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Hyper-resolution and Polycentric Panorama Acquisition and Experimental Data Collection

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Abstract

This report summarizes technical information regarding hyper-resolution and polycentric panoramic image acquisition and experimental data collection for a joint project between the Center for Image Technology and Robotics (CITR) in Auckland, New Zealand and the institute of space sensor technology and planetary exploration of German Aerospace Center (DLR) in Berlin, Germany.

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Abstract. This report summarizes technical information regarding hyper-resolution and polycentric panoramic image acquisition and experimental data collection for a joint project between the Center for Image Technology and Robotics (CITR) in Auckland, New Zealand and the institute of space sensor technology and planetary exploration of German Aerospace Center (DLR) in Berlin, Germany.

1 Introduction

This report provides relevant information about the image acquisition model, experimental setup, equipments, image data, and ground truth data collection information etc. Some potential applications or research problems are proposed for future projects. The report is organized in two parts: one is focusing the activity in Auckland and the other in Berlin.

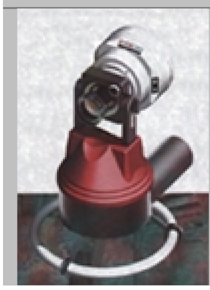
2 Hotspots of Auckland - City of Sails

There are totally 18 panoramic images acquired at 10 different places (hotspots) around a central part of Auckland. The pick-colored (dark-gray) spots labeled with places' names on the map of Auckland in **Fig. 1** indicate the acquisition locations.

Fig. 1. Auckland panorama hotspot map.

2.1 Equipments and Specification

The panoramic images have been acquired in Auckland with a panoramic camera system called EYESCAN M2 Metric [1] developed by KST GmbH in a co-operation with the German Aerospace Center (DLR). **Table 1** shows some selected specifications of the camera system.



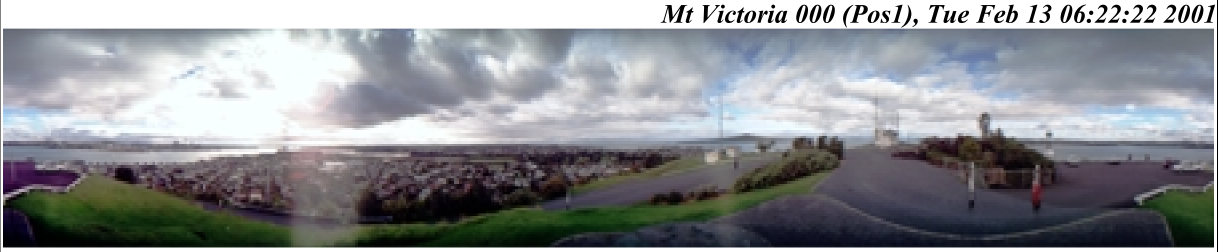
EYESCAN M2 Metric	
Number of CCD lines	3
Number of pixels each CCD line	10290
Pixel (CCD element) size	7 μm × 7 μm
Integration time	4 ms ~ 512 ms
Pixel depth	42 bit each line
Focal length	60 mm
Tilt angles	± 30° (15° stops)

Table 1. Specfications of Eyescan M2 Metric.

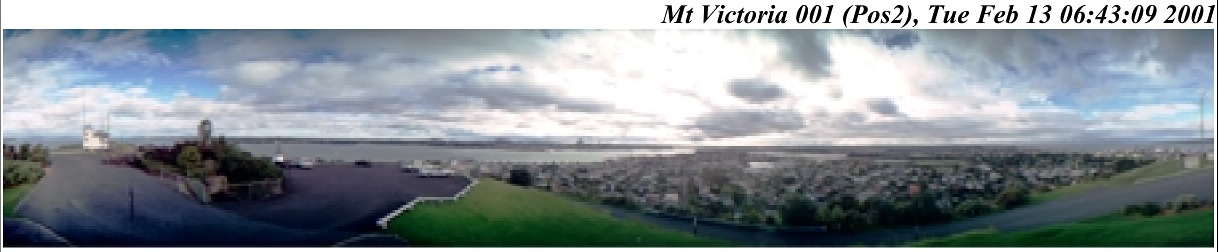
2.2 Images and Technical Information

This section shows all the acquired panoramas at very low resolution. The pictures also specify dates of acquisition and net addresses where larger versions of the pictures can be seen (only from within the auckland.ac.nz domain).

