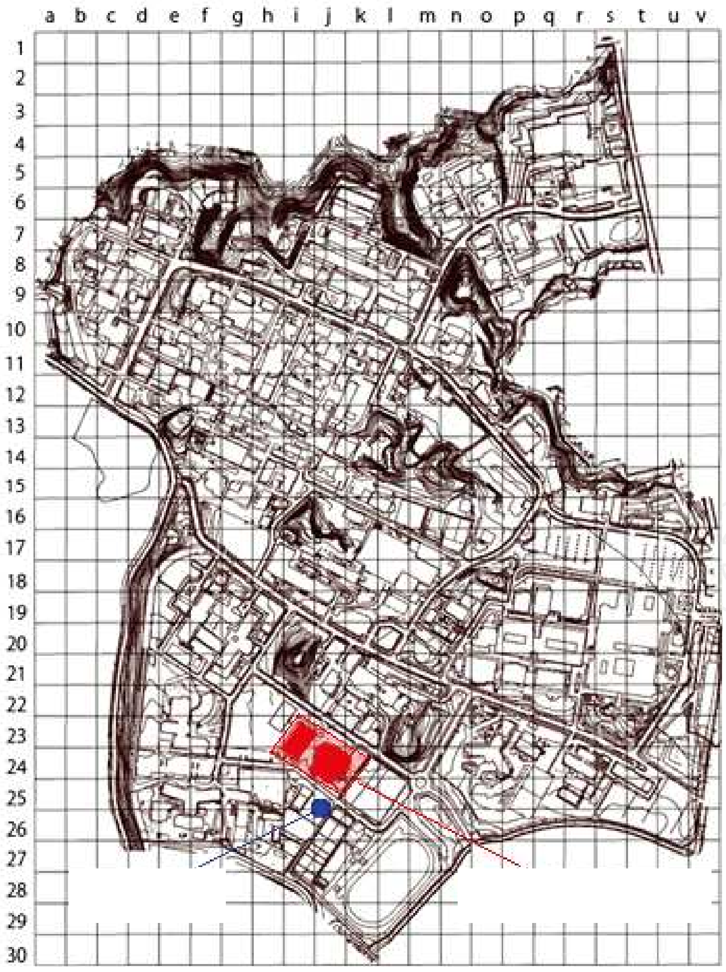


Fig. 7. Gridded map of Osaka University

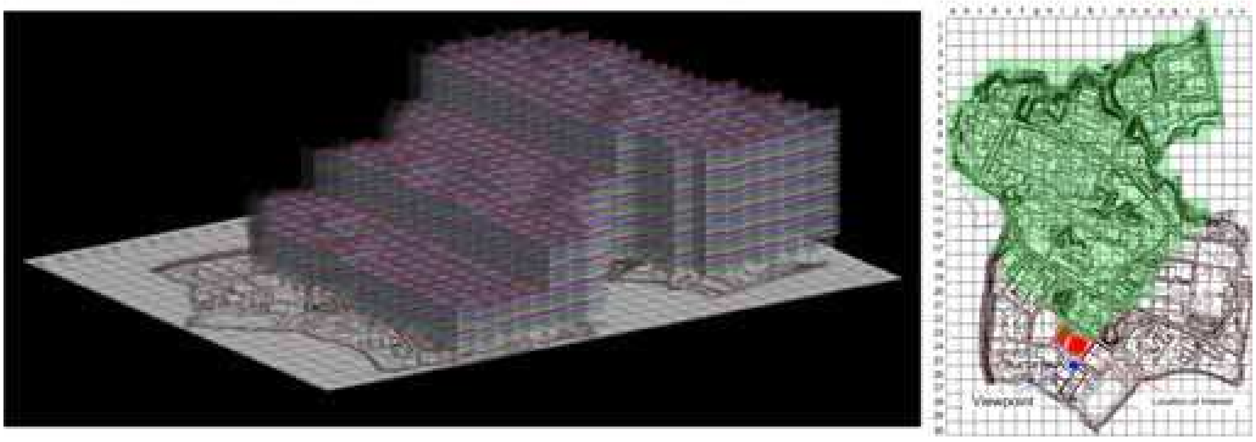


Fig. 8. All 3D CG scales placed on the gridded map of Osaka University

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
1																			26.6			
2																32.6	29.6	37.1	32.7	13.3		
3														43.7	39.5	34.6	33.6	31.6	26.6	10.8		
4				36.6	31.7	42.6	45.6	45.6	36.6	41.6	44.6	43.6	44.9	44.9	39.5	24.1	21.1	10	12.5	9.6		
5			37.8	34.8	33.6	42.6	46.6	45.6	36.6	42.6	43.6	43.7	32.6	28.6	28.6	28.6	10.1	10.2	10	10.9		
6		34.6	36.6	19.7	15.7	32.6	32.6	42.6	40.6	36.6	20.7	34.1	29.6	23.6	16.7	19.9	12	11.2	11.1	11		
7	21.9	21.2	21.6	14.8	14.3	32.6	32.6	29.6	17.7	17	16.9	35.7	32.7	16.9	17.1	16.6	16.6	10.2	7.6	8.2		
8	16.6	11.7	11.8	11.3	14.1	25.6	20.6	17.5	17.5	10.5	12.9	12.9	25.6	35.2	32.6	16.4	21.6	16.6	13.4	13.4		
9	17.9	6.4	5.6	8.9	10	10	9.9	10.7	10.4	10.9	12.4	12.4	15.6	34.6	32.6	19.2	23.9	19.6	12.2			
10	3.2	6.6	5.2	6.4	6.3	6.8	6.4	6.5	8.5	8.4	7.5	7.9	11.6	11.6	20.9	22.2						
11	3.2	11.2	5.2	6.4	6.5	6.8	6.4	6.5	8.5	8.4	7.5	7.9	11.6	6.9	20.9	22.2						
12		1.8	4.9	3.6	5.9	6.5	7	7.5	8.3	8.4	7.8	5	1.6	3	19.6	24.2	18.1					
13			0.3	2.7	13.7	10.2	7	9.4	9.5	10.1	12.6	16.6	6.6	2.6	9.6	15.8	17.5					
14					6.6	5.8	5.8	5.8	9.3	11.9	20	20.6	13.6	10.6	1.5	2.9	9.7	10.7	7.9			
