Description of Range Images

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This measurement was done as a part of the project RECCAD (Copernicus No. 1068). Data should be used to demonstrate a fusion of range images of an object taken from more view points. The objects have been measured from every sides and the data enable a full reconstruction of the objects with limitation of the range finder system in use.

1 Introduction

The following range images of RECCAD Tested Objects were obtained by Laser Plane Range Finder (LPRF). The LPRF was described by Pajdla in [1]. The precision is +/-0.2mm in each axis in one view. It was checked by a fitting planes to measured data. The density of measured points are dependent to adjustment of LPRF and geometry of the scene. Only the adjustment of LPRF can be controlled. Therefore the density of measurement is note in table for each view as distance between neighbourhood points in direction of axis x and y in operating area. Each object has been measured from more views so that a reconstruction of full surface is possible. At the same time, the number of views was minimized.

The views differ by approximately known rotation and unknown translation. We have not used any precise positioning system. Therefore, the directions of the views are described only approximately. The system of LPRF doesn't guaranteed position of axis origin. It is the reason why we don't know the translation between the views. However, often at least approximate registration of range image for their fusion is necessary. For each object we try to define object coordinate system. The directions of the views will be described in this object coordinate system.

We have used only turn table for precise positioning. This turn table was used for obtaining sequence of views which differ by known mutual rotation. The sequences are labeled in the tables of views in next paragraphs.

The views are stored in 3DP file format. It is a ASCII file which describes 3D data. The definition of this file format can be found in the next section or in "filesys.txt" in this directory. The views are ordered by the numbers of the objects to five subdirectorys O1 - O5. The 3DP files are compressed by GZIP, as the original files were too long.

2 File types description

2.1 3DP File

The 3DP file was the first type of the files which describes 3D data obtained by the Laser Plane Range Finder (LPRF). A 3DP file describes a 4-connected mesh without badly measured points. Points measured by LPRF lie in a rectangular grid but badly measured points are discarded before storing them in the 3DP file according to a light trace strength threshold and an edge length threshold. Therefore, the 3DP file does not contain every point from the rectangular grid.

The 3DP file is an ASCII file. On each line there are data corresponding to one point on the measured surface. Each line contains 3D coordinates and a neighbourhood definition. The coordinates are measured in a LPRF coordinate system which is almost fixed but can slightly vary from one calibration to other.

3DP file complies to the following rules:

a) ASCII text file (a'la Matlab ASCII matrix).

b) One line corresponds to one measured point.

c) All lines have the same number columns of numbers. However, there may be written by different number of characters.

d) The following tokens are stored in one line:
idx x y z N W S E

   1) idx = Index of the point. This positive integer number can be understood as a label of the point. The index numbers are used for describing neighbourhood points. Zero is not acceptable index, because the zero is reserved for non-existent neighbourhood point.

   2) x

   3) y   3D coordinates of the point.

   4) z

   5) - 8) The indices of four-neighbourhood of the point. The directions are sorted and written in order "North", "West", "South", "East" (the correspondence with axis direction isn't guaranteed). If the zero is used as the index, the neighbourhood point in the direction doesn't exist.

e) *.3DP is recommended extension of a 3DP file.

There was problem with visualization that needs a rectangular mesh and with the setting of thresholds what need not be set during the measurement but sometimes is useful even in the later stages of data processing. Therefore we have designed new file format which store more information about data than 3DP file.

2.2 NT File

The NT file describes a 4 connected mesh with the every points and with more information about measured points than their 3D coordinates. The NT type of file is extended 3DP file type and 3DP file can be simply extracted from NT file. The badly measured point are detected by the light thresholds and edge length threshold as in case of 3DP file. The bad points aren't discarded from file but they are marked by zero point index.

The NT file is an ASCII file. Data which correspond to one measured point are stored in fixed columns on one line. The data are measured coordinates, information about a belief of the point and texture on a surface. There are 3D coordinates and neighbourhood description too.