Mt Victoria 000 (Pos1), Tue Feb 13 06:22:22 2001



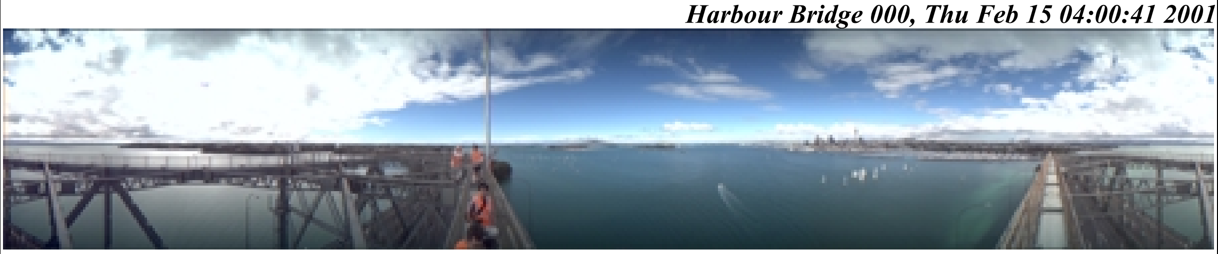
Mt Victoria 001 (Pos2), Tue Feb 13 06:43:09 2001



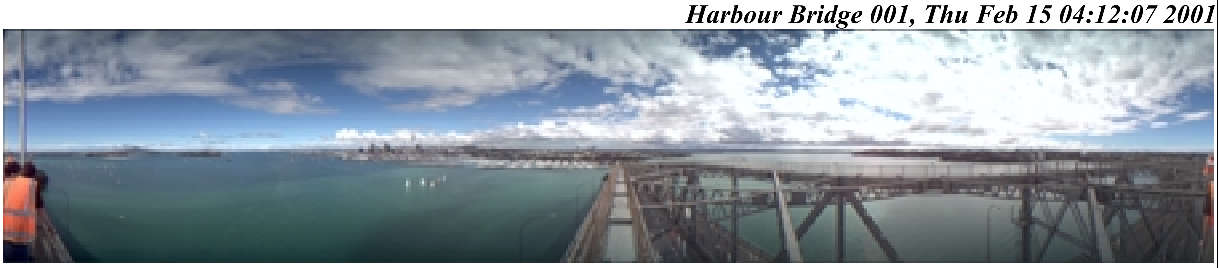
Mt Victoria 002 (Pos2+1m), Tue Feb 13 06:58:00 2001

Raw Data	Each 10290×56848 (≈ 3.4GB) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\MountVictoria
Scaled Image	Each 1029×5685, PRNU correction required, ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\MountVictoria\Scaled

