

# Collaborative planner for bicycle commuting in the urban environment

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**Abstract.** In recent years, bicycle users have increasingly been using route finding services on the web. This paper focuses on a route finding service for bicycle users that can be adapted to any city, even where there is no detailed, accurate and updated information as to the attributes of the road network that are relevant to the search of safe, competitive and comfortable paths for cycling (slope, intensity and speed of traffic, width of roads, quality of pavement, etc.). Our system involves and takes advantage of the efforts of the bicycle user community in each city. For this reason, our solution does not need a central entity responsible for the introduction and maintenance of road network attributes.

## 1 Introduction

In the main cities of Europe, bicycles have already conquered their space and have been used, for short distances, as an alternative means of transport to the car [1].

The bicycle means of transport has environmental and energy benefits. It improves the quality of the urban environment, having an impact on the physical, social and mental well-being of citizens [2]. The bicycle is the fastest and most efficient means of travel within the urban areas, especially for distances of less than 5 km [3].

Bearing in mind all the above benefits, it is necessary to stimulate the use of the bicycle as means of transportation in our country [4].

In Portuguese cities such as Lisbon, Oporto, etc., that have a low number of bicycle users, and still provide a scarce infrastructure for this means of transport, the choice of safe and comfortable paths is a crucial factor. In those cities, the choice of these paths for a person to move is normally a skill that is accessible only to the city's most experienced bicycle users.

The best paths are those which take into account all factors relevant to the commuting of a bicycle user. Factors such as distance, slope and safety are the most relevant to the search of a good path [5]. While the distance factor only takes into account the distance, allowing to obtain the shortest path, the slope factor allows to avoid steep ascents, returning if possible a more even path. The last factor aims to return a more secure and comfortable path. This is a path

that takes into account the type of pavement, tries to cover bicycle lanes and streets with light and calm motorized traffic.

Nowadays, the expansion of route finding services of bicycle paths on the web is more and more noticeable. Among the most popular examples that allow the search of bicycle paths you can find: Google Maps<sup>3</sup> (available in the United States, in the United Kingdom and recently in France, Germany, Poland, Ireland and Luxembourg), Ride The City<sup>4</sup> (some cities in the United States, Spain and France), among others.

There are already efficient and scalable algorithms of route finding for bicycles, geographical databases, well defined web architectures and interfaces that are already used, including multimodal services and open source services, with great success in some cities in the world [6,7,8,9,10].

So, what prevents these services from being replicated in other cities? The lack of detailed information (slope, intensity and speed of traffic, width of roads, quality of pavement, etc.) on the road network of those cities contributes largely to the nonexistence of those services in many cities. In addition, there is a lack of available entities to keep that information updated over time. For example, Google Maps now supports route finding services for bicycle users in various cities in the United States and Great Britain. However, the coverage of new cities has been slow because, in most cities, the information available is insufficient.

Our contribution is a system in which the two challenges above are exceeded by involving the actual bicycle users, in a collaborative effort of classification of paths of the town. With our system, as users pedal, they classify the segments of the paths in a collaborative way. This way, the knowledge of the information on the road network grows bigger and bigger so the system can return better paths to its users.

The main challenges to our system are:

1. How to facilitate the introduction of the classifications?
2. How to motivate the users to collaborate actively?
3. How to filter incorrect information?

Our system consists of a client application that runs on the web and on a server that allows the planning and classification of paths. Results show that this system can be very useful for users to share their experiences so that better paths are suggested to less experienced users in the use of this means of transport.

## 2 Related Work

### 2.1 Route finding systems

**2.1.1 Ride The City.** This system offers three options (safe, safer and direct) for the user to search for a path.

The system assigns a shorter distance the streets with exclusive bicycle lanes for, streets which are therefore considered safer. That is, when the user selects the

<sup>3</sup> <https://google.com/maps>

<sup>4</sup> <http://ridethecity.com>

safe or safer option, what the system really does is, it multiplies street distances times a factor between 0 and 1, so as to return a safe path that may include bicycle lanes. The multiplying factor used in the safer option is lower than the one used in the safe option.

This system allows you to classify segments, by choosing a category in a scale of answers (excellent, good, etc.). However, in the present version, the classifications only work as notifications for the team that keeps the service to manually correct the attributes of the map.

This system only works in cities in which there is a team that keeps the information (slope, safety, comfort, etc.) on the road network. That information cannot be directly changed by the bicycle users.

