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When is a Ring Road a 'Ring Road'? A Brief Perceptual Study

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Abstract. The shapes and patterns of the road network of a topographic map provide important visual cues when interpreting the map and moving between scales in interactive environments. The 'city ring road' is an example of a road structure we might use in the recognition and characterisation of a city. Our goal is the automatic identification (and preservation) of such structures through changing scales. In this preliminary study, we conducted an online survey and face to face interviews in order to obtain and prioritise the structural, topological and semantic properties that define 'ring road-ness'. We then created a practical ontology of ring roads, with a view to algorithm implementation that mirrors the human perception of ring roads.

Keywords. city ring roads, landmarks, visual cognition, perceptual survey

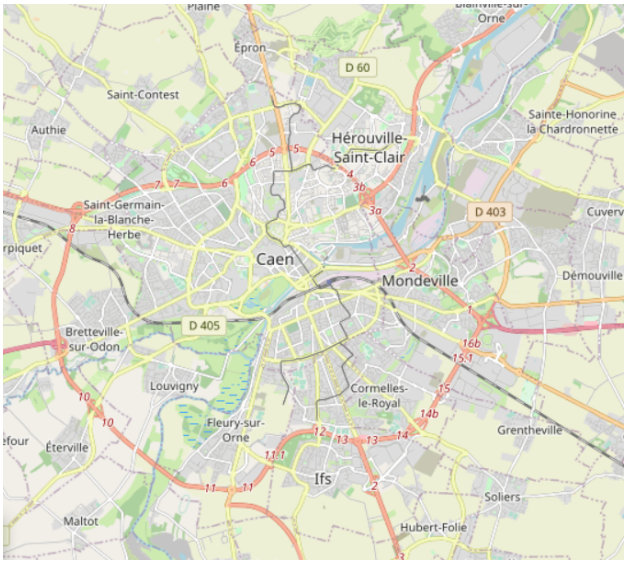

Figure 1. The well defined ring road of the French city of Caen.

1 Introduction

The automatic detection of road structures has been well researched. Extracted implicit information from a road network provides knowledge which can be used for many applications such as city planning, architecture, database enrichment and map generalisation. In map generalisation, the extracted knowledge helps when selecting the most characteristic patterns of a place in order to preserve them through changing scales (Heinzle et al., 2006).

This study is part of the Lost in Zoom project, which seek to detect multi-scale landmarks in order to improve the process of map generalisation. Landmarks are salient objects that allow people to orientate themselves in a real or virtual environment. A landmark can be visual, cognitive (related to someone's experience) or structural. A salient or 'strong' landmark often possesses two or three of these characteristics (Sorrows and Hirtle, 1999).

This paper will focus on ring road structures which are often significant landmarks, for example "le périphérique" ring road that surrounds the city of Paris . In Figure 1 we can surely all agree that the orange road demarcates a 'city ring road'? Thus our hypothesis is that a highly distinct city ring road makes for a 'strong' landmark and should therefore remain visible across multiple scales.

A successful implementation of circular road detection has been made in (Heinzle et al., 2006). Their study adopts a strong computational approach and focuses on the geometry of roads. Their model first detects the strokes in the road network and then aggregates the polygons formed by the roads but keeps intact the major strokes. This allowed them to simplify the road network sufficiently to be able to study all the cycles within it, and then select the ones that have the best ring road properties.

In the previously described model, the authors made some assumptions as to what a ring road was, and subjectively chose properties in order to aggregate the road polygons and select the ring roads. We wish to further develop their model by identifying additional properties that characterise ring roads.We wish to get closer to what a human would consider a ring road to be. Thus we conducted a

small human perceptual study in order to answer the question: 'when is a ring road, a 'ring road'?

The paper is structured as follows. Section 2 presents the survey, and the results of the survey are discussed in Section 3. Then, Section 4 discusses properties derived from the survey to measure a ringroadness index (the degree to which a collection of roads forms a perfect, recognizable and memorable ring road when looking at it in a map).