Harbour Bridge 000, Thu Feb 15 04:00:41 2001



Harbour Bridge 001, Thu Feb 15 04:12:07 2001

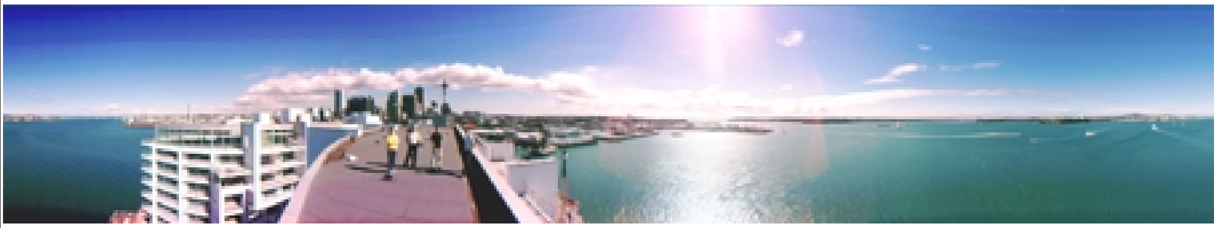


Harbour Bridge 002, Thu Feb 15 04:19:06 2001

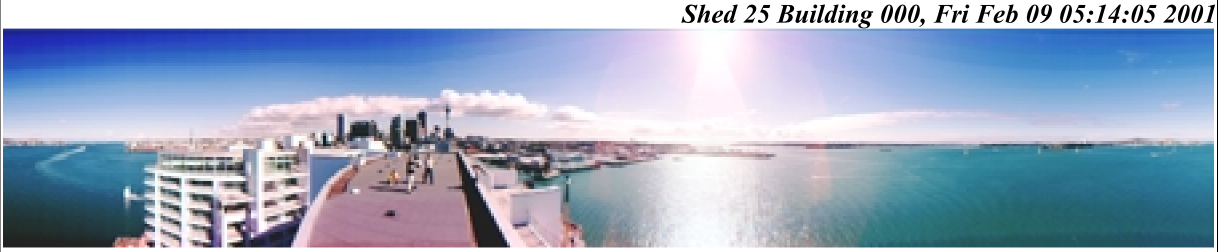
Raw Data	10290×{56112,56112,52848} (≈ 3.4GB) Vibration-correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\HabourBridge
Scaled Image	1029×{5611,5611,5285}, PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\HabourBridge\Scaled

Hp Building, Fri Feb 09 04:12:50 2001

Raw Data	10257×56848 (≈ 3.4GB) Vibration-correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\HpBuilding
Scaled Image	1026×5685 ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\HpBuilding\Scaled



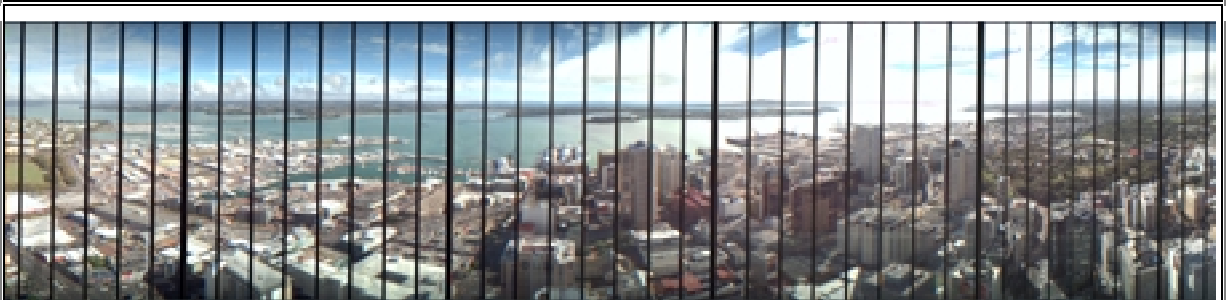
Shed 25 Building 000, Fri Feb 09 05:14:05 2001



Shed 25 Building 001, Fri Feb 09 05:14:05 2001

Shed 25 Building 002, Fri Feb 09 05:14:05 2001

Raw Data	Each 10257×56848 (≈ 3.4GB) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\nz shed25
Scaled Image	Each 1026×5685 ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\nz shed25\Scaled