**2.1.2 OpenTripPlanner.** The OpenTripPlanner<sup>5</sup> is an open source multi-modal planner of itineraries and has the OpenStreetMap as a source of geographic data. There are countless path search services on the web that are supported by the OpenTripPlanner. For example, the TriMet, the public transport agency in the state of Oregon, in the United States, offers a planner<sup>6</sup> that is based on the OTP.

A great part of the OTP was designed to allow the planning of paths that can be followed by bicycle users. This system offers users a way to plan their travel, based on three parameters: distance, safety and their slope. The quality of the path that is returned depends on the existence of that information.

## 2.2 Route finding systems with users feedback

**2.2.1 OurWay.** OurWay is a collaborative route planning system that uses feedback from the users to return paths that adjust to their interests [11]. This project is used within a building and supports navigation for users on wheelchairs.

The users classify the segments of suggested routes as to their accessibility (categories: good, not comfortable or inaccessible). Based on the aggregation of user classifications, the server calculates the best path between two locations.

The authors conclude that a collaborative route planning system is viable and can work well.

**2.2.2 Cyclopath.** Cyclopath<sup>7</sup> is a geographic wiki that is used to provide route finding services for bicyclists in an area called Twin Cities in the state of Minnesota, in the United States [12].

In this system, classifications introduced by a user are not used in the path search by other users. Since a user expresses his preferences into a small part of the road network, Supervised Learning algorithms are needed to infer his

<sup>5</sup> <http://opentripplanner.com/>

<sup>6</sup> <http://ride.trimet.org>

<sup>7</sup> <http://magic.cyclopath.org>

preferences into the other edges in the network. Users classify each segment with an attribute called *bikeability* in a scale from 0 (impassable) to 4 (excellent).

This system does not solve the problem described in this paper because the user contributions are not shared with the rest of the community. The objective of this system is to return a path according to the profile of the user that requests the search.

It should be noted that the concept of *bikeability* is vague; it is not consensual among the bike users. The authors [12] point out that in only 53% of the cases users classified a segment with the same value of *bikeability*.

### 3 Architecture

The system was implemented using an open source multi-modal trip planner, the OpenTripPlanner. It was necessary to change the RESTful API of this system to allow individual segments of a route so that they can be identified, in the client side, to be classified. It was also necessary to incorporate the users' classifications in the search of the shortest path algorithm.

#### 3.1 OpenTripPlanner

In order to compute the shortest path, it's used the following formula that calculates the weight of a segment (edge) based on its attributes:

$$P(segment) = (d * D) + (d * slopeFactor * I) + (d * safetyFactor * S)$$

The parameter  $d$  corresponds to the segment length,  $D$ ,  $I$  and  $S$  are the values specified by the users to the criteria distance, slope and safety respectively. The *slopeFactor* is determined by the OpenTripPlanner and depends on the elevation data. On the other hand, the OTP estimates a value for the *safetyFactor* via tags present in the OpenStreetMap.

For the system to support the search of a path, it needs to build a graph object, which is saved in disk, to be used when searching for a path. This object can be built using data obtained from the OpenStreetMap, elevation and public transportation data in GTFS format<sup>8</sup>.

#### 3.2 OpenTripPlanner with users' classifications

Since the OpenTripPlanner doesn't have elevation data, nor user classifications, this criteria is not used. Regarding the *safetyFactor*, it is set according to the tags present in the OpenStreetMap. However, this factor can be much more precise, if it takes in consideration the real speed and intensity of traffic.

With the collaboration of the users, the system can have this information and use it in route finding. Our system allows that the users, from their bicycles, search for a path in Lisbon and classify the segments (edges) of that path with

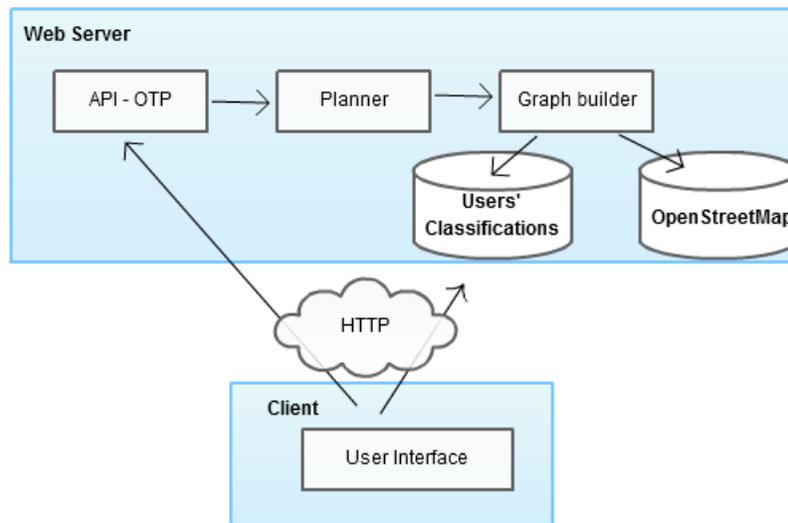
<sup>8</sup> <https://developers.google.com/transit/gtfs>