2 Methodology of the Survey

A small survey (28 participants) was conducted in English. 14 of the participants online and 14 participated in face to face 'think aloud' interviews in which participants explained their reasoning. No definition of a "ring road" was provided. All maps and results of this survey are available online[1].

2.1 Tasks

The survey was divided into three parts. In the first part, 10 maps were shown. Participants were asked to decide if they: could see a ring road (1), perhaps could distinguish one (2), or could clearly see at least one (3). In the second part, 10 maps were shown to the participants, but this time with arrow(s) pointing at specific roads (see figure 3). Participants were asked to rate how much of a ring road the specified roads were, using a score of 0 to 5. Finally, we asked the participants to rank 6 maps in terms of how apparent (distinct) the ring road was.

2.2 Maps

Our maps for the survey were extracted from OpenStreetMap. We selected 17 French cities. We displayed the full extent of each city. The zoom level was between 12 and 15 depending on the size of each city. We tried to make our sample diverse by including a range of small, medium and large cities, a few cities with no ring road, a few with what we thought were obvious ring roads, and many where it was hard to tell.

2.3 Procedure

The survey was created and hosted on Limesurvey. We made the maps of each part of the survey appear in a random order to minimize bias. From the 28 participants, 11 were observed while undertaking the survey and asked to "think aloud" in order to better understand how they arrived at their answers.

[1] https://zenodo.org/record/6538873

2.4 Participants and Apparatus

The pool of participants was heterogeneous, and composed of people from the spatial data laboratory, from the schools around, and online volunteers. Two-thirds of the participants were French, two-thirds were male, and one-third worked in the field of GIS. Participants who took part in the think aloud procedure used a 15 inch laptop with 1920x1080 resolution. The apparatus of the online participants was not controlled.

3 Results

3.1 Quantitative Results

Results from the first part of the survey ("Is there a ring road ?") are presented in Table 1. The ring roads of Bordeaux and Caen were easily recognised by the participants. Our first intriguing result was for the city of Brest (Figure 2) where a substantial proportion of participants argued that the ring road was "closed by the sea". In effect the coastline 'closed the loop'; it illustrates how borders and non-road boundaries can impact on ring road perception.

Table 1. Results of the first part of the survey : "Do you see a ring road in the map below ?".

N°	City name	No	Maybe	Yes
1	Bordeaux	0	0	28
2	Brest	9	12	7
3	Caen	0	2	26
4	Carcassonne	1	5	22
5	Chateaubriant	17	6	5
6	Condom	27	0	1
7	Le mans	1	13	14
8	Montbrison	18	4	6
9	St-Rémy-De-Pce	21	4	3
10	Tours	13	10	5

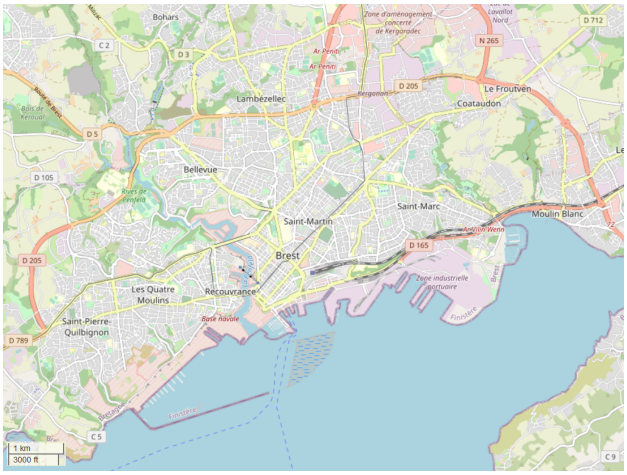

Figure 2. The city of Brest, bordered by the Atlantic Ocean.