15					- 2	6	6	6.4	5.7	9.3	10.7	16.6	15.1	14.6	5.6	- 4.6	3.5	16.6	14.4	18.5	11.6	
16				- 4.5	2.2	11.3	7.2	8.4	22.6	17.6	6.7	6.6	5.2	6.5	5.7	- 0.6	4.9	5.7	5.8	6.6	6.1	8.7
17					6.1	6.2	7.4	8.4	22.6	22.6	11.1	3	5.1	5.2	5	4.1	5.9	5.3	5.6	5.8	7.3	11.6
18				- 5	5.6	7.4	8.2	8.2	8.4	14	14	6.2	5.8	11.6	16.6	13.1	6.9	6.6	6	6.1	6.2	5.9
19			- 5.3	5.1	7.5	7.3	8	7.8	8.9	8.2	10.6	7.2	6.4	11.8	5.4	6.5	6.6	6.6	1.9	1.4	6.2	5.8
20			- 5.5	4.7	7.4	6.9	7	7.7	24.6	7.4	6.1	4.7	4	3.2	1.5	1.8	1.8	1.7	1.4	1.4	7.2	6.1
21			- 5.8	4	4.9	7.1	7	6.6	25.6	10.3	5.8	9.6	1.8	0.6	1.3	1.6	1.6	1.6	1.4	1.4	7.1	1.3
22			- 6.1	3.5	4.1	4.3	4.6	4.9	1.9	5	9.8	15.1	15.1	1.7	0.4	1	1	1.2	6.9	7.4	6.6	- 3.4
23			- 6.9	2.6	2.8	4	4.1	1.2	1.7	1.3	4.7	15.1	15.1	0.5	0	- 0.3	- 0.8	0.6	3.2	4.7	- 1.1	2.7
24			- 7.9	1.6	1.8	1.4	0.7	0.7	0.1	0.6	0.7	11.6	0.5	1.4	1.5	0.7	1.4	0.7	- 0.4	- 0.6	- 6	- 11.5
25			- 9.4	0.3	1.9	0.5	0.4	0.2	0.2	◎	0.5	0.5	- 1	- 1.4	0.1	- 0.2	0.5	0	0.3	- 0.1	- 0.7	- 0.2
26			- 10.9	- 0.3	- 0.7	0.9	0.3	- 0.1	- 0.6	- 0.3	0.5	- 0.1	- 1.1	- 0.3	- 0.8	- 1.1	0.4	- 0.5	0.2	0.2	0.2	- 0.8
27			- 12.4	- 2.2	0	1.9	1.7	0.3	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2	- 0.3	- 1.8						- 0.6	- 1.4
28								0.3	0.2	- 0.1	- 0.2	- 0.1	- 0.3	- 2.5								
29									- 0.2	0.5	- 0.2	- 0.2	- 3.4									
30											3.1	- 3.3										

