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CrossroadsDescriber - Automatic Textual Description of OpenStreetMap Intersections

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Abstract.

Crossing an intersection is a challenge for visually impaired people. While tactile maps can be a medium for appropriating this complex space, they benefit from being complemented by audio information.

In this paper we propose a data model to describe an intersection, the paths that allow to cross it, and their accessibility attributes. We also present methods to generate this model automatically from OpenStreetMap, by inferring missing data through graph analysis techniques.

Finally, we present an implementation, the evaluation of which confirms the ability of the model to generate a compliant description for intersections with enough data.

Keywords. OpenStreetMap, intersection, data model, text generation

1 Introduction

For visually impaired people, urban mobility is a challenge. Walking in open areas such as intersections with multiple vehicle lanes and complex traffic sequences is even more difficult. Furthermore, infrastructures that facilitate street crossing (tactile paving, audible traffic lights) are not always available, so the need to have a clear understanding of the configuration of intersections is mandatory.

Tactile maps of intersections exist and are used in orientation and mobility training; however, their availability is sparse as they are made manually by instructors, and they are unsuitable for representing dense areas. To tackle this problem, we explore the possibility of complementing them with audiodescriptions to enhance their understandability.

The literature explored blind pedestrians' navigation for years, by developing optimized ways of describing itineraries (Gaunet, 2006) and automatically generate these descriptions (Balata et al., 2016). However, few studies have focused specifically on describing the accessibility of intersections. Moreover, to our knowledge, there is no resource dealing with the automatic generation of description of intersections derived from an existing geographic database such as OpenStreetMap.

In this paper, we propose a data model dedicated to the generation of a textual description of intersections, designed to be instantiated from OpenStreetMap data. We will first present a state of the art regarding the accessibility of geographic data to visually impaired people, then we will present the data model we propose and the way we designed it. Finally, we will present an implementation and an evaluation of this model regarding its ability to generate satisfying descriptions.

2 State of the art

A tactile map is a medium that enables visually impaired people to understand how a space is designed. The automatic design of such maps was well explored in the literature, notably through generalization and stylization approaches of existing geographic databases (Stampach and Mulicková, 2016; Touya et al., 2019). Other approaches use deep learning on aerial images to mimic the maps as they are made by professionals (Fillières-Riveau et al., 2020). However, a tactile map cannot represent dense graphic information nor fine details at a large scale (Touya et al., 2019). Thus, it needs to be complemented with other means of representing the information.

Sound is then another way of making spatial data accessible to blind users. An approach consists in bounding specific sounds to dominant colours to sound a topographic map (Josselin et al., 2016). For continuous data such as digital elevation models, Schito and Fabrikant (2018) propose to use binaural sound techniques. Soundscapes may also be used to immerse the user within an urban environment (Edler et al., 2019). These techniques aim to describe maps at a small scale and are therefore not suitable for large scale accessibility information.

A common way of providing information about a place is to describe it verbally. The existing literature proposes formalisms for describing routes (Gaunet, 2006) and methods for automatically generating them from a data structure (Balata et al., 2016). Dedicated data models were also used to describe points of interest (Boularouk et al., 2017). While enabling the description of large scale details, these approaches do not focus on issues related to the accessibility of intersections, especially concerning their crossing.

Very few literature focused on intersections exist. Some route description formalisms integrate description of basic crossroad branches (Gaunet, 2006). Guth et al. (2019) proposes to integrate elements of the crossroad configuration into a flat database used to describe very succinct general and by crossing descriptions, but these descriptions are presented as data sequences, not full sentences. This aspect is addressed by Kalsron et al. (2021), however in both approaches the database is filled manually, not automatically derived from GIS data. We develop these aspects in the work we present here.

3 Data and method

Describing the pedestrian accessibility of a crossroad requires adequate data. Our analysis of the literature in the previous section leads us to consider, in particular, data related to the number of branches of the intersection, the number and type of lanes per branch, and the pedestrian crossings and their accessibility attributes (tactile pavings, traffic signals, sound devices).

Several topographic databases, particularly those produced by national mapping agencies, offer a detailed representation of urban space. However, these databases usually focus on the road network and do not offer a satisfactory representation of pedestrian and accessibility infrastructures. Their coverage, moreover, is limited to a given territory, which leads us to consider the use of OpenStreetMap.

