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Article · January 2007

Source: OAI

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2nd International Conference on Experiments/Process/System Modelling/Simulation & Optimization
2nd IC-EpsMsO
Athens, 4-7 July, 2007
E-Proc, ISBN: 960-530-093-1, © IC-EpsMsO

CONVERSION OF GPS DATA TO CARTESIAN COORDINATES VIA AN APPLICATION DEVELOPMENT ADAPTED TO A CAD MODELLING SYSTEM

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Keywords: Coordinates conversion, CAD development, GPS data, CAD modelling and simulation

Abstract. *Nowadays, common methodologies in telegeoprocessing–telegeomonitoring use telecommunication means such as the GPS in order to transmit geographical coordinates to modelling and simulation systems. These 3D geodetic coordinates (φ, λ, h) can be used by modeling systems via specifics interfaces in order to proceed to real-time modelling of the remotely transmitted data.*

A previous published work describes a real-time remote 3D digitizing and modelling procedure via transmitted Global Positioning System (GPS) data from the field towards to a CAD system. However, these GPS data must be converted to adequate coordinate's format (x, y, z) so that the CAD system can use them.

This paper presents the computing development of a specific application adapted to a CAD modelling system permitting the conversion of the geodetic coordinates to cartesian coordinates. It presents the relation between geodetic and cartesian coordinates, the options of the final developed application and finally some schematic aspects of the computing process.

The application development is realized in AutoCAD modelling system environment via special developed interface in Visual Basic (VBA) and Visual Lisp programming language.

The aim of this work is to give the possibility to a CAD modelling system to "translate" and receive automatically geographical coordinates or to convert manually and selectively geodetic coordinates φ, λ, h to cartesian coordinates x, y, z.

1 INTRODUCTION

New technologies such as GPS, VHF devices, telecommunication means and specific methodologies are used in telegeoprocessing – telegeomonitoring in order to simulate in real-time spatial information (e.g. animated cartography, meteorology, telecom, GIS, radio-communications, etc) [1]. A specific procedure, based on these methodologies, has been developed and presented in a previous published work [2]. According to this procedure, via remote connection of special telecommunication devices and sensors we can capture spatial information-data (geographical coordinates, rates of sound, temperature, light etc) and transmit them remotely in to a modelling and simulation system such as a CAD system. Precisely, the first function-step of the procedure refers to capturing, transmission and final editing of the data in an adequate format. The second-one refers to receiving and to an adequate editing of the data into a CAD modelling and simulation system in order to proceed in real-time modelling of the remotely transmitted data [3].

However, the transmitted data and especially the geodetic coordinates of the GPS device (φ, λ, h) must be converted in cartesian coordinates, so that the CAD system can use them.

The original contribution of this work is not only the proposed developed application (add-on) adapted to a CAD system which permits the automatic or manual conversion of GPS data to cartesian coordinates but basically the adaptation of this application to a development in process real-time modelling and simulation procedure of remote transmitted data ; the procedure in question facilitates the link between the captured data in-situ and their "translation" into modelling and simulation system.

2 FUNDAMENTALS

The earth is not flat and sphere but a simplified model of it might look like to an almost ellipsoid shape which is used in order to approximate the bulk of the Earth's shape. However, because of the complex of the irregularities of the earth's surface, different highs and elevations are defined in order distances from earth's surface to be determined with more precision. Thus, the "geoid" is a surface which coincides approximately with the mean ocean surface and departures from the ellipsoid are represented by the geoid elevation above or below the ellipsoid [4]. The Earth Gravitational Model 1996 (EGM96) is one of the latest global models which estimates and shows the global geoid undulations helping to measure the GPS height (h). The geoid can be as low as 107 meters below the ellipsoid or as high as 85 meters [5] (fig. 1).