slope, safety and type of pavement scales. The architecture of the system is represented in Fig. 2.

The user accesses to the system through a website where is possible to visualize the city map. Then he provides the search parameters for a certain path and the server returns the path that is, later on, drawn on the map.

The module named Graph Builder is responsible for building the graph object that, later on, is explored when the user plans a path. The resources used to create the graph come from the data in the OpenStreetMap of the city in question and from our database, which stores all the classifications done by the users. This graph has to be previously created and stored in disk, so that it can be used by the module named Planner, which is called when the user sends an HTTP request to the server, i.e., it requests a path search.

At the moment, the Planner module uses the A\* algorithm to find the shortest path between two nodes in the net. This algorithm runs the edges that were previously encapsulated in the Java object stored in disk, which represents the graph.



**Figure 2** - The architecture of the system.

### 3.3 Reputation mechanism

The behavior of our system is very similar to the Wikipedia system<sup>9</sup>. Systems like this allow any person with internet access to insert/edit information about many different domains to ensure the growth of the system. The main concern with this type of systems lays on the credibility of the information submitted. Negligent or bad intended users can contribute with wrong information. In the context of our system, in case all classifications are considered with equal importance, these

<sup>9</sup> <http://www.wikipedia.org/>

users could jeopardize in a significant way the quality of the paths suggested by the system. Therefore, our solution uses a reputation mechanism to prevent users from harming the performance of the path search algorithm.

The system estimates the reputation of the users based on the classification they provide for each segment. To do this, the system uses formulas already developed for collaborative domains such as Wikipedia. The reputation of a user ranges from -1 to 1.

The reputation of a user  $i$ , for certain criterion  $j$ ,  $R_i^j$ , assumes that, if the user classified a section with the criterion  $j$  in a trusting way, his classification will be near the average classification for that criterion in that segment. If the classifications made by the user  $i$ ,  $U_i$ , are close to the next average classifications for the different segments classified by  $U_i$ , the reputation value  $R_i^j$  will be close to 1.

Since there are many classifications for each criterion  $j$  by segment, it is necessary to consolidate the classifications of the several users to a single value  $\rho_s^j$  so it can be used later on by the path search system.

The Equation 1 allows the consolidation of multiple classifications of the  $j$  criterion for a section  $s$  in a single classification. This way, it is given larger importance to the classifications done by the users with higher reputation. Besides that, only the classifications done by users with positive reputation are taken into account ( $U_s^+ : \{U_i\} \forall i \text{ tal que } R_i > 0$ ).

The term  $\rho_{i,s}^j$  is relative to the classification by the user  $i$  on the criterion  $j$ , on the  $s$  segment.

$$\rho_s^j = \begin{cases} \frac{\sum_i \rho_{i,s}^j * R_i^j}{\sum_i R_i^j}, \forall i \text{ tal que } U_i \in U_s^+ \\ \epsilon, U_s^+ = \{\} \end{cases} \quad (1)$$

## 4 Conclusions and Future work

In this document we promote bicycling as a means of transportation and enumerate several systems that allow path planning for bicycle use. Then we presented our system that receives classifications from the users in order to obtain better paths.

Our approach differs from many other path planning systems because we use feedback from the users in path search. The system uses the OpenTripPlanner to allow the path planning. Besides building the graph that composes the road network using the OpenStreetMap data, it also gathers users' classifications stored in a database to know slope, safety and pavement attributes of the different segments.

This type of system is very interesting to be consulted through mobile devices, in moments where the bicycle users need the most to commute. In order to do that, it's essential that there is an accessible version in a website, with reduced dimensions (namely for smartphones and tablets), or the existence of an application for different operating systems, like Android and iOS.

Besides this, we intend to exploit the use of GPS as well from other sensors, like the accelerometer, from the mobile platforms in order to minimize the effort done by the user when classifying the segments already travelled.

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