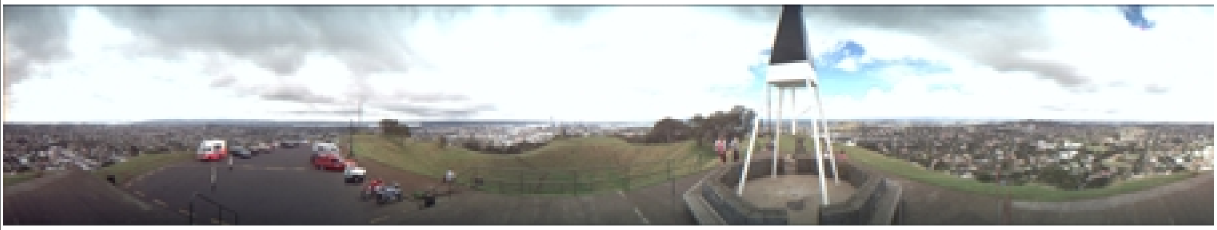
Sky Tower, Tue Feb 13 22:28:08 2001

Raw Data	10290×44688 (≈ 2.7GB), Turning speed and cycle time desynchronized ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\SkyTower
Scaled Image	1029×4469 ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\SkyTower\Scaled

Achilles Point, Ladies Bay 000, Mon Feb 12 06:14:19 2001

Achilles Point, Ladies Bay 001, Mon Feb 12 06:14:19 2001

Raw Data	Each 10290×40400 (≈ 3.4GB) Vibration-correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\LadiesBay
Scaled Image	Each 1029×4040, PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\LadiesBay\Scaled

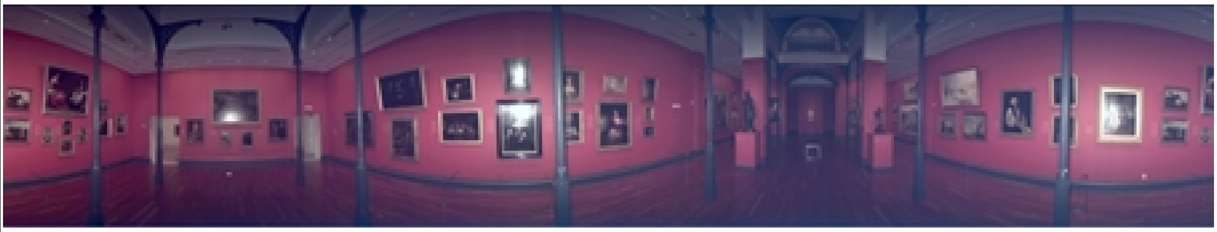


Mt Eden, Thu Feb 15 01:56:00 2001

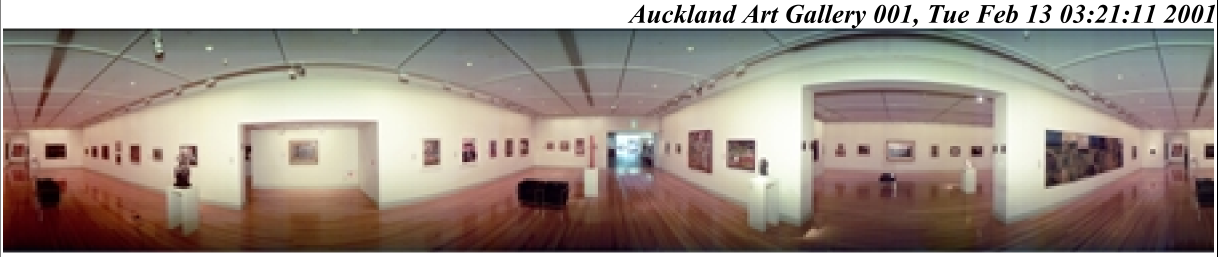
Raw Data	10290×56112 (≈ 3.4GB) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\MountEden
Scaled Image	Each 1029×5611, PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\MountEden\Scaled

Nags Head Tavern 001+002, Mon Feb 12 23:35:03 2001

Raw Data	2573×{7488, 7120} (≈ 450MB each) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\NagedHead
Scaled Image	PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\NagedHead\Scaled



Auckland Art Gallery 001, Tue Feb 13 03:21:11 2001



Auckland Art Gallery 002, Tue Feb 13 04:15:08 2001

Raw Data	001:1286×6928 (≈ 417MB); 002:1715×9232 (≈ 556MB) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\AucklandGallery
Scaled Image	PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\AucklandGallery\Scaled

RoberVision2001 Conference Participants outside Sport Science Stadium, Tamaki Campus, University of Auckland, Sun Feb 18 01:43:45 2001

Raw Data	10290×55360 (≈ 3.4GB) ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\Campus
Scaled Image	1029×5536 PRNU correction required ⇒ \\Citr-gl0\Vision\Auckland_Eyescan_SingleCenterPano\Campus\Scaled

Table 2. Previews and data information of the Auckland panoramas.