Table 1. Elevation differences between the location of the marker and grid points

The experiment was performed by two students (Figure 9). One student wore the HMD and video camera and looked at the buildings the scales. The other held and operated the AR system and the PC, and captured images. A sample captured image is shown in Figure 10. From the captured image, the maximum invisible height for each rectangular solid scale was measured. They also walked around the square and confirmed that it was possible to view both the real video image and virtual scales, while walking.

Based on the invisible height measured from the captured images, a sample of height regulation plan was made. Then, all the scales were arranged so that each height was the same as the regulated height and linked to the marker (Figure 11). The experiment showed that the virtual shortened scales looked shorter than the target buildings from the viewpoint field (Figure 12).

Fig. 9. Photographs taken during the experiments at Osaka University

Fig. 10. 3D CG scales in the 16th row registered using AR

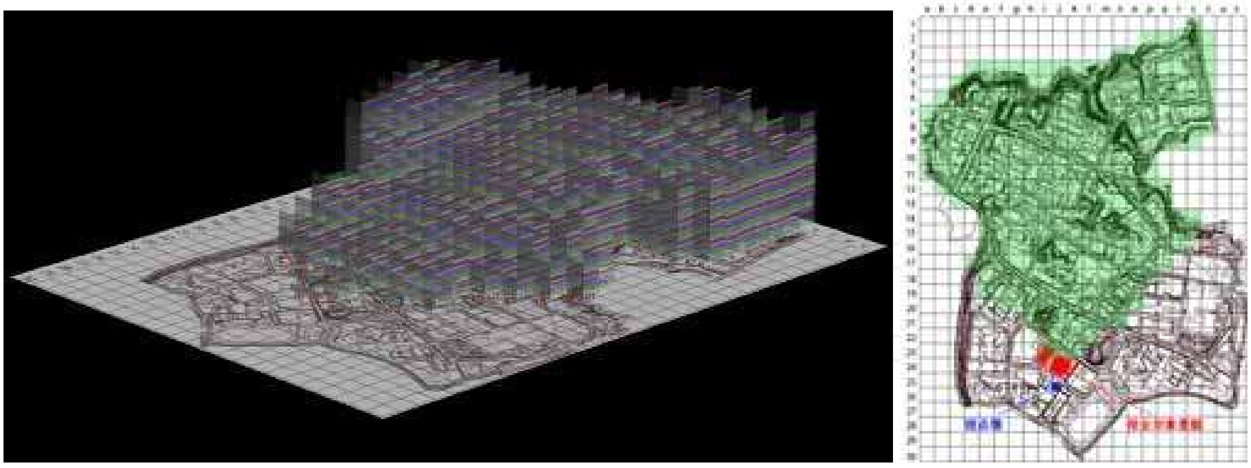


Fig. 11. 3D CG scales which conform to the height regulation placed on the gridded map

Fig. 12. A screen shot of the video image of the real buildings and marker with 3D CG scales of the 16th row, of which height are shortened so that they comply with the proposed regulation plan