3.1 Quality of the OpenStreetMap Data

The road network occupies an important place within OpenStreetMap, however the presence of data related to pedestrian accessibility has improved considerably in recent years. The representation of sidewalks and pedestrian crossings is permitted by OpenStreetMap, however their presence and precision vary depending on the area studied (Mobasheri et al., 2017). If sidewalks are still generally poorly documented, pedestrian crossings are very present (Favreau and Kalsron, 2022). Moreover, the latter can be combined with attributes indicating the presence of a tactile paving or a sound device (Table 1).

Tag	Number of objects	Concerned crossings
`tactile_paving`	826 232	14.10 %
`traffic_signals:sound`	136 766	2.33 %

Table 1. Number of objects with the tag crossing associated with tags related to accessibility. The total number of objects containing the tag crossing is 5 861 123 (april 2022).

Another problem with OpenStreetMap data, which is also applicable to other databases, concerns the intrinsic attributes of the intersection. To describe an intersection, professionals refer in particular to the branches that make it up, and this implies being able to delimit the intersection and their branches within a road graph. The semantics of OpenStreetMap make it possible to delimit an intersection[1], but this possibility is only very rarely used today (851 432 objects in April 2022), and does not make it possible to specify the branches. This lack can be compensated by the work of Favreau and Kalsron (2022), which proposes a method for segmenting intersections and their branches within a graph, and on which we will rely.

3.2 Description architecture

In order to design the description we want to generate, we interviewed people from the vision impairment community, including visually impaired people, locomotion instructors, urban architects and pedestrian mobility companies. Intersections can be described according to a non-standardized typology, however commonly used by visually impaired people and urban planners : cross-shaped intersections, T-shaped intersections, X-shaped intersections, etc. (Fogliaroni et al., 2018). This typology is based exclusively on the geometry of the intersection. Historically, in France, locomotion instructors described intersections by street. The new generation of locomotion instructors now describes intersections by branch : a cross-shaped intersection made of two streets is a four branches intersection, with each branch comprising a number of lanes and possibly a crossing path. This presentation allows a synthetic vision of the intersections configuration, including all the crossings, i.e. the possible passages from one sidewalk to another. The plan of the description is shown on Figure 1.

3.3 Modelling intersections

To automatically generate descriptions of intersections, we propose the data model in Figure 2. It actually represents a graph, with edges (Way) and nodes (Junction), to allow its instanciation from OpenStreetMap. Each branch is identified by a number and contains all the ways that are part of it, and a crossing if the branch can be crossed. We also introduced some specific behaviours :

[1] https://wiki.openstreetmap.org/wiki/Tag:junction=yes


Source : CRAIG, 2020

General description

The intersection of avenue Carnot and Cours Sablon is a 4-branches intersections.

Branches description

(...)
The second branch is composed of one outgoing bus lane, one incoming car lane and one incoming bus lane.
(...)

Crossings description

(...)
The third branch can be crossed in two times. All crosswalks are protected by pedestrian traffic lights. There are tactile pavings.
(...)

Figure 1. The plan and an example of the generated description.

- The semantics of OpenStreetMap objects are in the form of key-value pairs. A single node can therefore represent several objects, such as a pedestrian crossing and a traffic light. To reproduce this behaviour within an object model, we used the decorator design pattern (Gamma et al., 1994) which allows us to dynamically define a new behaviour for an existing object.
- The different lanes of a way are indicated by attributes on OpenStreetMap[2]. We have therefore added the Channel class to represent this information in an object way.
- Sidewalks and islands are not just tags on the way but actual objects, that inherit from the PedestrianNode class. Each way may contain a pair of objects of class PedestrianNode, thus enabling to indicate for each way which sidewalk or island is on its right and on its left.
- We want to be able to indicate for each branch how it can be crossed. For this purpose we introduce the Crossing class, which consists of the sequence of crosswalks between two sidewalks. The crosswalks themselves are composed of two PedestrianNode objects which indicate where the ends of the crosswalk are located, i.e. on a sidewalk or an island.

This model was thought to be instanciated from OpenStreetMap using the intersections segmentation tool proposed by Favreau and Kalsron (2022). It will notably be used to delimit and create branches in the intersection, but also to instanciate sidewalks, islands, and crossings, as presented in the following sections.