2.4 Acquisition Vibration Problem

Due to the vibration of the Harbour Bridge construction, resulting images captured at this location contain mis-alignment among adjacent image columns. **Fig. 2** illustrates a close-up of the problem.

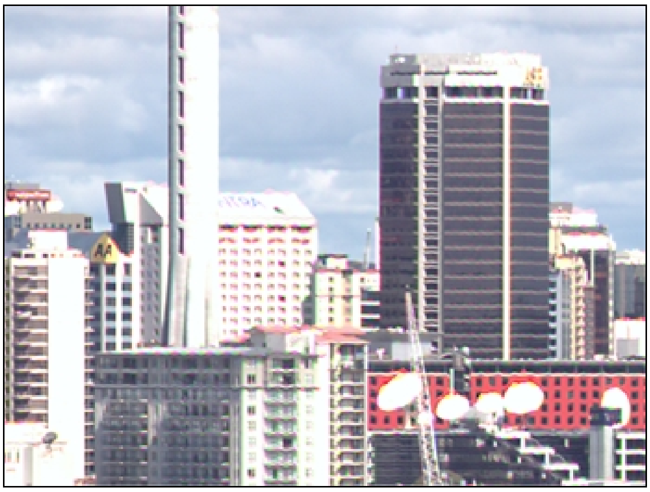


Fig. 2. Close-up of the adjacent image column misalignment problem.

2.5 Perspective Projects

Visualization of Hyper-resolution Images
Develop an interactive visualization tool for such hyper resolution panoramic images. The software requires a highly efficient image data retrieving and caching schemes for being visualized interactively on a PC or Mac commercially available.

Simulation of Walk-through in Multiple Panoramas
Develop a prototype system for visualizing the walk-through simulation among multiple panoramas acquired at several points of interest over a large open site and allowing viewer perceiving a consistent and smooth navigation. The problems of pose estimation and view interpolation need to be investigated.

3 Data Acquisition for Polycentric Panorama Related Projects

The information provided in this section should directly benefit and/or referable to the people who are interested in realization of a stereo panorama system; stereoscopic and panoramic visualization; calibration; epipolar geometry; pose estimation; stereo matching; 3D reconstructions etc. using polycentric panoramas. Some related applications can be found in [2].

3.1 Image Acquisition Model

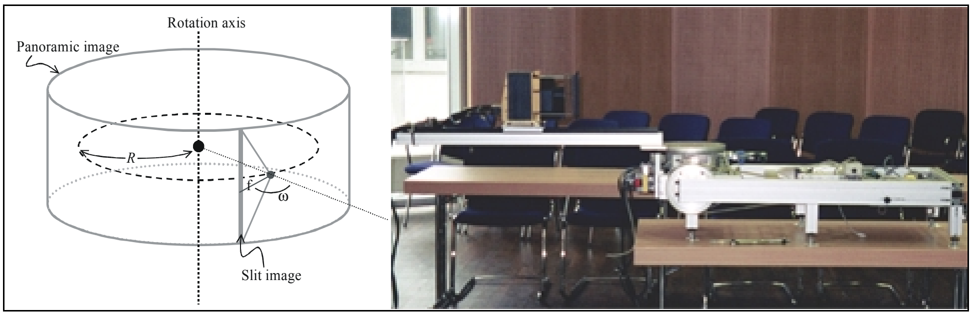


Fig. 3. Conceptual panoramic image acquisition model and its realization.