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
1																			235			
2																260	230	210	210	215		
3														240	255	235	230	220	210	210		
4				175	160	155	160	165	175	200	200	200	200	205	215	225	215	195	190	180		
5			205	195	160	150	160	175	195	200	205	210	220	225	225	215	220	205	190	180		
6		205	195	200	160	150	160	160	170	180	200	190	190	200	220	190	190	180	180	180		
7	220	215	200	200	170	140	145	150	175	195	200	185	185	205	210	195	180	175	165	175		
8	210	210	210	200	190	140	135	155	170	190	195	200	185	175	185	185	170	160	175	200		
9	200	210	200	185	175	140	145	155	165	175	175	175	175	165	145	150	125	125	170			
10	200	200	195	185	175	140	145	155	165	175	180	180	180	190	175	160						
11	190	185	185	175	160	135	135	145	155	165	175	175	175	150	140	125						
12		175	180	175	160	135	125	130	145	155	160	165	170	160	130	110	100					
13			160	160	140	130	110	115	125	135	140	140	150	140	120	105	125					
14					140	130	110	110	120	125	125	125	115	110	105	100	110	60	90			
15					140	120	95	95	105	115	115	115	110	100	95	105	60	70	75	——	——	
16				120	120	105	100	80	70	90	105	110	100	85	85	65	80	85	——	——	——	——
17					105	105	90	75	65	75	90	95	75	75	50	55	45	——	——	——	——	——
18				——	90	90	80	65	65	70	75	80	65	55	15	40	——	——	——	——	——	——
19			——	——	65	70	70	60	50	60	65	65	55	45	40	——	——	——	——	——	——	——
20			——	——	——	55	60	50	25	50	55	45	40	30	35	——	——	——	——	——	——	——
21			——	——	——	——	——	40	10	30	40	30	25	30	——	——	——	——	——	——	——	——
22			——	——	——	——	——	——	25	25	25	10	——	——	——	——	——	——	——	——	——	——
23			——	——	——	——	——	——	15	15	15	——	——	——	——	——	——	——	——	——	——	——
24			——	——	——	——	——	——	0	0	0	——	——	——	——	——	——	——	——	——	——	——
25			——	——	——	——	——	——	——	◎	——	——	——	——	——	——	——	——	——	——	——	——
26			——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——
27			——	——	——	——	——	——	——	——	——	——	——	——	——						——	——
28								——	——	——	——	——	——	——								
29									——	——	——	——	——	——								
30											——	——										

Table 2. A hypothetical regulation plan of height of buildings and structures to preserve the landscape

5. Experiment for assessment of accuracy

5.1 Accuracy and errors

Since ARToolKit is based on the computer vision technique which depends on the image of a physical marker on the video display, errors are inevitable. The factors of accuracy include precision of the camera, form of the marker, tilt angles of the marker, camera's angle against the marker, the number of pixels reprenting each edge of the marker on the computer display, computer programs and hardware, etc.

Each camera has its own camera parameters such as coordinates of the center of the camera, focal length, lenz distortion, etc. The default values of the camera parameters of ARToolKit must be adjusted to the camera used. This process is called "camera calibration." As all lenzes have distortion, correction of distorted images is very important.

Markers must be made as precise as possible and must be placed accurately because tilt angles of the marker have impact on the errors. Camera's angle against the marker is also an important factor. It is widely known that ARToolKit tends to become unstabel and have large error values if the camera is at the front of the marker, which will be described in the discussion section.

Markers should be displayed large enough relative to the video image because the precision depends on the number of pixels representing each edge of the marker. Thus, the size of the marker should be large enough, and the marker should not be placed far from the video camera. Since the captured video camera image is binarized and the marker is detected, the error is generated by whether the edge pixel is included or not. ARToolKit refers to the pixels on the computer display instead of the video camera's CCD pixels. Therefore, the user should use a computer with a large and high density display.

5.2 Experiment of measuring errors

An experiment was executed to measure the errors prone to the marker orientation and the distance between the marker and the virtual object. The marker was set at the distance of 7m from the video camera.