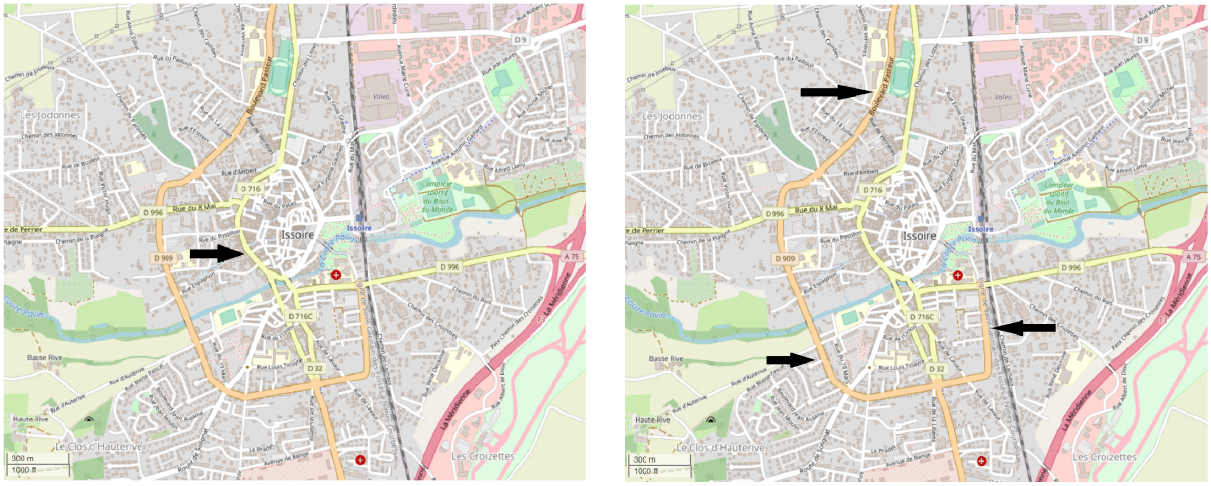

Figure 3. Issoire (1) and Issoire (2), images from the second part of the survey.

Table 2 shows the results of the second part of the survey ("How much of a ring road this is ?"). As we see in figure 3, the city of Issoire is presented twice with different roads highlighted. In this case the bigger but incomplete ring scored a bit better than the inner, very round, ring. Therefore we argue that roundness alone is not sufficient and that we should not exclude such partial open rings from our definition.

Table 2. Results of the second part of the survey : "Rate the ring road pointed by arrow(s)".

N°	City name	Average rating /5	standard deviation
1	Caen	4.75	0.80
2	Carcassonne	1.46	1.64
3	Clermont-ferrand	4.21	1.10
4	Fleurance	2.29	1.49
5	Issoire (1)	1.71	1.38
6	Issoire (2)	2.04	1.23
7	Lille	3.29	1.27
8	Milau	1.57	1.37
9	Montcuq	1.86	1.60
10	Sauzet	0.68	1.36

The third part of the study was confirmatory (so not shown here), though an unexpected outcome emerged when subjects considered the perfect ring road of Marne-La-Vallée (Figure 4). This ring seems to be 'too different' from the usual ring road because of its perfection. Moreover, instead of surrounding a city, it surrounds the Disneyland resort. The results were not consensual, and some did not consider it as a ring road.

Generally we noted that the smaller the city was, the less likely it was that circular roads were recognized as being "ring roads". We also noted that gender, profession, knowledge of GIS, or origin of the participants seemed not to have a significant influence on their answers or way of thinking. We might expect that particular professions such as truck drivers would view the maps from a particular perspective but the survey did not allow us to reach such a conclusion. We observed that younger participants focused more on the visual aspect of the ring road while older participants focused more on the structural aspect, but this requires further investigation given the small sample size.