NT file complies to the following rules:

a) ASCII text file (Matlab ASCII matrix)

b) One line corresponds to one measured point.

c) All lines have the same number columns of numbers. However, there may be written by different number of characters.

d) The following tokens are stored in one line:
ltn u v lt img x y z idx N W S E
The first 3 column contains camera and LPRF support coordinates of points :

1) ltn = Number of light trace
2) u = camera coordinate
3) v = camera coordinate

Next two columns store light point parameters

4) lt = belief (brightness of light trace)
5) img = texture (brightness with normal light)

Next columns describes 3D mesh as 3DP file

6) x
7) y There is 3D coordinates of the point.
8) z
9) idx = Index of the point. This positive integer number can be understood as label of the point. The index number are used for describing neighbourhood points. The bad points (by thresholds) have zero index.
10) - 13) The indexes of four-neighbourhood points. The directions are sorted and written in order "North", "West", "South", "East" (the correspondence with axis direction is not guaranteed). If the zero is used as the index, the neighbourhood point in the direction does not exist.

e) *.NT is recommended extension of NT files.

The NT file can describe texture and allowed to generate different 3dp files for varying parameters. This features are positive but many parameters are contained in one file and the information is used only some times. The problem is that the bad points are not included into mesh and if we like to use the point we must construct the mesh again. The problems should be solved by using new file system.

3 RECCAD Test Object 1

Description: The Object 1 is a truncated pyramid on rectangular parallelepiped base.

Coordinate system: Let's supposed that the largest rectangular base is parallel with x-y axis plane and the axis z is parallel with the axis of the object. The axis x and y are parallel with hypotenuses of rectangular base.

The views are distributed on two orbits. First orbit is in x-z plane and second is in x-y plane. The direction of view will be described by two angles a, b. Angle a is the angle between axis z and the direction of the view. Angle b is the angle between axis x and the projection of view direction to x-y plane. The positive direction is from x to y and from z to x.

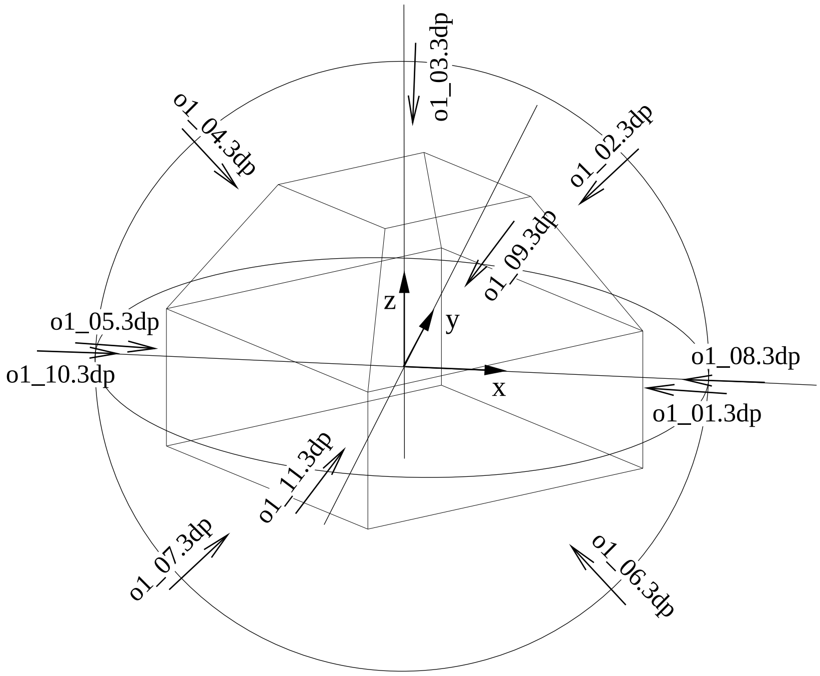

Figure 1: RECCAD test object 1 - plan of measurement

Views:

	file	a	b	density
Sequence 1:	o1_01.3dp	92	0	1.2x1.5mm
	o1_02.3dp	47	0	1.2x1.5mm
	o1_03.3dp	2	0	1.2x1.5mm
	o1_04.3dp	- 43	0	1.2x1.5mm
	o1_05.3dp	- 88	0	1.2x1.5mm
Sequence 2:	o1_06.3dp	137	0	1.2x1.5mm
	o1_07.3dp	-133	0	1.2x1.5mm
Sequence 3:	o1_08.3dp	0	0	1.2x1.5mm
	o1_09.3dp	0	80	1.2x1.5mm
	o1_10.3dp	0	180	1.2x1.5mm
	o1_11.3dp	0	260	1.2x1.5mm

4 RECCAD Test Object 2

Description: The Object 2 is a flange. The body consists of a basic flat rectangular parallelepiped with a stumps and smaller rectangular parallelepiped with pit which is located on the basic rectangular.