3.3.1 Sidewalks Aggregation

Sidewalks in OpenStreetMap are not marked with a unique identifier, but are only marked independently on each way section. If you want to consider a complete sidewalk, you have to aggregate the corresponding ways and determine on which side of them the sidewalk is located.

The generation is carried out in the following way: first, the branches computed by the segmentation tool are not ordered so we order the branches clockwise (Figure 3.2). For each branch of the intersection, one by one in clockwise order, we start from the node located at the end of the rightmost way and we traverse the graph by systematically turning left at each junction until we reach an end (Figure 3.3). The edges thus traversed correspond to our sidewalk (Figure 3.4). If the road edge is traversed in its geometry direction, the sidewalk is located on its left, otherwise it is located on its right. If no attribute indicates the absence of a sidewalk, we consider that it is present. We made this choice because most cities have sidewalks, and OpenStreetMap is not yet sufficiently complete on related tags.

3.3.2 Islands generation

Apart from the CROSSING:ISLAND tag which indicates the presence of an island in the middle of a crossing but whose presence is marginal, islands are absent from the semantics of OpenStreetMap which does not allow them to be represented when they are located between two pedestrian crossings. However, usage shows that the islands are represented by the faces of the graph and can therefore be deduced in this way (Vitalis et al., 2022). The process starts by closing the branches represented by two or more ways (Figure 4.1) in order to detect all islands (Figure 4.2).

3.3.3 Crossings Generation

If we have the necessary information according to the methods mentioned above, a crossing will correspond to a sequence of several crosswalks which allow to reach a sidewalk from another sidewalk by passing only by islands. We can therefore generate these crossings using a dual graph where the sidewalks and the islands become the nodes, and the crosswalks the edges. Computing the crossings will be equivalent to computing from sidewalk to sidewalk the shortest path that does not pass through another sidewalk (Figure 5).

4 Implementation and Results

We propose an implementation of the model in Python. Figure 6 shows the data processing pipeline from data to text generation. The text realization is not purely made in Python as it relies on a jsRealB server (Molins and Lapalme, 2015).