The left hand side of **Fig. 3** shows the geometric basics of the image acquisition model.

- R : the radius of a circular path passing through the focal point of line (slit) camera.
- f : the effective focal length of a line camera.
- ω : the angle between the normal of the circle and actual viewing direction of the line camera.

The panoramas acquired with respect to the same rotation axis are called *concentric panoramas* while with respect to different rotation axis *polycentric panoramas* [3]. The right hand side of **Fig. 3** shows the actual setup implemented in DLR.

3.2 Specifications

A Wide Angle Airborne Camera (WAAC [4]) is used in the experiment. The camera mounts on a rotational rig supporting an extension arm up to 1m. The specifications are summarized in **Table 3**.

WAAC and Rotational Rig	
Number of CCD lines	3
Number of pixels each CCD line	5184
Pixel (CCD element) size	7 µm × 7 µm
Spectral range of middle line	470~670 nm
Spectral range of front/back lines	580~770 nm
Focal length	21.7 mm
Pixel depth	11 bit each line
Possible ω	0° and ± 25°
Possible R	0~100cm

Table 3. Specifications of WAAC.

3.3 Configuration of Polycentric Panorama Acquisition for Experiments

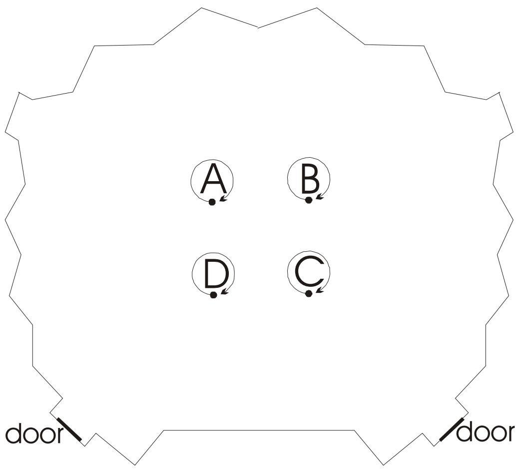
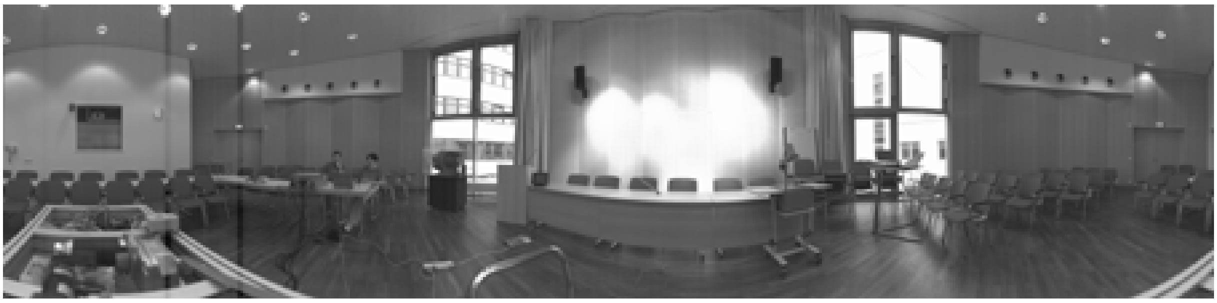


Fig. 4. Top view of DLR's seminar room and the four panorama acquisition locations.

Figure 4 illustrates a top view of the seminar room at DLR, Berlin. The image acquisition is implemented at four locations labeled as A, B, C, and D. Two symmetric panoramic (i.e. $\omega_1+\omega_2=0°$) pairs are acquired for each location, each for the configuration R=0 and 10cm with ω=± 25°. The relative geometric transformation between A and B are horizontally aligned (i.e. both leveled and at same height ≈ 126.3cm of optical center of WAAC above the ground). For C, the acquisition model is tilted about 2.6° with respect to the bottom of the feet of the platform (i.e. the right most one in the figure). For D, the acquisition model is raised up 45mm. The distance between A and B, B and C, C and D, D and A are all about 1m. The starting orientation in all four positions is facing to the south of the figure and the arrows show the rotation direction. Total horizontal angle of view is 359° for each panorama. The more precise relative poses might be recovered later.