Four existing real buildings which are visible from the experiment site and of which precise location and dimension data can be obtained were selected. Then, virtual 3D wireframe rectangular solid models representing the edges of those buildings were made using OpenGL and linked to the marker. Three node points, A, B, and C, were marked for each virtual model. The distance between the marker and each building was 124 m, 428 m, 964 m and 2,851 m (Figure 13). The orientation from the marker to the video camera varied 0, 15, 30, 45, 60 degrees. The 0 degree case means that the camera was just in front of the marker. A photograph of the site for the case of 964 m is shown in Figure 14.

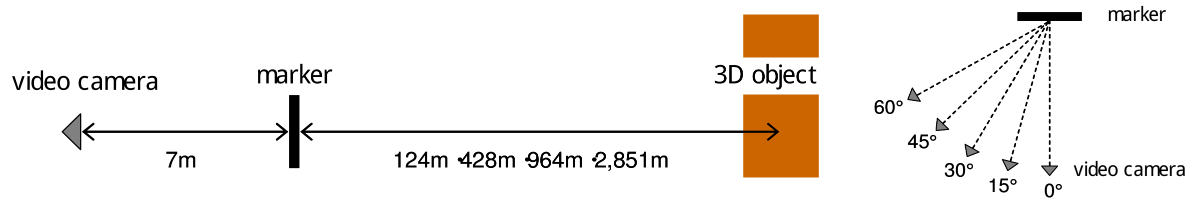


Fig. 13. Layout of video camera, marker and 3D objects (actual buildings)

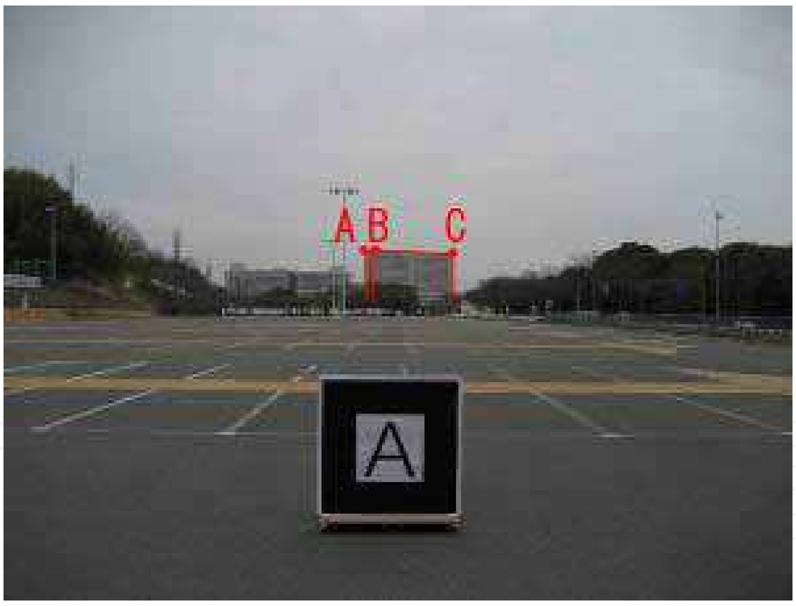


Fig. 14. The marker, actual building, and virtual 3D CG object. Distance between the marker and the building = 964m.

For each angle of each case, the error of each node between the actual video image of the existing building and the wireframe virtual CG model located at the building place was observed in terms of the number of pixels. Then, the error in pixel was converted to height error in meter. Figure 15 shows the relationship between the average height errors in meter and the distance between the marker and the existing buildings for 5 different angle cases. Apparently, the cases of 0 degree indicated large errors of over 15m for the cases of 964m and 2,851m, which suggests the inability. However, for other cases, including the farthest building, the average errors were less than 7m. Especially, for the cases where the camera-marker angle is larger than 15 degrees and the distance between the marker and 3DCG object is less than 1km, the average errors were less than 3m.

