Applied Mathematics and Computation 000 (2017) 1–13

Contents lists available at ScienceDirect

Applied Mathematics and Computation

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

A recommender system for train routing: When concatenating two minimum length paths is not the minimum length path

Antonio Hernando [a], Eugenio Roanes-Lozano [b,*], Alberto Garcia-Álvarez [c]

[a] Depto. de Sistemas Inteligentes Aplicados, E.T.S.I. de Sistemas Informáticos, Universidad Politécnica de Madrid, Madrid, Spain
[b] Instituto de Matemática Interdisciplinar & Depto. de Álgebra, Universidad Complutense de Madrid, Madrid, Spain
[c] Fundación de los Ferrocarriles Españoles, Madrid, Spain

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Railway routing optimization
Graph theory
Dijkstra algorithm
Railway network
Track gauge
Variable gauge train

ABSTRACT

In this paper, we propose a method for finding the optimal route for a specific train from a station to another one in the Spanish railway network (or any railway network involving different incompatible features like gauges, electrification and signaling systems). The complexity of the Spanish railway infrastructure makes it difficult to give an estimation of the fastest route of a train from a given station to another. Indeed, very unintuitive situations may happen. The problem of finding fastest routes is typically modeled by a graph where nodes represent stations and edges represent railway sections. However, this approach is not suitable for the Spanish railway network. In order to solve the problem of calculating the fastest routes, we will propose here a novel approach based on modeling the railway network through a different graph whose nodes represent railway sections.

1. Introduction

In this paper, we will propose a method for finding the optimal route for a specific train from a station to another one. The Spanish railway network is quite complex since it considers different features which do not always make it possible for a train to go through a railway section (this happens when the features of the section are not compatible with those of the train).

Different track gauges. The 'track gauge' is the distance between the inner sides of the heads of the two load bearing rails of the track.

In the Spanish railway network (run by the railway infrastructure administrator *ADIF*), two different track gauges coexist (see Fig. 1): the classic Iberian track gauge (1668 mm) and the 'standard gauge' (1435 mm), used in the new high-speed lines.[1]

Problems derived from the coexistence of these two gauges are partially surpassed by the development of rolling stock that can run on both kinds of tracks. For instance, *Renfe* (Spain's government railway operator) owns [22]:

- variable gauge locomotive-hauled Talgo trains formed with lightweight, single-axle (independent wheels) coaches

* Corresponding author.
E-mail addresses: ahernando@etsisi.upm.es (A. Hernando), eroanes@mat.ucm.es, eroanes@fi.upm.es (E. Roanes-Lozano), albertogarcia@ffe.es (A. Garcia-Álvarez).

[1] The 1000 milimeters network operated by the now extinct *FEVE* was absorbed by *ADIF* in December 31st 2012. It is not considered in this work as there is no rolling stock that can run on narrow gauge tracks and tracks of any of the other gauges.