[2] https://wiki.openstreetmap.org/wiki/Key:lanes

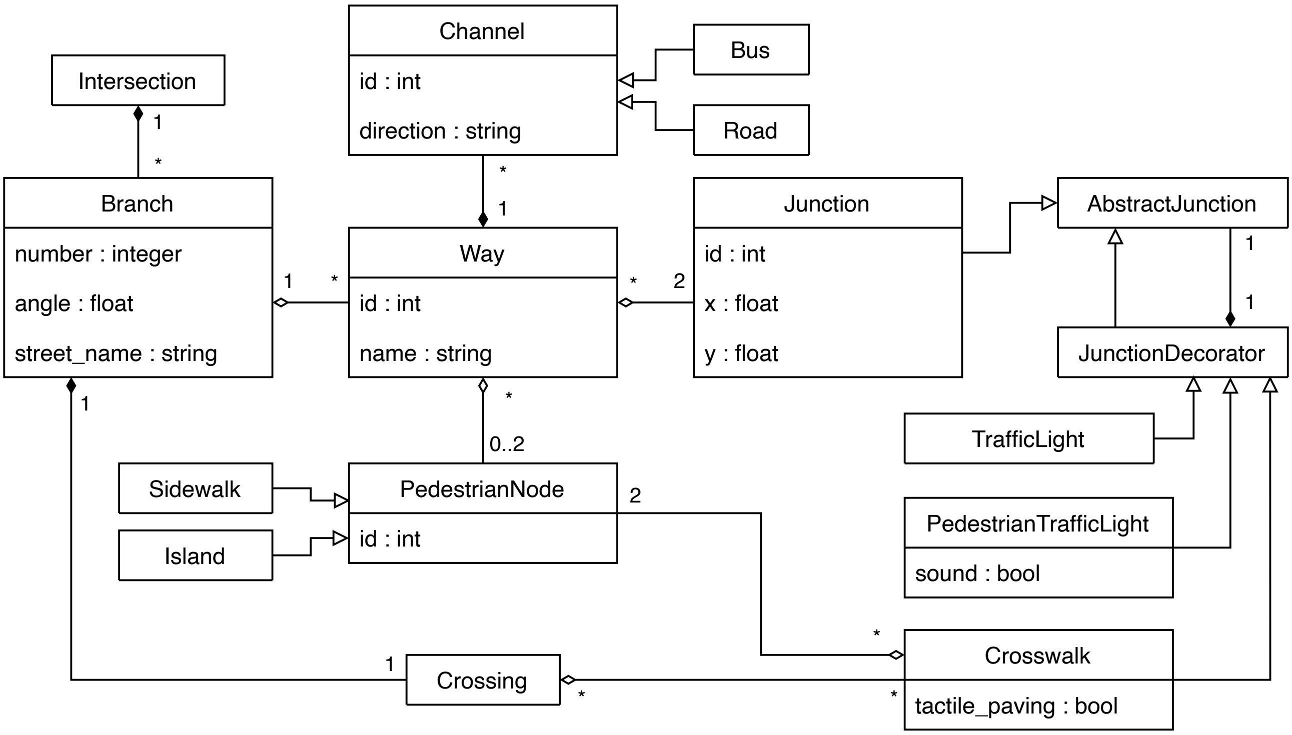

Figure 2. The proposed data model.

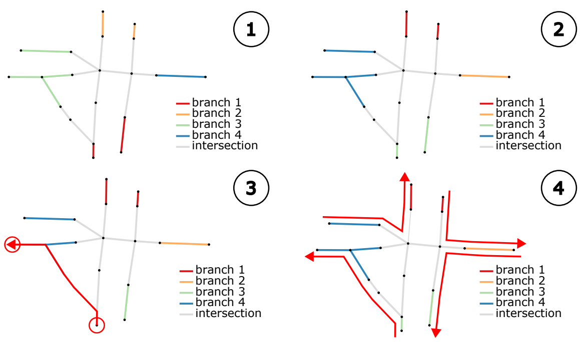

Figure 3. Steps needed to generate sidewalks as presented in 3.3.1. Corresponding ways will contain the sidewalk's PedestrianNode.

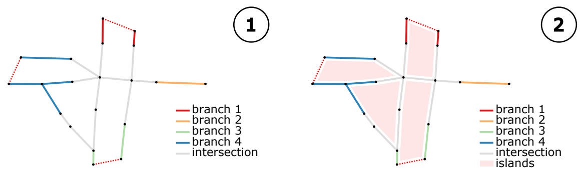

Figure 4. Steps for generating islands as presented in 3.3.2. Corresponding ways will contain the island's PedestrianNode.

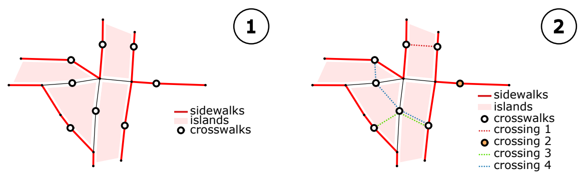

Figure 5. Crossings generation process as illustrated in 3.3.3.

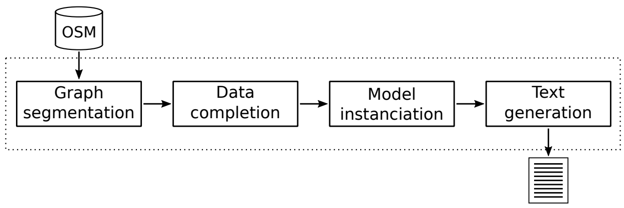

Figure 6. The processing pipeline from the OpenStreetMap data to the generated text.

4.1 Statistical evaluation

The evaluation of the implementation of the model allows us to estimate its capacity to generate satisfactory descriptions with regard to the data available in OpenStreetMap. We chose to carry out the evaluation on three French cities: Lyon (522 969 inhabitants), Clermont-Ferrand (147 865 inhabitants), and Brive-la-Gaillarde (46 330 inhabitants).

