HIGH ACCURACY IN SHORT ISS MISSIONS

Abstract

Traditionally Inertial Surveying Systems (ISS) are used for missions of 30 km to 100 km length. Today, a new type of ISS application is emanating from an increased need for survey control densification in urban areas often in connection with land information systems or cadastral surveys.

The accuracy requirements of urban surveys are usually high. The loss in accuracy caused by the coordinate transfer between IMU and ground marks is investigated and an offsetting system based on electronic tacheometers is proposed.

An offsetting system based on a Hewlett-Packard HP 3820A electronic tacheometer has been tested in Sydney (Australia) in connection with a vehicle mounted LITTON Auto-Surveyor System II. On missions over 750 m (8 stations, 25 minutes duration, 3.5 minute ZUPT intervals, mean offset distances 9 metres) accuracies of 3.7 mm (one sigma) in position and 8 mm in elevation were achieved. Some improvements to the LITTON Auto-Surveyor System II are suggested which would improve the accuracies even further.

1. Introduction

Over the last ten years, inertial surveying systems (ISS) have been used typically in helicopters for long missions of up to 100 km. More recently, these systems are increasingly employed for survey control densification in urban areas where coordination is urgently required for large scale mapping, multipurpose cadastres and land information systems. Operations in urban areas require car mounted systems, increased precision (1 to 5 cm, 0.5 to 2 inch) and flexible offsetting systems which allow efficient work in dense traffic.

The commonly employed protractor offset system cannot meet the requirements of urban surveys, both, in terms of precision and flexibility. The ideal offset system should be accurate (1 cm or better), have an operational radius of 50 m (across 6 to 8 lane roads) and allow offsetting in a sector of 270 to 360 degrees.

Commercially available electronic tacheometers (total stations) can meet the above requirements if the ISS is mounted on the loading bridge of a one ton truck and the tacheometer on top of the ISS. The theory and practice of installation and operation of a tacheometer based offset system is discussed in the following sections.

2. Coordinate Transfer Between IMU and Survey Marks

2.1. Offsetting Techniques

The centre of the inertial measuring unit (IMU) is typically defined by the intersection of the three gimbal axes of a local level inertial platform. This centre is not accessible to the user and cannot be measured to nor positioned over a survey mark. Over the years, three offsetting techniques evolved which allow to relate the position of a survey mark to the centre of the IMU. These offsetting methods may be described as follows:

1) **Protractor System**: A protractor is permanently attached to the host vehicle (e.g., bumper bar of a car). The coordinates of the protractor are then determined in terms of the IMU case coordinate system. Survey marks are connected by protractor bearing, horizontal distance and height difference.

2) **Electronic Tacheometer System** (Rüeger, 1984; Colman, 1985): An electronic tacheometer (total station) is permanently mounted on the IMU's case. This tacheometer is aligned to the IMU case coordinate system. The coordinates of the intersection of the tacheometer's vertical and horizontal axes are determined in the same coordinate system. Survey marks are connected by measuring "horizontal" and "zenith" angles as well as slope distances. The three measured elements are subsequently transformed into Cartesian coordinates.

3) **Gimballed IMU System** (Hadfield, 1980): The IMU is suspended in a gimbal system featuring a "horizontal" and a "vertical" axis. A simple electronic distance meter (equipped with aiming telescope) is permanently mounted on the IMU and aligned to its case axes. The connection to survey marks is obtained by pointing the EDM instrument to a reflector over the mark and measuring the slope distance.

Some details of the offsetting techniques will be considered later when discussing the errors of these techniques. Firstly the mathematical side of offsetting is introduced.

2.2. Coordinate Transformation

Considering local-level platforms with a three gimbal configuration in order of roll $\gamma$, pitch $\theta$ and heading $\psi$ and with the inner most element orientated to north, the transformation from vehicle coordinates $d_v$ to platform coordinates $d_p$ may be written as (Farrell, 1976, Eq. (2.12)):

\[
d_p = \begin{bmatrix}
X_p \\
Y_p \\
Z_p
\end{bmatrix} = T_{p/v} \begin{bmatrix}
d_v \\
T_{p/v}
\end{bmatrix} = T_{p/v} \begin{bmatrix}
X_v \\
Y_v \\
Z_v
\end{bmatrix}
\]

(2.2.1)

where the transformation matrix $T_{p/v}$ from vehicle coordinates to platform coordinates yields (Farrell, 1976, Eq. (2.16)).