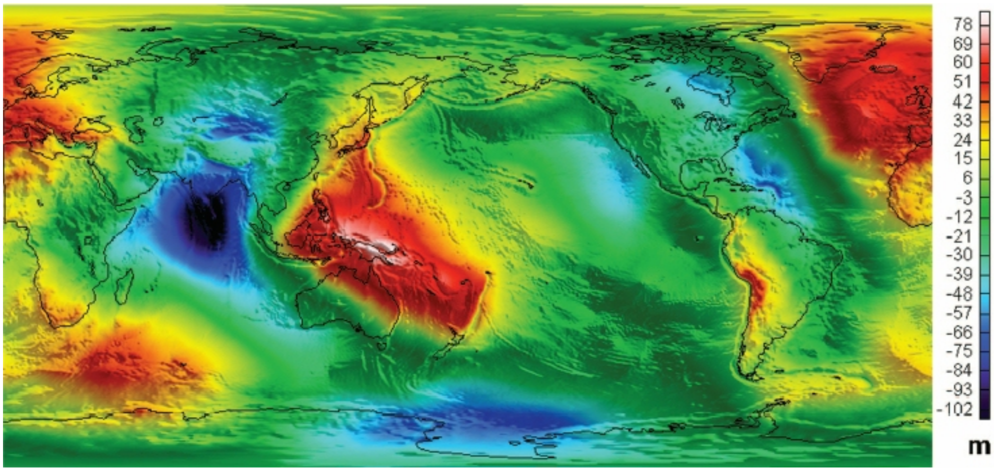

Figure 1. The Earth's Geoid : Global geoid undulations produced by EGM96 [5]. The undulations range from 107 m below the ellipsoid and 85 m above and have an error range of +-0.5m to +-1:0m worldwide. Black lines indicate coast lines.

GPS, which the last few years has become the leading positioning technology, produces many different kinds of height depending, among other, on selected points on earth, base stations and satellite positions. The GPS xyz coordinates are transformed and transmitted into geodetic coordinates such as latitude, longitude and ellipsoidal height taking into account the ellipsoid model of the earth. The ellipsoid height, which refers to the ellipsoid, is denoted "h" [6] (equation 1). In short, h, (the ellipsoid height) is the sum of H (the elevation which refers to the geoid), and N (the geoid height) (undulation) [7] (fig. 2) :

$$h = H + N \tag{1}$$

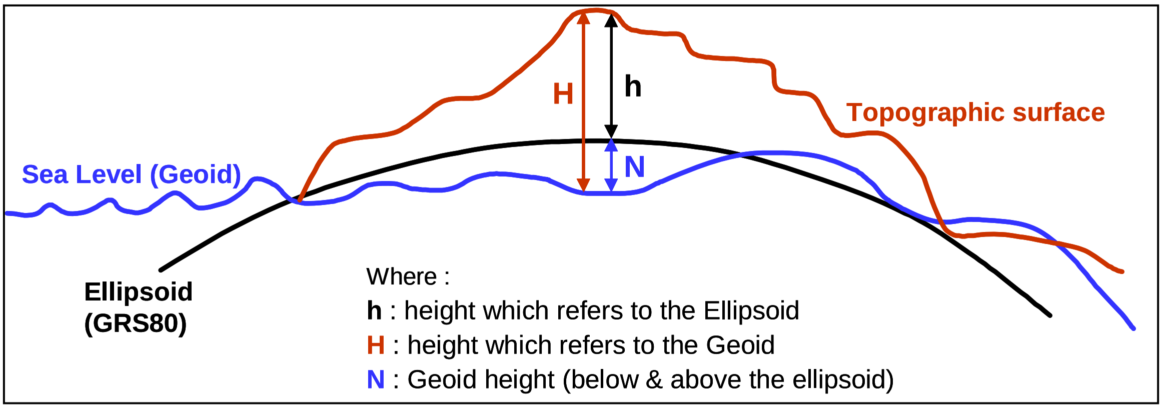

Figure 2. Relationship between ellipsoid – geoid and topographic surface (the landmass topography as well as the ocean bathymetry).

Therefore there are many reference locations systems, including elevations, called "datum" which describe more precisely the irregularities of the earth surface. The most common datum are the World Geodetic System 1984 (WGS84), which is used by the GPS, and the Geodetic Reference System 1980 (GRS80). These systems define among other geometric parameters which are absolutely necessary to calculate many gravity formulas in order to give important information such as coordinates, positions, distances, heights, etc. In geodetic coordinates the earth's surface is approximated by an ellipsoid and locations near the surface are described in terms of latitude (φ), longitude (λ) and height (h). The ellipsoid is completely depended on the semi-major axis "a" and the flattening "f" which are constants permitting, among other, to calculate the conversion of the geodetic coordinates (φ, λ, h) to cartesian coordinates [7].