The quality of the description was assessed according to its conformity with the terrain and the available data. A description defined as correct corresponds to the terrain. A partially correct description indicates that it partly corresponds to the terrain but that the data, the implementation, or the segmentation were insufficient to provide a complete description. An incorrect description does not match the terrain at all. Descriptions of 20 intersections per city, randomly chosen, were generated, and the 3 parts of each description were evaluated. The evaluation is based on the tool proposed by Favreau and Kalsron (2022). The values of the OpenStreetMap attributes were verified using aerial

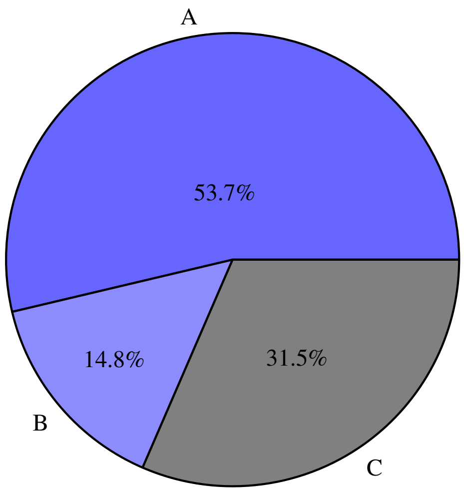

Figure 7. Distribution of issues type encountered during the evaluation process. A (29 intersections): missing objects or attributes from OpenStreetMap, B (8 intersections): implementation issues, either unsupported attributes or algorithm errors, C (17 intersections): errors mixing implementation, segmentation and data issues.

Description quality	General description	Branches description	Crossings description
Correct	40	19	24
Partially correct	17	40	34
Incorrect	3	1	2
Number of intersections	60	60	60

Table 2. Quality of described intersections by description type.

images to assess data issues. Pedestrian crossings sound devices were not take into account as aerial images don't enable to check this information.

The general description is the one with the best results. These are mainly dependent on the quality of the segmentation (19 out of 20 intersections, i.e. 95% of the errors encountered). Descriptions by branch and by crossing are more sensitive to the quality of the OpenStreetMap data (respectively 26 out of 41 and 30 out of 36 intersections, i.e. 63.4% and 83.3% of the errors encountered). The branches were also strongly affected by implementation errors (19 out of 41 intersections, i.e. 46.3% of the errors encountered) because not all OpenStreetMap tags, particularly those relating to bus routes, were considered. These results are summarised in Table 2.

The overall results indicate that only 6 intersections in the sample were perfectly described. On the other hand, 56 intersections were at least partially correctly described. The main problem that caused a degradation of the description was the quality of the OpenStreetMap data (Figure 7) where missing tags or objects impacted the description. It can be noted, however, that the three cities chosen do not have the same quality of OpenStreetMap data (Table 3).

Issues type	Lyon	Clermont-Ferrand	Brive-la-Gaillarde
OSM-related	8	13	17
OSM-unrelated	9	4	3
Number of issues	17	17	20
Number of intersections	20	20	20

Table 3. Issues encountered and their relation to the OpenStreetMap (OSM) data by city.

4.2 Data and software availability

Our implementation is available under the GNU GPLv3 free software license[3]. All its dependencies, notably osmnx (Boeing, 2017) and crseg (Favreau and Kalsron, 2022), are also available under free software licenses. Text generation is done using the jsRealB javascript library (Molins and Lapalme, 2015), also available under a free software license.

The data used as input is taken as is from the OpenStreetMap database, available under the ODbL open license.

5 Conclusion and Future Work

In this paper, we have proposed a data model and an implementation for generating text descriptions of intersections. We proposed a way to describe an intersection elaborated with professionals, then presented the model and the implementation used to generate it from OpenStreetMap. After presenting the specificities of this model, we conducted an evaluation phase that allowed us to highlight the model capacity to generate coherent descriptions, with regard to the available data.

Our results may be improved in several ways. First, we saw that our implementation may consider more tags to accurately represent the different lanes of a way as it was the cause of some incorrectly generated descriptions. Moreover, the current model and implementation do not consider cycleways that may be present either on the road or on the sidewalk, thus being an important information to describe.

The current description is a single text, not tied to any spatial representation. As methods to automatically generate tactile maps tend to emerge, a perspective of this work could be to spatialize this description to integrate it into a multimodal tactile map.

Future works could also consider the multiscales dimension of intersections. We have proposed a description limited to a single scale, however as maps can propose multiscales representations, the data model may be extended to describe an intersection at several scales.

[3] https://github.com/jeremyk6/crossroadsdescriber/releases/tag/agile-2022

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