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GPS MONITORING OF BUS SPEED

Annotation: Commercial bus speed is a key factor in the operation of public transport systems because it represents a direct measure of the quality of service provided to users and also considerably affects system costs. By commercial speed, we are referring to the average speed of buses over stretches, including all operational stops. Evaluating system performance by monitoring the commercial speed provided by bus services is highly desirable; however, in dense networks, it becomes a difficult task because of the amount of information required to implement such a monitoring procedure.

Keywords: Speed of buses gps, monitoring, system performance.

1. Introduction

In operational terms, commercial bus speed is a key variable in the operation of public transport systems because it is related to both the level of service provided to users and the system cost. By commercial speed, we are referring to the average speed of buses over stretches, including all operational stops (bus stops, terminals, and traffic lights). This definition of commercial speed is different from what is defined as running speed, which only considers moving buses. Monitoring the status of commercial speed (hereinafter referred to as speed) is important, although it becomes very difficult in cases of dense route networks, mainly because of the amount of information required for such a process. Currently, vehicles are equipped with GPS technology, which allows us to overcome this difficulty by means of proper interpretation and handling of the data provided by GPS devices.

Data description and processing

1.1. Original data

With regard to the availability of data, we focused our analysis on the information available from the Transantiago bus system. Although information exists for the entire operational period from March 2007, we extracted data from a single week (09/01/2008-09/07/2008).

The database was structured into tables. The bus position table contains geo-coded bus information (latitude, longitude and time). The GPS device provided bus positions at regular, 30-s intervals when the bus was moving (the buses were moving for 80% of the observations). If the driver pressed the panic button (which was sometimes pressed accidentally), then the position was registered every 10 s (this interval was found in approximately 15% of the sample observations). If the bus was not moving, then a control register was taken every 5 min (5% of the data in our 1-week sample). In total, 6178 different buses (determined by license plates) were observed in the system. An additional table contains bus assignments and pro- vides information about each bus route over a certain period. There were 737 different routes in the system, including variations such as express or short services. The route assignment information was provided by Transantiago. Linking both tables, we obtained 44,476,637 observations of bus positions that were assigned to known routes.

1.2. Path rectification

Storey and Holtom (2003) discussed the need to represent routes in the simplest way possible by using the road center line and fitting each data point to the center line of the most appropriate section of road. Based on such recommendations, we simplified the representation of the information available from the defined paths for each route. The paths are identified in the form of a shape that is translated into geocoded points.

The original data contained regularly separated points (at very short distances) and showed some disturbances at intersections with other routes. We transformed the original data into a

more manageable and precise path definition using the Douglas and Peucker (1973) procedure. We were then able to identify the minimum number of points required to define the route path within an error bound e. Douglas and Peucker's method started with the original multiple points definition of the path and recursively selected the points that generate new segments that are sufficiently close to the original line.

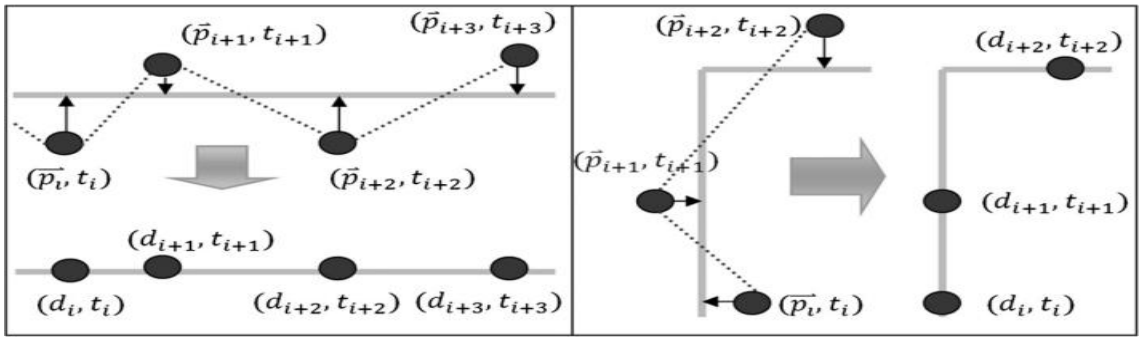
A representation of the procedure is depicted in Fig. 1a, where the original curve is given by the ordered set of points shown in part 0, and the final curve is shown in part 4. This figure shows that the algorithm recursively split the line. Initially, all points between the first and last point were considered.

The visualization of the paths and GPS points in Google Earth shows that the procedure provided reasonable results.

The path rectification method was used to deal with problems that arose close to the junctions and to simplify the path definition. This rectification was accomplished by reducing the number of redundant nodes that did not contribute to the definition of the route path within a predefined error bound. With regard to the final goal of computing commercial bus speeds, the rectification of paths through the Google Earth tool allowed for the correct computation of route distances.

Apart from this practical issue, there were certain problems with the path definition. For example, some routes used reversible roads (a common practice in Santiago), and in other cases, there were traffic deviations. We defined a procedure to identify those GPS points that were far from the corresponding path so that those outlying points could be eliminated from the analysis.

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on of GPS pulses to rectified paths. One important issue is the projection of the GPS locations onto the path definitions. These points were properly rectified using the methodology described previously (computing the orthogonal projection of the GPS points into the path line that is defined by the segmentation points). In Fig. 2, we show the projection process in the following two interesting cases: a straight path and a 90° turn.

In Fig. 2, each pair ðp¯ᵢ; tᵢÞ denotes the position (in two-dimensional coordinates) that is instantly recorded by a GPS pulse *i*. The pair (d_i, t_i) corresponds to the new description of a GPS pulse *i* in which the position is translated into a distance measurement relative to the origin of the pulses' associated route path.

2. A methodology to compute representative speed values

The computation of a representative speed for the Transantiago buses is a major challenge, mainly due to the amount of information and the degree of data disaggregation. To obtain reliable speed values, a crucial issue is the proper management, processing and estimation of the required inputs for the calculations (distance and lapses based on interpolations in time and space).

The monitoring system provides information regarding GPS pulses that register bus positions every 30 s. As GPS devices automatically generate instantaneous speed data, a natural initial analysis is to compute the average of those observations, which are directly available in the database. However, instantaneous speeds are unstable in urban conditions because buses are constantly accelerating and decelerating, and the information is considered unreliable by system operators.

The objective is to devise a flexible and representative methodology that would allow a decision maker to manage different disaggregation levels in space and time. Based on that objective, we define a typical time-space diagram grid for each given route, where each element of the grid is defined by a rectangle of edges *D* and *T*.

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