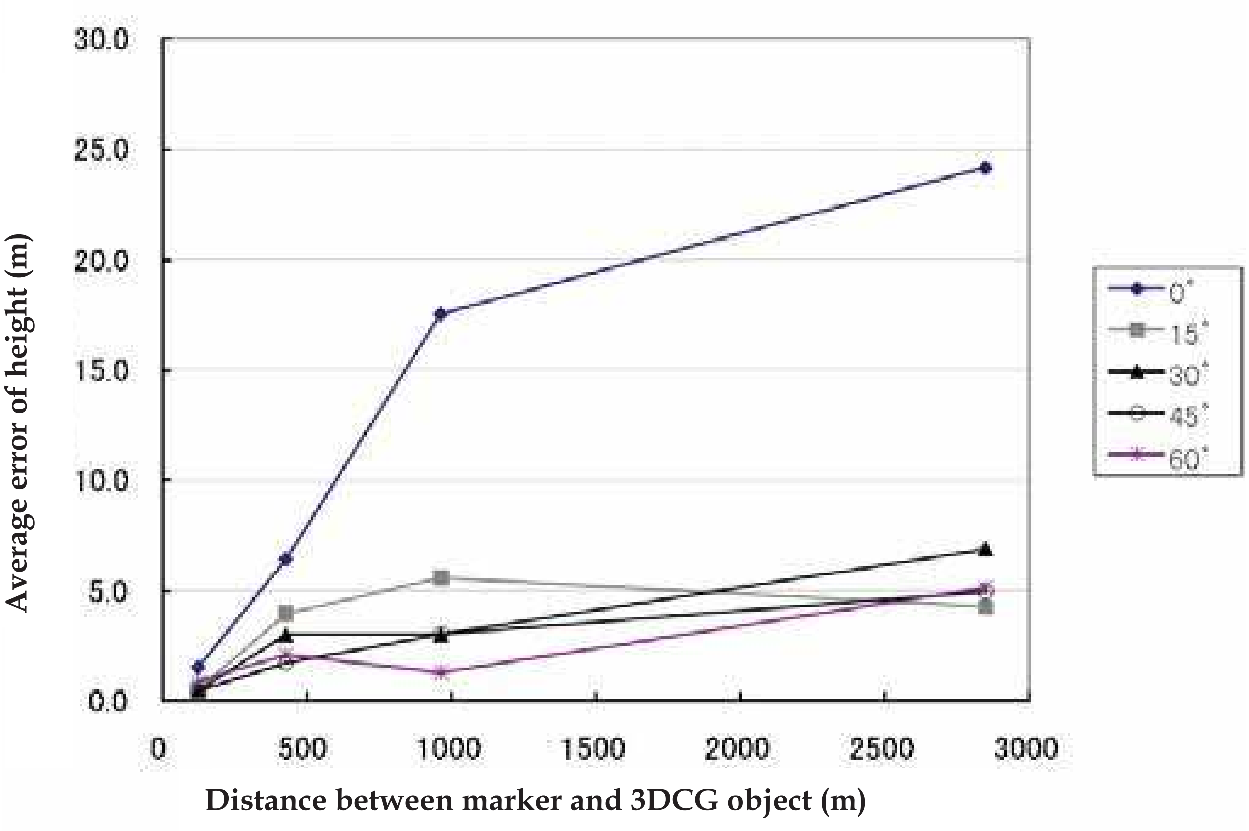


Fig. 15. The relationship between the average height errors and the distance between the marker and the buildings for 5 different marker-camera angle cases.

6. Discussion

The demonstration experiment result at Osaka University showed that the AR-based method proposed in this research was feasible and practical for determining invisible height from viewpoints to preserve good landscape. On the other hand, problems of accuracy and stability particularly related to ARToolKit have been identified.

The camera-marker angle of 0 degrees often produces unstable state or inability to identify the marker. It was reported the result of extensive accuracy experiments and concluded that the camera-marker angle between 0 and 30 degrees had low accuracy (Abawi et al., 2004). This problem has been identified by many AR researchers and is related to the reflection of light.

The size of the marker should be shown large enough on the computer display. However, if the marker becomes farther, the marker becomes smaller and thus, the error would become larger. To solve this problem, the author proposed a new method of using a set of four markers as a very large marker (Ota et al., 2010). In this method, the size of each marker is 400mm x 400mm. However, the four markers shown in Figure 16 work together as a single large marker of which edge length is equivalent to 2,000mm. As shown in Figure 17, the new method showed higher accuracy than the single marker method.