http://dx.doi.org/10.1016/j.amc.2017.05.043
0096-3003/

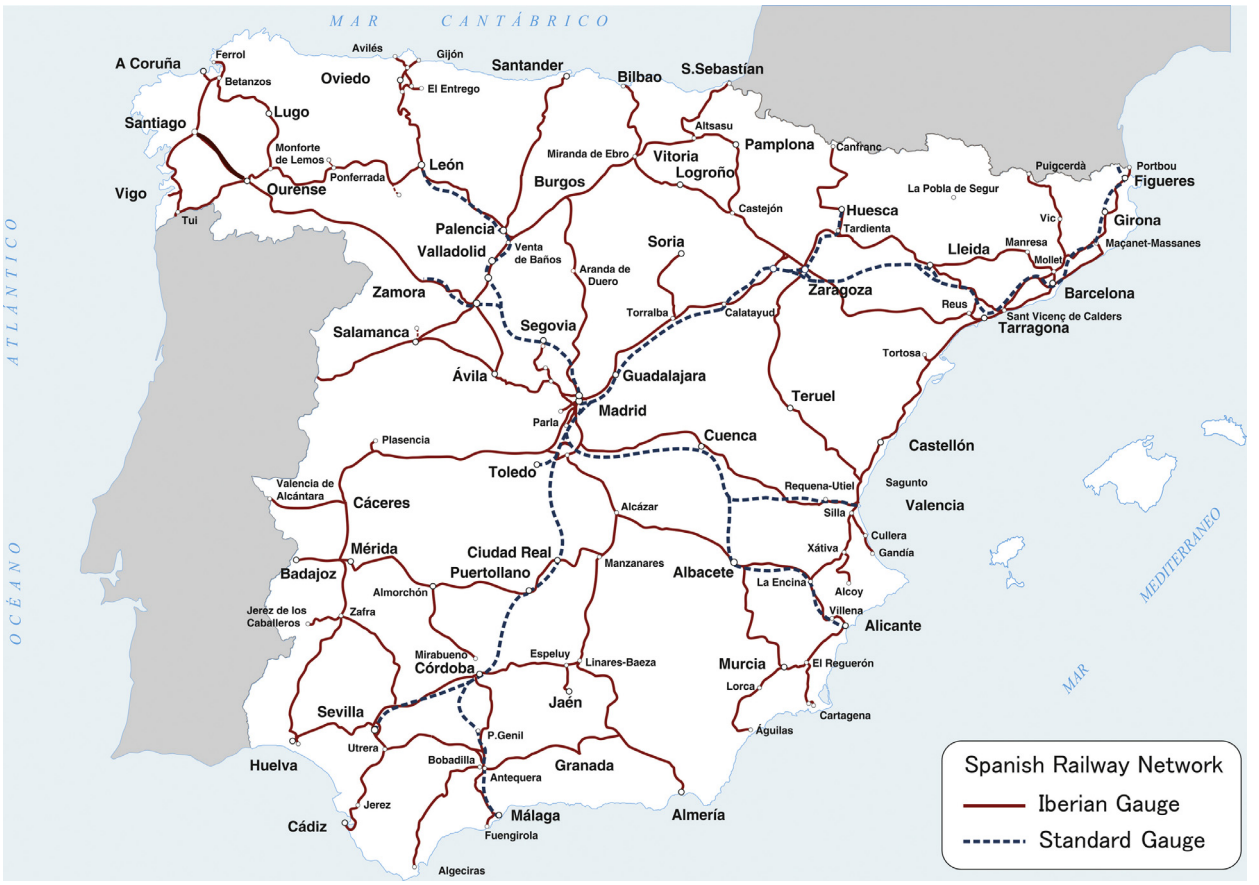

Fig. 1. The Spanish railway network (2017). Courtesy of the Fundación de los Ferrocarriles Españoles.

as well as variable gauge multiple units of self-propelled passenger trainsets (trains without an independent locomotive):

- *Renfe* classes 130 (see Fig. 2) and 730, developed and constructed by *Talgo*
- *Renfe* classes 105, 120 and 121, designed and built by *Construcciones y Auxiliar de Ferrocarriles* (*CAF*).

Appropriate devices, called 'cambiadores de ancho' (gauge changers) [9] have been installed at certain junctions, to allow these variable gauge trains to pass from the new network to the old one and vice versa (these devices are required to unlock, reposition, and relock the wheels in the new position). Unlike multiple units, the locomotives of locomotive-hauled trains cannot pass through gauge changers; these trains must instead be uncoupled from their locomotives, pushed through the gauge changer and coupled to another locomotive (of the other gauge). Variable gauge systems for powered axles is far more difficult than for axles of coaches or goods wagons (the first gauge changers were installed in the border between Spain and France in 1969 and were used for variable gauge *Talgo* coaches) [9].

In this way, for instance, the variable gauge trains acquired by the railway operators running from Madrid to Bilbao can use the new line up to Valladolid, pass through a gauge changer that can be found there and continue along the classic line for the rest of the journey.

Passing through a gauge changer takes between 10 and 15 min for a multiple unit.

Regarding gauge, it should also be taken into account that there are certain sections of the railway network with three rails (double gauge sections). In *ADIF*'s railway network this is the case in:

- Tardienta – Huesca section (in the Zaragoza – Canfranc branch line),
- Girona – Figueres (in the Barcelona – French border railway line),
- some sections of the Barcelona bypasses,
- some sections of the 'Mediterranean corridor',
- some sections of the Basque 'Y'.

Different electrification systems. In *ADIF*'s network there are two different electrification systems: 3 kV direct current (DC) and 25 kV alternating current (AC).

Please cite this article as: A. Hernando et al., A recommender system for train routing: When concatenating two minimum length paths is not the minimum length path, Applied Mathematics and Computation (2017), http://dx.doi.org/10.1016/j.amc.2017.05.043