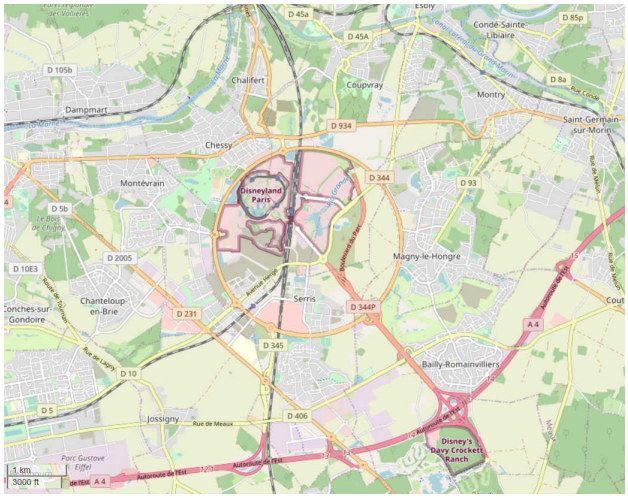

Figure 4. The perfect circular road of Marne-La-Vallée.

3.2 Notes from the Think Aloud Method

The think aloud method provided valuable insight. In particular:

- Participants tried to interpret the morphology of the city and the function of the roads in each case. A particularly important criteria was how the ring road might help circulation in the city, and how it was connected with major arterial road(s).

- In general, it felt as if older participants focused more on the functional aspect while younger ones focused

Table 3. Properties of a ring road, in order of priority

Property	Landmark type	Category	Measurement techniques / indicators
Is associated with a particular city	Structural	Ontology	
Is large enough	Visual & Structural	Topology	Length, radius, area
Approximates a circle	Visual	Topology	Compactness, convexity
Connects most parts of the city	Structural	Space syntax	Closeness centrality
Contains X% of the city area	Visual & Structural	Topology	inner city area / city area
Contains the gravitational center of the city	Visual & Structural	Topology	GIS from city polygon
Forms a closed cycle	Visual	Graph theory	Cycles detection
Names of roads include "ring" or equivalent	Cognitive	Dataset	Explicit attribute
Connects with X major arterial roads	Structural	Graph theory	Strokes
Roads internal to the ring road have higher density than external roads	Visual	Graph theory	Graph density
Allows fast flow of traffic	Structural	Space syntax	Betweenness centrality
Minimises the number of changes in direction	Structural	Space syntax	Angular centrality
Has fewer intersections than the average in the road graph of the city	Structural	Graph theory	Graph density

Table 4. Some manually calculated indicators of few ring roads from the survey.

	St-Rémy-de-Pce	Issoire (1)	Lille	Caen
Ringroadness from the survey (/5)	not a ring road	1.71	3.29	4.75
Urban area	4.9km^2	8.18km^2	123km^2	65km^2
Ring road area	0.07km^2	0.14km^2	8.5km^2	46km^2
Urban area in ring road area	1%	2%	7%	62%
Ring road length	1km	1.4km	12.7km	26.5km
Compactness	0.89	0.92	0.66	0.83
Closed cycle	Yes	Yes	Yes	Yes
Inner arterial roads connected	0	4	10	12
Outer arterial roads connected	4	3	9	9

more on the visual aspect; we don't have enough data to confirm this hypothesis.

- Color had a big impact on the perception of roads (hierarchies). The color and density of the surrounding entities was also mentioned by candidates particularly in helping to separate urban from rural since ring roads typically border both.

- Toponyms and annotations also informed the participants and seemed to have an important impact on their decision. They would rate higher a ring road that enclosed a substantial part of the city. Some participants used the names to help demarcate the administrative limits of the city.

- Participants were more likely to agree on the presence of a ring road if they knew the city, especially if they had driven the road. This was true even when the roads did not appear to be circular on the map. Perhaps this is a process of reinforcement of the cognitive and structural aspects in the participant's mind despite a possibly poor visual rendering.

In conclusion, participants had a very similar sense of the defining properties, but they applied them in differing levels depending of their own definition of a ring road and their experience of the city. Participants bounced between the visual and structural properties in reaching their decision.

3.3 Limits of the survey

The order in which the images were presented to the participants affected their decisions. We observed that the participants tended to formalize their definition of a ring road early in the study and often kept to this definition until the end.

We acknowledge that the geographical extent of the ring road compared to the total extent of the images impacts on how people perceived the ring roads. Our sample is too small to show a clear correlation between extent and the recognition of ring roads.

