Manual of Offshore Surveying for Geoscientists and Engineers

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R.P. LOWETH

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4.1 Introduction

This chapter deals with the basic concepts of positioning at sea; we start with an introduction to least squares, on which all modern positioning computations are based, and then develop the various formulae used in the computations.

We are going to put into a single chapter the information that is disseminated to undergraduate surveyors in about a year of study, so some of the detailed explanations and proofs will necessarily be shortened.

Before going straight into least squares, we will briefly revise the coordinate systems available to us in the context of computations.

4.2 Coordinate systems

4.2.1 The ellipsoid

The ellipsoid is the mathematical figure which approximates most closely the true shape of the earth. Unfortunately, many people have tried to establish the best-fit ellipsoid for the earth, and many of the ellipsoids they calculated are in use. Life would be very much easier if there were only one ellipsoid (or spheroid).

In Australia we generally use the Australian Geodetic Datum as a datum for our offshore surveys. Even this is somewhat complicated by the following facts:

- There are two Australian datums in use — AGD66 and AGD84.
- Neither of the two datums is geocentric.
- Australia intends to move to a geocentric datum in 2000.

The AGD66 datum has the following definition:

Semi-axis major: 6378160.0m

Flattening: 1/298.25 exactly.

The minor axis of the spheroid was defined in 1966 to be parallel to the earth's mean axis of rotation in 1962 (this was later changed in 1970), and the meridian of zero longitude was defined as being parallel to the Bureau International de l'Heure (BIH) meridian plane near Greenwich. The centre of the spheroid was defined by the coordinates of Johnston Geodetic Station, a station in the centre of Australia. At that time it was assumed that the spheroid — geoid separation was zero at Johnston, and also zero at all the other geodetic stations listed in the 1966 adjustment.

Since 1966 a huge amount of information on the shape of the geoid has become available, particularly through satellite observations, and it was realized that the 1966 adjustment was no longer accurate. In 1982 all the information then available was put into a new least squares network

One way of resolving this problem is to rotate and translate the global Cartesian system into a system whose origin is a point on the surface of the chosen spheroid, and such that the Y axis points true north, the X axis points 90 deg East and the Z axis is the normal at the point of origin, positive upwards. Now, within a radius of 10km or so from the point of origin, we can define **true distances within the spread** as

$$D = \sqrt{(x'-x)^2 + (y'-y)^2 + (z'-z)^2} \tag{4.6}$$

and we can define **true azimuths within the spread** as

$$A_{PP'} = \operatorname{atan2}((x'-x), (y'-y)) \tag{4.7}$$

These are the simplest equations of all to use, and they involve no scale factors or convergence!

We therefore propose that the best method to use is as follows:

- Compute the vessel position in terms of the global 3D Cartesian system.
- Transfer the global 3D position to the local 3D system, using an origin which moves from shot to shot and which is located at the vessel's navigation reference point.
- Compute the in-spread data (i.e. sources and streamers) on the local system.
- Transfer the output back to the spheroid and/or projection as required.

Note that the computation from one system to another only ever involves point computations, not lines; therefore scale factors and convergence never enter into the computation. We will use X and Y coordinates throughout the computations rather than E and N, to emphasize that we are working in a local 3D Cartesian system.

4.3 Least squares

4.3.1 Why least squares?

The person responsible for postulating the least squares process was Legendre, in 1806. He proposed that, given a set of n equally reliable measured values ($x_1, x_2, \ldots, x_n$) of a quantity, the most probable value (MPV) x of that quantity is that which makes the sum of the squares of the residuals a minimum. A residual (v_i) is defined as

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