

# Recovery of 3-D coordinates of Environmental Points

R. Dutta

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## 1 Introduction

This is a supplementary write-up for the paper entitled *A Data Set for Quantitative Motion Analysis*. It contains the following

1. Further details on the data collection procedure for determining the 3-D position of selected environmental points.
2. Procedure for conversion of raw data to 3-D coordinates.
3. The 3-D position of selected environmental points at the various sites at which the image sequences were collected.

The primary focus of this report is to give estimates of the reliability of the data.

## 2 Data Collection Procedure

The data was collected in two stages. In both stages two theodolites were used. One of the theodolites had a laser range finder with which to check the results. The description of the two stages follow.

**Stage 1** Researchers from UMass measured the horizontal and vertical angles for various environmental locations while collecting the image sequences. The number of environmental points for which such readings were taken were very few (The only exception being the rocket field site). Stakes were put at the positions at which theodolites had been placed.

**Stage 2** After a few weeks researchers from Martin Marietta visited the sites and placed the theodolites at the positions at which the stakes had been put and took additional measurements for a larger number of points at the various sites.

**Coordinate System** - Two theodolites were used. They are referred to as Theodolite-M and Theodolite-D. Theodolite-M was equipped with

a laser range finder. As shown in Fig 1 the coordinate of Theodolite M is (0,0,0). The position of environmental objects are given in the XYZ coordinate system. The positive Y-axis is directed into the paper in Fig. 1.

**Drawbacks** - We could not take all the readings while taking the image sequences because of shortage of personnel and time. Also, before taking readings it was not possible to determine if the index error in the vertical circle of the theodolites was zero or not. However, later on it was concluded from other measurements that for Theodolite-M the index error was not very different from zero. Hence the Z-coordinates of the environmental points have been determined with the vertical readings of Theodolite-M. The heights of the theodolites, even when they are placed on the same position on different days, would vary somewhat. This would cause the Z-coordinates of the same environmental point to differ on different days. While it is theoretically possible to make a correction for this it could not be done in our case because we did not always have reliable common points in Stage 1 and Stage 2 <sup>1</sup>

### 3 Data Conversion Procedure

Let  $d$  be the distance between the theodolites as measured by the laser range finder. Let  $\gamma$  be the vertical angle measured by Theodolite-M as shown in Fig 1. Let P be an environmental point with environmental location  $(x,y,z)$ . Let  $\alpha$  and  $\beta$  be the horizontal and vertical angles of P measured with Theodolite-M. Let  $\alpha'$  be the horizontal angle of P measured with Theodolite-D. Then

$$(1)$$

$$(2)$$

$$(3)$$

### 4 Data

The data for the various sites is given in the attached sheets. The environmental points are labelled in the corresponding images. For environmental points which were physically reachable by the researchers the distance given by the laser range finder and the the

<sup>1</sup> Sometimes the one or two common points we had gave different correction factors. Therefore, no correction was done.

theodolites agreed very closely (e.g. in the rocket field sequence the average error was considerably less than 1% at a distance of about 30 meters).

## **5 Conclusion**

The overall conclusion is that the X and Y coordinates of environmental points are quite reliable. The Z-coordinate is somewhat less reliable because of the following reasons:

- The difference in heights between the same theodolite on different days.
- The small vertical angles for most environmental points.
- The approximation of the index error in the vertical circle.

However for depth determination the somewhat inaccurate Z-coordinates do not matter very much because the magnitude of the Z-coordinate is usually very small when compared to the other coordinates. Physically this means that most the objects were rather far and spread widely on the ground but were not very large in height (exceptions being mountain tops, pole tops etc.).