Coordinate system: Let's put the object to x-y coordinate plane. So that the largest side will be on the coordinate plane. The axis z and the axis of symmetry of the object are identical. The direction of axis z is from base up to the side with the pit. Axis y is parallel to the longer edge of rectangular base and axis x is parallel with shorter edge. The coordinate system is right-handed.

Eight vies are distributed to two perpendicular orbits. The angle 45° is contained by the orbits and x-y plane contains.

The direction of a view is described by angles a and b. Angle b is declination of an orbit. It expresses the angle between axis y and the projection of the orbit to the y-z plane. Negative direction is from y to z. Angle a represents the direction of a view on the orbit. The angle is measured from the crosspoint of the orbit the and half-plane y-z with negative y coordinate. Positive direction is from the origin to the positive direction of axis x.

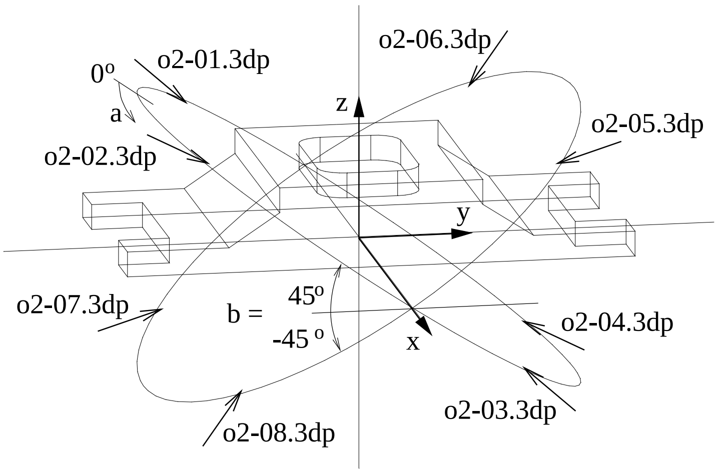

Figure 2: RECCAD test object 2 - plan of measurement

Views:

	file	a	b	density
Sequence 1:	o2_01.3dp	- 50	45	0.8x1.2mm
	o2_02.3dp	40	45	0.8x1.2mm
Sequence 2:	o2_03.3dp	140	45	0.8x1.2mm
	o2_04.3dp	- 130	45	0.8x1.2mm
Sequence 3:	o2_05.3dp	130	- 45	0.8x1.2mm
	o2_06.3dp	- 140	- 45	0.8x1.2mm
Sequence 4:	o2_07.3dp	- 50	- 45	0.8x1.2mm
	o2_08.3dp	40	- 45	0.8x1.2mm

5 RECCAD Test Object 3

Description: Object 3 consists of a rectangular parallelepiped base and a smaller rectangular parallelepiped with stumps which is put to the center of the base. There are two symmetrical openings in the base.

Coordinate system: The base of the object is the largest planar side. This base is laid in x-y coordinate plane. The axis z is perpendicular to this plane and is identical with the axis of the object. The axis y is parallel to longer edge of base. Positive direction of axis z is from the base through the object and the directions of the rest of axis are defined by the conditions of right-handed coordinate system.

The plain of measurement is like in the case of Object 2. Eight views are distributed to two perpendicular orbits. The angle 45° is contained by the orbits and x-y plane.

The direction of view is described by two angles a and b. Angle b is the angle between axis y and the projection of the orbit to the y-z plane with negative direction from y to z. Angle a represents the direction of a view on the orbit. The angle is measured from the crosspoint of the orbit and the half-plane y-z with the negative y coordinate. Positive direction is from the origin to the positive direction of axis x.