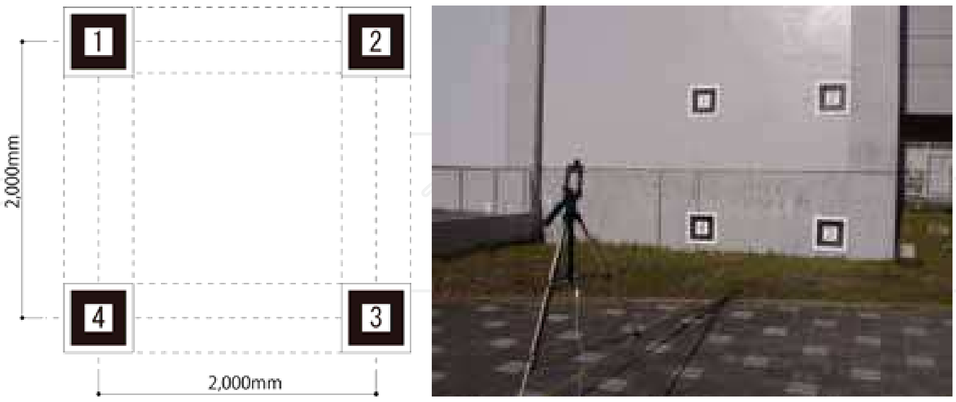


Fig. 16. A drawing of the four marker set (left) and a photograph showing the set of four markers placed on the wall

(a) (b)

Fig. 17. (a) Captured image of the wall and virtual CG structural blue lines in a single marker usage. Although four markers exist, only one marker was recognized. (b) When the four-marker method was used, the red lines had good agreement.

In the demonstration experiment at Osaka University, all the invisible heights were measured manually by reading the vertical scales with the interested structures on the captured images. Apparently, it takes much time and this process should be automated by making a program based on the image processing. In this research, translucent color-coded cubes were employed for representing height scales. If thin color-coded lines had been used instead, more rows could have been shown on the screen rather than just one row of scales.

7. Conclusion

Good landscape is often a symbol or treasure for the people living in the region. Such good landscape could be destroyed by constructing a new tall structures. In order to preserve good landscape, regulation of height of newly designed buildings is necessary. However, it would take a long time and much cost to evaluate invisible height of the background area from multiple viewpoint fields of the interested structure which makes a good landscape. Thus, in this research, a new methodology was proposed for evaluating the invisible height of virtual buildings that may be designed in the future from the multiple viewpoint fields using AR technology. Then, the prototype system was developed and applied to a sample good landscape site at Osaka University. To reduce errors, a large marker was made. Based on the maximum invisible height from the viewpoint field, a sample regulation plan was produced. The experiments showed the feasibility and practicality of the proposed methodology.

In order to evaluate the errors of the proposed method, an experiment was executed at Osaka University. Although when the marker-camera angle was 0 degrees the system showed some inability, it showed that necessary accuracy could be obtained through the proposed method, especially when the marker-camera angle ranges from 15 to 60 degrees.

Currently, more accurate and stable methods are being pursued. One of them is to use a set of four markers for representing a virtual very large marker. The result of this new method recently obtained was briefly introduced in the discussion. Future research includes using point cloud data which can be obtained using laser scanners for the registration of the camera in the 3D world in order to improve the accuracy and efficiency.

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Technological advancement in graphics and other human motion tracking hardware has promoted pushing "virtual reality" closer to "reality" and thus usage of virtual reality has been extended to various fields. The most typical fields for the application of virtual reality are medicine and engineering. The reviews in this book describe the latest virtual reality-related knowledge in these two fields such as: advanced human-computer interaction and virtual reality technologies, evaluation tools for cognition and behavior, medical and surgical treatment, neuroscience and neuro-rehabilitation, assistant tools for overcoming mental illnesses, educational and industrial uses In addition, the considerations for virtual worlds in human society are discussed. This book will serve as a state-of-the-art resource for researchers who are interested in developing a beneficial technology for human society.

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