The third part of the survey was about ranking ring roads according to their saliency (distinctiveness). Smaller images were used in this part of the experiment in order to

facilitate comparison. This may have encouraged the participants to focus more on the visual aspect of the ring road because they did not have access to as many details of the map compared with the previous parts of the experiment.

It is important to consider linguistic considerations. There are several French definitions and it is certainly possible that the assumed definition of the French population is not the same as one from another country.

4 Measuring Ringroadness

4.1 Characterization Properties

The wider ambition is to create an algorithm that automatically detects and quantifies the ringroadness among a collection of roads. From our observations we have identified in Table 3 a list of ring road properties and alongside, potential measurement techniques and indicators. Some indicators, such as compactness and length, may be computed directly using existing GIS tools, while others, such as the difference in road densities, need to be computed indirectly as explained in (Zhang, 2004) or by using space syntax techniques (Czerkauer-Yamu and Voigt, 2011). The calculations for some of these indicators is presented in table 4.

The survey revealed that some properties are mandatory to the definition of ring road, while others less so. These differences need to be further studied and prioritised in any implementation.

4.2 Ring Road Ontology

An ontology of ring roads was constructed from the 'think aloud' participants. Participants highlighted the role played by ring roads (easing inner city car congestion). In turn, this functional perspective governed their expectation that the ring road would be circular in form, would largely 'contain' the city, be connected to a set of major roads that radiated outwards from the city, have a limited number of connections, and be of a minimum geographical size. Whilst some of these properties are relatively simple to model, other properties are more difficult to model such as the 'interactions' between the ring road and 1) other entities (such as rivers, and the surface morphology) and 2) other bounding structures. Participants noted that other bounding structures reinforced the notion of a ring road (for example where the road followed the lake shore). In some cases other network structures 'complimented' the path of the road (such as where rail and river networks ran parallel to the road). The very process of creating an ontology of city ring roads (Figure 5) helped us to identify other entities and relationships that we need to model.

4.3 Approach by Congruence

The degree of similarity between a complex object and its *ideal prototype* is called the "degree of congruence" and can be expressed as a value between 0 and 1. A measure of congruence is especially useful when the studied concept has an unclear definition yet many properties that we can describe individually (Lüscher et al., 2008).

Having listed the properties of an idealy ring road, we can measure the degree of congurence between a selected group of roads and a theoretically perfect ring road. In our case, a very recognizable ring road would have a ringroadness of almost 1 while an object which is barely a ring road would have a ringroadness close to 0. One approach would be to rate all the properties between 0 and 1, sum them, and divide by the number of properties. We could then bring more subtlety to the algorithm by giving each property a weight.

Measuring ringroadness requires us to define (and detect) other complex objects such as "arterial roads". Congruence can again be used to help us classify such objects. We can use congruence recursively until all the complex features are rated (Lüscher et al., 2008).

There are of course complex interactions between various map entities. In addition to modelling congruence, we intend to explore the use of deep learning to help in the classification of objects (ring road / not a ring road) and to estimate ringroadness.

5 Conclusions

To conclude, the paper has presented the results of a preliminary survey exploring how people perceive ring roads. In particular, city ring roads are seen as a potentially defining character of cities and can thus be viewed as landmarks that we may wish to give emphasis to in the map. Various factors affect the perception of ring roads; they are complex and their perception can be reinforced (and eroded) by the presence of other entities.

The next phase of work will be to translate these findings into an automated computation of ringroadness for a selected group of roads, based on the properties of the ring roads extracted from the literature, the think aloud method, and the perceptual study. We see two possible approaches to combining these properties into a ringroadness index, and both will be explored: (1) use a congruence principle (Lüscher et al., 2008), (2) use machine learning with a training set based on additional inputs from a similar survey. We plan to use this ringroadness index to identify the ring roads that can be used as multi-scale landmarks and anchors, to make them more visible and memorable in maps with different levels of detail, and thus make the zooming process more fluid and intuitive (Touya et al., 2021).