The latitude (φ) is a measure of north-south extent on an ellipsoid of revolution and it is the angle between the normal to the ellipsoid and the equatorial plane and the longitude (λ) is a measure of the east-west extent on an ellipsoid of revolution and it is the angle or rotation in the equatorial plane (with north being up) from a reference, zero line [8]. Both coordinates are angular and are usually measured in degrees (longitude is between -180 and 180 degrees while latitude is between -90 and 90 degrees) [9] (fig. 3).

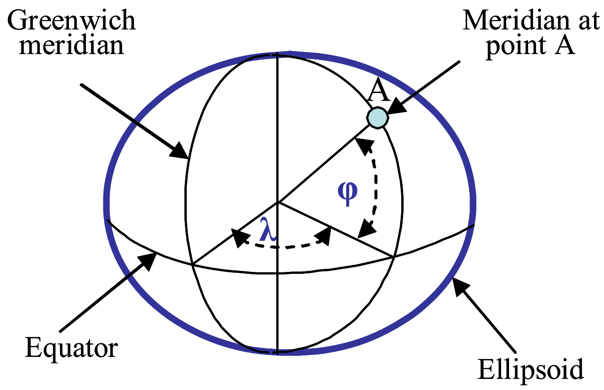

Figure 3. Geographic coordinates of a point on the ellipsoid

3 BASIC CONCEPTS AND CALCULATIONS

The direct problem involves the computation of the X, Y, and Z coordinates of a given point with its latitude, longitude, and height. The relationships between the computation of the cartesian coordinates x, y, z of a given point with its latitude (φ), longitude (λ) and height (h) are well known and shown below [10] (equations 2 to 7).

$$X = (N + h) * \cos \varphi * \cos \lambda$$

$$Y = (N + h) * \cos \varphi * \sin \lambda \qquad (2)$$

$$Z = [\, N^* (1-e^2) + h \,] * \sin \varphi$$

Where :

N = radius of curvature in the prime vertical : $N = \dfrac{a}{\sqrt{1 - e^2 * \sin^2 \varphi}}$ (3)

e = first eccentricity : $e^2 = \dfrac{a^2 - b^2}{a^2}$ or $e^2 = 1\text{-}b^2/a^2$ or $e^2 = 2f\text{-}f2$ (4)

f = flattering : $f = \dfrac{a - b}{a}$ = (f = 1 / 298.257223563 = 0.003353 by WGS84) (5)

a = semi-major axis of the ellipse (semi-diameter of the longest axis of a reference ellipsoid called equatorial axis) = (6 378 137 by WGS84) (6)

b = semi-minor axis of the ellipse (semi-diameter of the shortest axis of a reference ellipsoid called polar axis) = a(1-f) = (6 356 752 by WGS84) (7)

4 APPLICATION DEVELOPMENT

The proposed application is an “add-on” routine adapted to the AutoCAD platform. This routine takes into account the above fundamentals and is based to the previous formulas in order to convert the geographical coordinates to cartesian coordinates. This conversion is an intermediary step that links the phase of the remotely transmitted GPS data reception and the final phase of modelling and simulation to a CAD system; these phases are parts of a finalisation in process real-time remote 3D digitizing and modelling procedure (fig. 4).

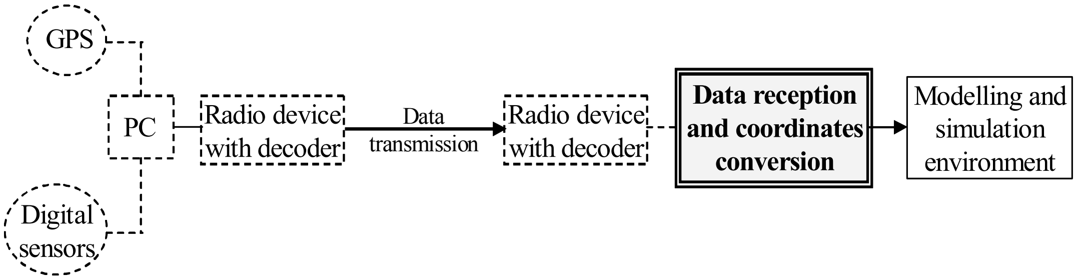

Figure 4. Schematic flow of the coordination conversion phase position in to real-time remote 3D digitizing and modelling procedure