3.4 Images and Technical Information

Here we only show one of 8 pairs in **Fig. 5** to give the idea of how the image looks like. The anaglyph of the selected pair shows the seminar room in 3D.



Location B, *R*=10cm, *ω*=-25°, (bS03_small_cropped.tif)

Location B, *R*=10cm, *ω*=25°, (fS03_small_cropped.tif)

The Anaglyph

Fig. 5. A symmetric panoramic pair and its anaglyph.

Image File Location:
\\Citr-gl0\Vision\Berlin_Waac_PolyPano_220301\Resized_tiff_x2\Correctedto_0-359\

Acq. Location	Image File Name	*R*	ω	Size
A	bS01_small_cropped.tif	0	-25°	2592x10618
	fS01_small_cropped.tif	0	25°	2592x10618
	bS02_small_cropped.tif	10cm	-25°	2592x10694
	fS02_small_cropped.tif	10cm	25°	2592x10694
B	bS03_small_cropped.tif	10cm	-25°	2592x10694
	fS03_small_cropped.tif	10cm	25°	2592x10694
	bS04_small_cropped.tif	0	-25°	2592x10694
	fS04_small_cropped.tif	0	25°	2592x10694
C	bS05_small_cropped.tif	0	-25°	2592x10694
	fS05_small_cropped.tif	0	25°	2592x10694
	bS06_small_cropped.tif	10cm	-25°	2592x10668
	fS06_small_cropped.tif	10cm	25°	2592x10668
D	bS07_small_cropped.tif	10cm	-25°	2592x10688
	fS07_small_cropped.tif	10cm	25°	2592x10688
	bS08_small_cropped.tif	0	-25°	2592x10688
	fS08_small_cropped.tif	0	25°	2592x10688

Table 4. Specifications of experimental polycentrci panoramic images.

3.5 Ground Truth Data

There are two kinds of ground truth data. One is collected by tape measuring. The other is collected by Theodolith.

For the first approach, the measurements are based on the size of the scene object of interest, such as walls, widows, tables, and so forth. For the walls, the measurements include the relative orientations. **Fig. 6** shows the script of the measurements. The maximum measurement errors should be within 1cm, which corresponding to 6 pixels in the half resolution. Please contact the authors for these data if the accuracy is sufficient to your applications.

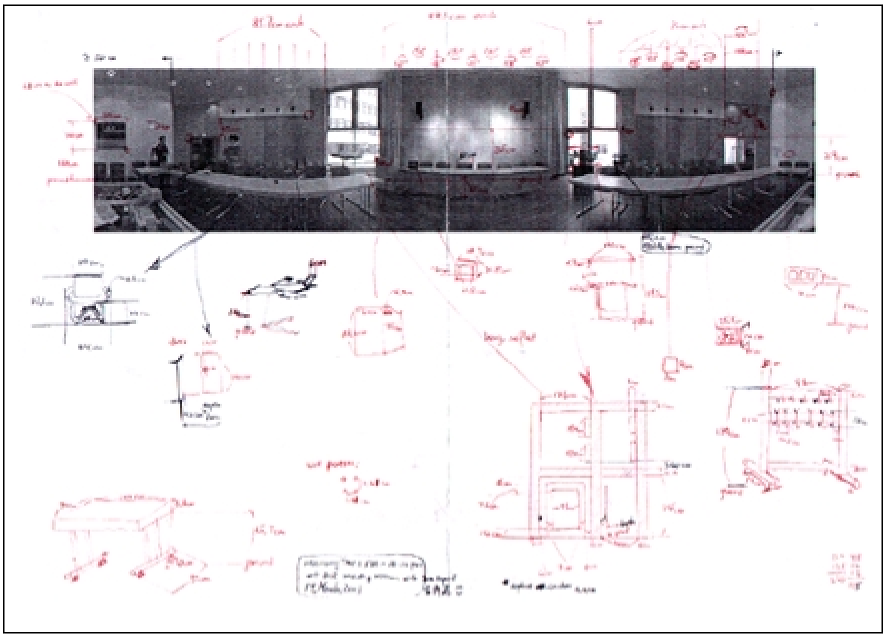


Fig. 6. The script of the tape measurement.