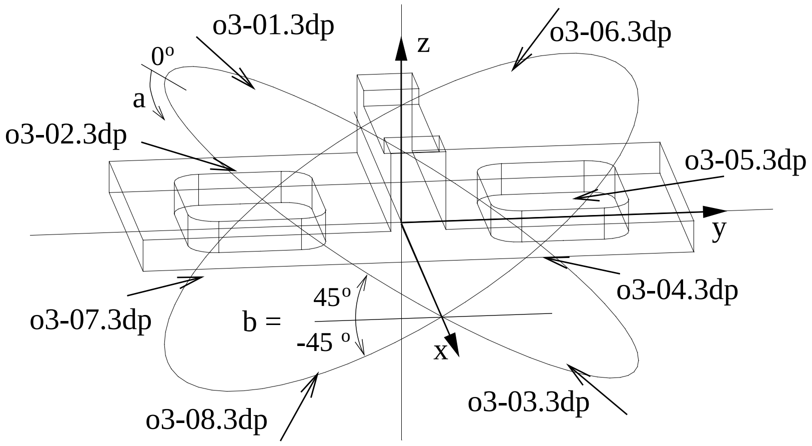

Figure 3: RECCAD test object 3 - plan of measurement

Views:

	file	a	b	density
Sequence 1:	o3_01.3dp	- 50	45	0.8x1.2mm
	o3_02.3dp	40	45	0.8x1.2mm
Sequence 2:	o3_03.3dp	140	45	0.8x1.2mm
	o3_04.3dp	- 130	45	0.8x1.2mm
Sequence 3:	o3_05.3dp	130	- 45	0.8x1.2mm
	o3_06.3dp	- 140	- 45	0.8x1.2mm
Sequence 4:	o3_07.3dp	- 40	- 45	0.8x1.2mm
	o3_08.3dp	50	- 45	0.8x1.2mm

6 RECCAD Test Object 4

Description: Object 4 consists of a basic slide rectangular parallelepiped and a smaller rectangular parallelepiped on the base which is propped by two buttresses in the opposite sides.

Coordinate system: Let's supposed that the largest rectangular base is parallel with x-y axis plane and the axis z is parallel with the axis of the object. The axis x and y are parallel with edges of base. Axis x goes around the buttress and axis y is perpendicular to the x-z plane. Positive direction of axis z is up from the base through the object and the orientation of axis x, y is defined by right-handed system.

Four measurements were obtained from the orbit in x-y plane. Another seven views are distributed on the orbit which is perpendicular to the x-y coordinate plane and parallel to the diagonal of the base. The direction of view is described by two angles a and b. Angle a is the angle between axis x and the projection of the view direction to x-y coordinate plane. The angle b is the angle between x-y coordinate plane and direction of the view.

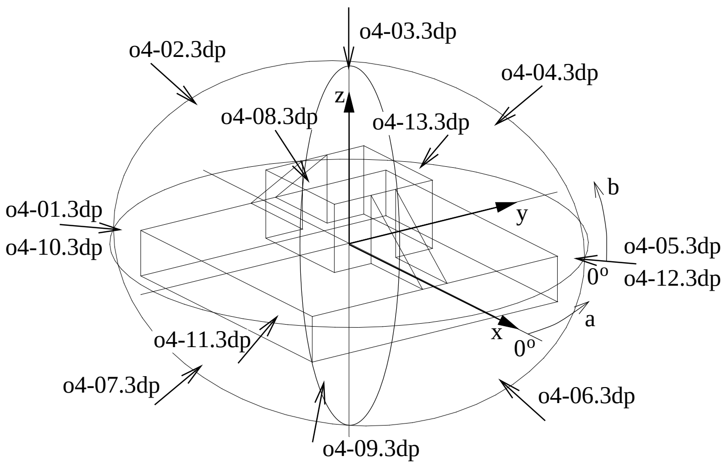

Figure 4: RECCAD test object 4 - plan of measurement

Views:

	file	a	b	density
Sequence 1:	o4_01.3dp	- 135	10	1.2x1.5mm
	o4_02.3dp	- 135	45	1.2x1.5mm
	o4_03.3dp	45	90	1.2x1.5mm
	o4_04.3dp	45	45	1.2x1.5mm
	o4_05.3dp	45	10	1.2x1.5mm
Sequence 2:	o4_06.3dp	- 135	- 45	1.2x1.5mm
	o4_07.3dp	45	- 45	1.2x1.5mm
Sequence 3:	o4_08.3dp	- 45	50	1.2x1.5mm
	o4_09.3dp	- 45	- 40	1.2x1.5mm
Sequence 4:	o4_10.3dp	- 135	0	1.2x1.5mm
	o4_11.3dp	- 55	0	1.2x1.5mm
	o4_12.3dp	45	0	1.2x1.5mm
	o4_13.3dp	125	0	1.2x1.5mm

7 RECCAD Test Object 5

Description: Object 5 is a rectangular parallelepiped with two cut corners and with the rabbet on the largest side.

Coordinate system: The largest planar side is identical with x-y coordinate plane. The axis x is parallel to the axis of symmetry of the object. The positive direction is from the center of the object to the side which has skewed corners. The axis z is perpendicular to the base with positive direction from the base to the side with rabbet. The direction of axis y is defined by the condition of clockwise coordinate system.

The plain of measurement is like in the case of Object 2 and 3. Ten views are distributed to two perpendicular orbits. The orbits and x-y coordinate plane contains the angle 45°.

The direction of view is described by angles a and b. Angle b is the angle between axis x and the projection of orbit to the x-z plane with the positive direction from x to z. Angle a represents the direction of view on the orbit. The angle is measured from the crosspoint of the orbit and half-plane x-z with positive x coordinate. Positive direction is from the origin to the positive direction of axis y.

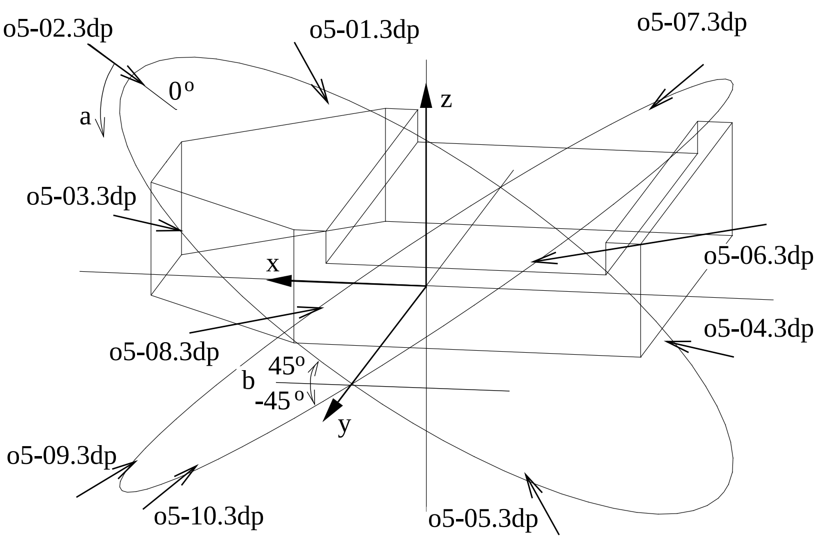

Figure 5: RECCAD test object 5 - plan of measurement

Views:

	file	a	b	density
Sequence 1:	o5_01.3dp	- 45	45	1.2x1.5mm
	o5_02.3dp	0	45	1.2x1.5mm
	o5_03.3dp	50	45	1.2x1.5mm
Sequence 2:	o5_04.3dp	- 130	45	1.2x1.5mm
	o5_05.3dp	140	45	1.2x1.5mm
Sequence 3:	o5_06.3dp	135	- 45	1.2x1.5mm
	o5_07.3dp	- 135	- 45	1.2x1.5mm
Sequence 4:	o5_08.3dp	- 45	- 45	1.2x1.5mm
	o5_09.3dp	0	- 45	1.2x1.5mm
	o5_10.3dp	- 45	- 45	1.2x1.5mm

References

[1] Tomáš Pajdla and Václav Hlaváč. Laser plane range finder. In *CTU Workshop'96*, Zikova 4, 166 35 Prague 6, Czech Republic, January 1996. Czech Technical University, Prague.