Computers in Industry 89 (2017) 1–12

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

Mapping the time. Method for logistics management software: Application in Spain

C. Enríquez[a], J.M. Maqueira[b,*], S. Bruque[b]

[a] University of Jaen, Department of Cartographic Engineering, Geodesy and Photogrammetry Campus Científico Tecnológico, Edificio Departamental y Laboratorios Oeste, Cinturón Sur s/n, 23700 Linares, Jaén, Spain
[b] University of Jaen, Department of Business Administration, Campus Científico Tecnológico, Edificio Departamental y Laboratorios Oeste, Cinturón Sur s/n, 23700 Linares, Jaén, Spain

ARTICLE INFO

Article history:
Received 26 September 2016
Received in revised form 11 January 2017
Accepted 22 March 2017
Available online xxx

Keywords:
Software for logistics management
Distribution logistics
Thematic cartography

ABSTRACT

The usual form to represent a point in a map is based in its geographical coordinates, establishing their relationship with other points in terms of distances and angles, usually azimuths. However, sometimes, the distance is not the most crucial factor when we want to represent certain relations. Thus, it may be important to represent jointly the travel time between two cities and the distances between them. In this representation greater distances are not always associated with longer times to drive. These maps, which also represents the time as a pseudo distance, would be useful for decision-making related to logistics management. This occurs in distribution logistics, where companies must meet delivery times, making prompt deliveries and timely deliveries. A software to perform comparative mapping from a source to a destination of distances and times between different geographical areas for road, rail and flight transport, would be useful for making decisions about what transport type should be used in order to minimize travel time between two points. This article shows method for joint representation of both magnitudes, which has been implemented in CHRONAS-MAP an initial version of software that implements this method in Spain.

1. Introduction

“Time is money” is a popular phrase coined by the XIXth novelist Edward Bulwer-Lytton which expresses the idea that in business every minute you waste is money that you lose. Following this idea we update the usual form to represent a point in a map, which is made in terms of its geographical coordinates, by the time needed to travel from one point to another. We do this because, sometimes, the distance is not the most crucial factor when we want to represent certain relations. For example, while studying cost of keeping cool food it can be more useful to know the travel time between two cities than the distances between them.

The idea of representing maps in terms of travel times has not been very developed [1–3]. Since this method provides information at a glance and in a visual way about how cities are connected among them. Also this kind of mapping can point out inhomogeneities in the transportation network, indicating which cities are isolated from the rest. In logistics management, both distance and time are variables of utmost importance [4].

In this paper, we pursue the aim of presenting a method that allows joint representation on a map of distances between cities and times that are used to travel these distances, being represented this time by way of pseudo distances using a method similar to the distances in mapping calculation [5,6]. This method presented can be implemented in software applications for logistics management purposes, and is especially useful for decision-making in distribution logistics [7,8]. As an example of the possibilities presented method, it has been implemented in a new beta software development called Chronas-Map which has been used to apply the method in the case of Spain. Chronas-Map is a minimum viable product [7,9] that displays several outcomes in the application of the method. This method could be implemented in other software applications for logistics management, appearing as a powerful tool for decision making in this area. Thus, in Chronas-Map we have elaborated an anamorphic map, in fact pseudoequidistant an azimuthal projection [10,11], in which the radius is the travel time to go from the center point of the projection to another point.

The paper is structured as follows. After this introduction the second section shows the new method proposed to represent the

* Corresponding author.
E-mail addresses: cenriquez@ujaen.es (C. Enríquez), maqueira@ujaen.es (J.M. Maqueira), sbruque@ujaen.es (S. Bruque).

http://dx.doi.org/10.1016/j.compind.2017.03.005
0166-3615/

time on a map. This second section also shows the mathematical foundations on which it is based and the application of these fundamentals is the new particular method we propose. The third section includes the implementation of the method in Chronas-Map software in Spain, and different results showing distances and times by road and rail from various major cities in Spain to others. As an example, flight journey times are also shown to other cities in other countries. The discussion is shown in section four. The paper ends with conclusions in the fifth section.

2. The method

In this section we collect the mathematical foundations of our method and the individualization of these fundamentals to the representation of time on a map.

2.1. Mathematical basis of the projection

The azimuthal equidistant projection is defined as a projection in which all points on the map are at correct distance and azimuth from the center point, called *pole of the projection* [10].