The ten scene points particularly chosen for Theodolith measurement are illustrated in **Table 5**.

Scene Point Index	Scene Point Description
P_1	Bottom right outer corner of data projector window
P_2	Top right corner of the door to the left of figure
P_3	Bottom right corner of air-hole extension to the left of figure
P_4	Top left corner of lower left window to the right of figure
P_5	Head of man on EXIT sign to the right of figure
P_6	Center point of front wall
P_7	Bottom left corner of air-hole extension to the right of figure
P_8	Bottom right corner of air-hole extension to the right of figure
P_9	Bottom left corner of air-hole extension to the left of figure
P_{10}	Center of clock

Table 5. Ten scene points selected for Theodolith measurements.

Table 6 lists the measurements of four control points (C_1… C_4) with respect to two Theodolith locations (T_1 and T_2) for calibrating the Theodolith locations relatively.

Theodolith Location	Control Point	Distance	Horizontal Degree	Vertical Degree
T_1	C_1	5.592m	0.080°	95.875°
	C_2	7.776 m	321.033°	90.166°
	C_3	7.706 m	220.582°	89.905°°
	C_4	5.450 m	180.977°	83.869°
T_2	C_1	8.334 m	357.737°	94.070°
	C_2	10.141m	328.896°	90.242°
	C_3	6.015 m	237.718°	90.079°
	C_4	2.737 m	183.958°	78.154°

Table 6. Measurements of four control points with respect to two Theodolith locations.

The coordinates systems of ten scene points can then be recovered using the data in **Table 7**.

Theodolith Location	Scene Point	Horizontal Degree	Vertical Degree
T_1	P_1	123.275°	106.465°
	P_2	179.668°	84.236°
	P_3	219.621°	77.709°
	P_4	300.150°	85.453°
	P_5	9.823°	82.335°
	P_6	271.046°	85.040°
	P_7	322.158°	77.761°
	P_8	0.743°	73.152°
	P_9	180.118°	72.738°
	P_{10}	151.784°	66.332°
T_2	P_1	18.609°	98.625°
	P_2	181.488°	78.771°
	P_3	237.050°	74.433°
	P_4	311.183°	86.291°
	P_5	4.004°	85.104°
	P_6	286.012°	85.458°
	P_7	329.887°	80.738°
	P_8	358.148°	78.748°
	P_9	182.429°	57.549°
	P_{10}	32.952°	58.422°

Table 7. Measurements of 10 scene points with respect to two two Theodolith locations.

4 Conclusions

The acquired data is used for theoretical and experimental analysis of panoramic images. Some results can be found in [5, 6]. Please contact the author(s) for obtaining the data and/or discussing the usability of the data in your application.

Reference

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3. S.-K. Wei, F. Huang, R. Klette: Classification and characterization of image acquisition for 3d scene visualization and reconstruction applications. *Multi-image analysis*, Dagstuhl, Germany (March 2000) pp. 83--94.
4. R. Reulke, M. Scheel: Der drei-zeilen ccd-stereoscanner waac: Grundaufbau und anwendungen in der photogrammetrie. *Photogrammetrie, Fernerkundung, Geoinformation* **3**, (1998) pp. 157--163.
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6. S.-K. Wei, F. Huang, R. Klette: Characterizations on Image Acquisition and Epipolar Geometry of Multiple Panoramas. To appear in *Proc. CAIP'2001*, Warszawa, Poland (September 2001).