The developed application is based on remote transmitted data reception which are stocked in three files format such as text files (*.txt), calculation sheets (*.xls) or data base files (*.mdb). A special developed interface filters the geodetic coordinates (φ, λ, h) from these data files and sends them to the developed application in order to transform them in cartesian coordinates. Before the beginning of the conversion it is necessary to select the adequate datum in order to adapt the coordinates be converted to the right references locations. The next example shows some different geodetic reference systems and their geometric parameters which are used and adapted to the proposed application [7] (table 1).

Geodetic reference system	**(Semi major axis *a* in meters)**	**Reciprocal of flattening (1= *f*)**
Airy 1830	6 377 563.396	299.324 964 6
Helmert 1906	6 378 200	298.3
International 1924	6 378 388	297
Australian National	6 378 160	298.25
GRS 1967	6 378 160	298.247 167 427
GRS 1980	6 378 137	298.257 222 101
WGS 1984	6 378 137	298.257 223 563

Table 1. Examples of different geodetic reference systems and their geometric parameters.

Furthermore, an option of the application helps to input manually the geodetic coordinates in order to convert them; this option a) contributes to the modelling process and/or b) evaluates the results of the conversion (cartesian coordinates).

Finally, the application permits and contributes to the real-time modelling and simulation of these coordinates in CAD environment (fig. 5)

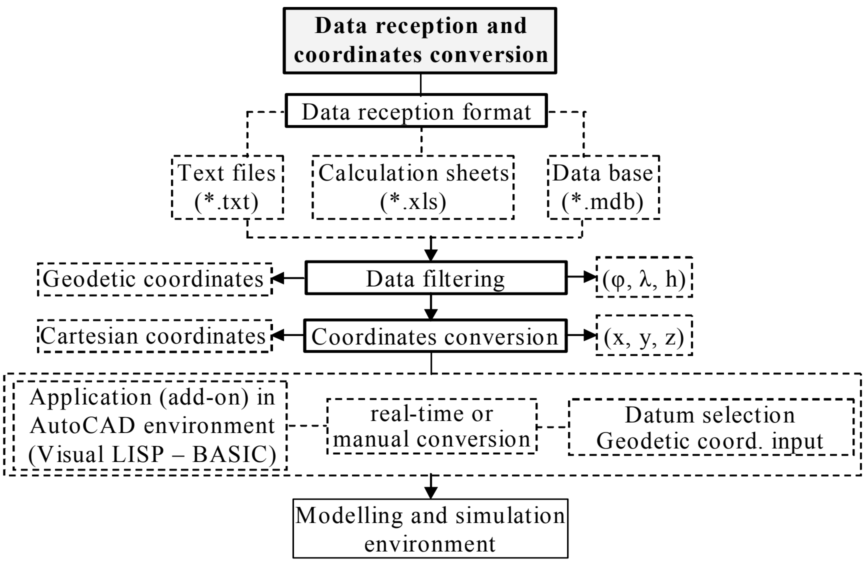

Figure 5. Schematic flow of coordinate's conversion process in developed application adapted to a CAD system

5 CONCLUSIONS

The proposed application is composed of developed routines in CAD environment with Visual Basic for Applications (VBA) and Visual Lisp programming language. The main options permit to: a) select adequate reference location system, b) input manually or extract automatically geodetic coordinates from remotely transmitted data, c) convert geodetic to cartesian coordinates.

The application development is based a) on fundamentals notions concerning the irregularities and the elevations of the earth and b) on basic calculations concerning the relationships between the computation of the cartesian and geodetic coordinates. These calculations take into account earth's computation parameters such as positions, distances, heights which are described by geodetic reference systems.

The aim of the proposed application, except from the obvious coordinates conversion, is also a) to facilitate the link between the transmitted data from a field to a computer system and their "translation" into a modelling and simulation system b) to be adapted to a CAD environment system and finally c) to contribute to a development in process real-time modelling and simulation procedure of remote transmitted coordinates.

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