The equations of the equidistant azimuthal projection can be obtained through spherical trigonometry. If in a unit sphere, a point P (ϕ_0, λ_0) is the center of the projection then the distance and the azimuth to a point A (ϕ, λ) are given by the solution of the spherical triangle P_N-P-A [11]. If we apply the Law of Cosines to this spherical triangle (see Fig. 1) we get the distance:

$$\cos\ a = \cos(90-\phi_0)\cos(90-\phi)+\sin(90-\phi_0)$$
$$\sin(90-\phi)\ \cos(\Delta\lambda)\ = \sin\ \phi_0 \sin\ \phi + \cos\ \phi_0\ \cos\ \phi\ \cos\ \Delta\lambda \quad (1)$$

With the Law of Sines or the third fundamental formula, we can get the azimuth:

$$\sin\ \theta = \sin(90-\phi)\frac{\sin\ \Delta\lambda}{\sin\ a}$$
$$\sin\ a \cos\ \theta = \cos(90-\phi)\sin(90-\phi_0)$$
$$-\sin(90-\phi)\cos(90-\phi_0)\cos\ \Delta\lambda \quad (2)$$

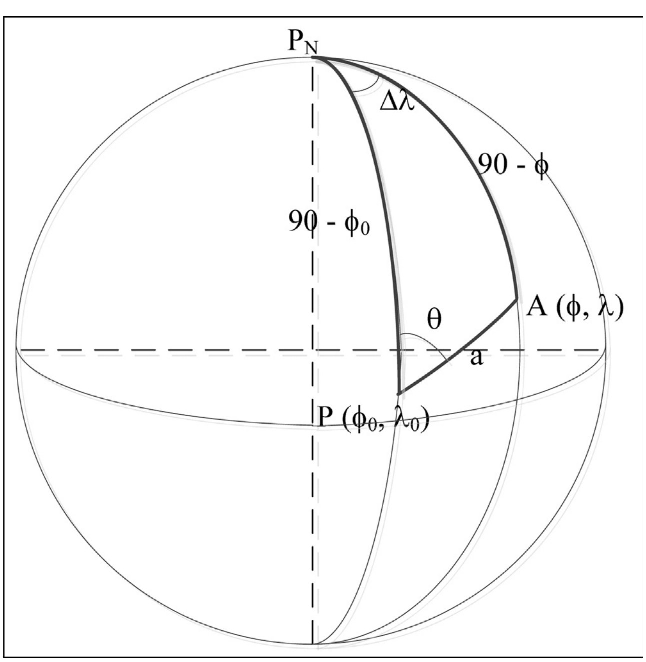

Fig. 1. Azimuth and distance over the sphere.

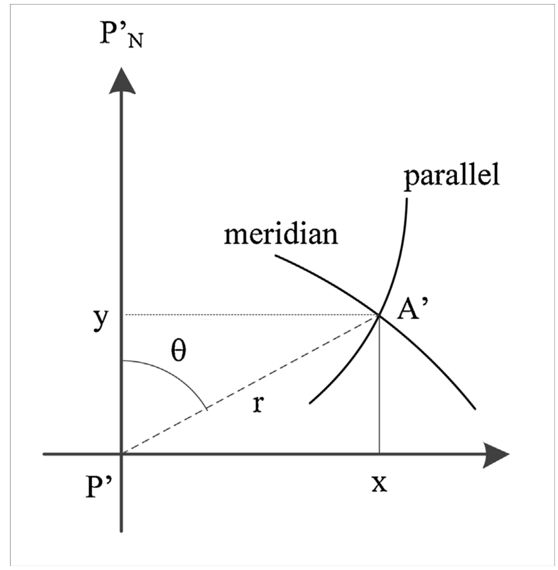

Fig. 2. Relationship between Polar and Cartesian coordinates.

If the Y axis coincides with the central meridian λ_0 and y increases northerly (see Fig. 2), the Cartesian coordinates are:

$$x = r\ \sin\ \theta$$
$$y = r\ \cos\ \theta \quad (3)$$

In this case $r = a$ so substituting a and θ given by (1) and (2) we obtain the desired equations:

$$x = k\cos\ \phi \sin\ \lambda$$
$$y = k(\cos\ \phi_0 \sin\ \varphi - \sin\ \phi_0 \cos\ \phi\cos\ \Delta\lambda) \quad (4)$$

being

$$k = R\ \frac{r}{\sin\ r} \quad (5)$$

where R is the radius of the Earth equals to 6400 km.

If *cos a = 1*, equation is indeterminate, but $k = 1$, and x = y = 0. If *Cos a* = –1, the point opposite the center ($-\phi_0$, $\lambda_0 \pm 180°$) is indicated; it is plotted as a circle of radius πR.

2.2. Mapping the time

In our case, the distance, *r*, in Eq. (3), must be substituted by the pseudodistance τ, defined as the time needed to travel from point P to point A. So Eq. (4) becomes

$$x = \tau\ \sin\ \theta$$
$$y = \tau\ \cos\ \theta \quad (6)$$

Substituting θ given by (2) we obtain

$$x = \kappa\ \cos\ \phi\ \sin\ \Delta\lambda$$
$$y = \kappa(\sin\ \phi\ \cos\ \phi_o - \cos\ \phi\ \sin\ \phi_0\ \cos\ \Delta\lambda) \quad (7)$$

where

$$\kappa = \frac{\tau}{\sin\ a} \quad (8)$$

and the value of a can be obtained from Eq. (1).

In practice the application of the proposed method involves knowing geodetic and cartesian coordinates of each city with respect to the city that acts as a central point to represent these distances on the map, and the times when walking such distances, data can be tabulated (see Appendix A). Applying the Eqs. (4) and (5) the distances are represented on the map. Applying the Eqs. (1), (7) and (8) times are represented in the map.