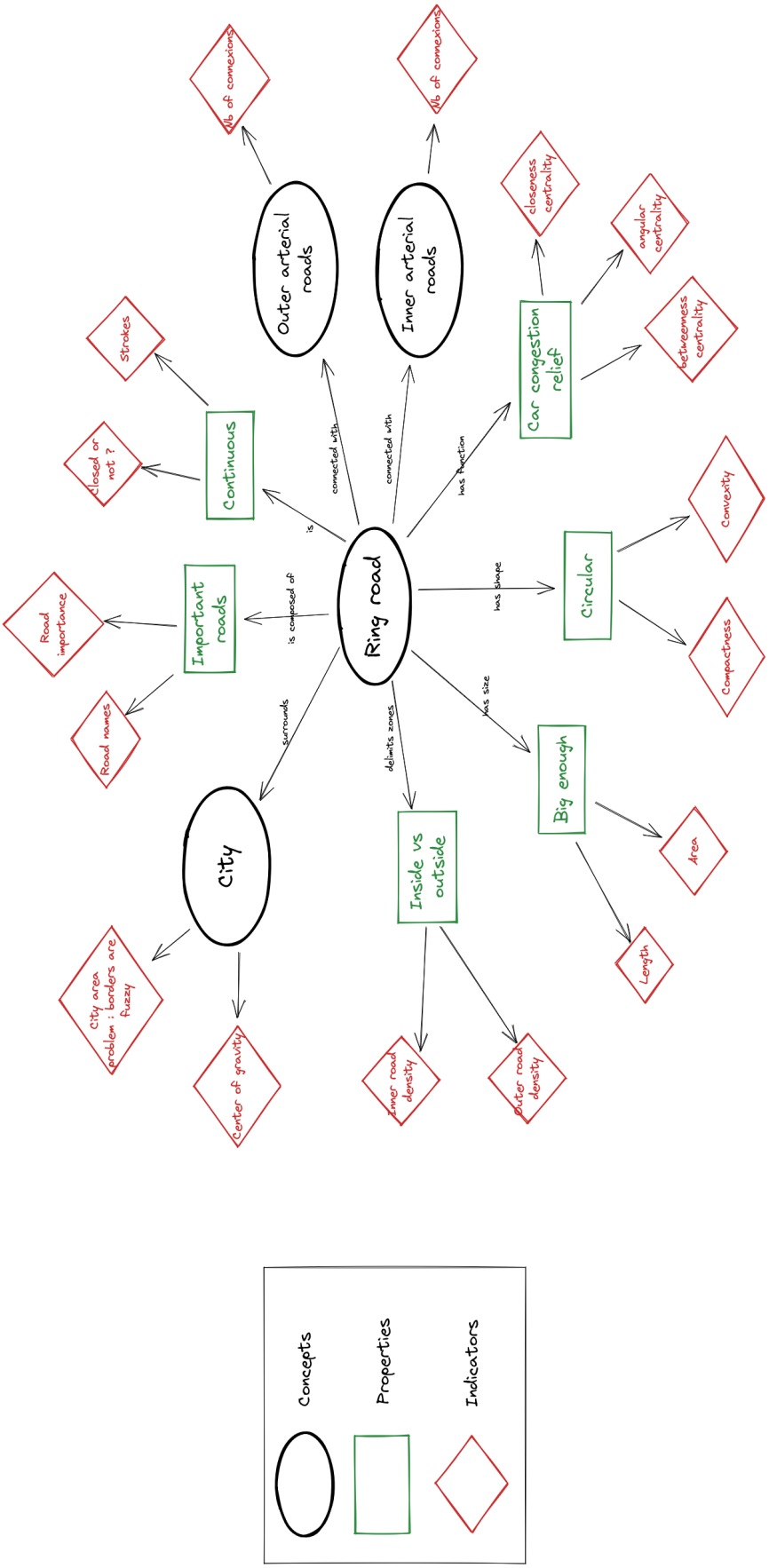

Figure 5. Ontology of a ring road: Visual and structural characteristics from a human perspective and their linked indicators

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