Spatial Periodicity Analysis of Urban Elements Application to the Ancient City of Amida

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Abstract

The characterization of urban structures using morphological indicators is the subject of many applications in the domains of urban planning and transport, but also in less traditional disciplines, such as urban archeology. When reading actual urban plans, it may be possible to identify relics of ancient cities, and to characterize them with the help of appropriate indicators. In this context, we propose a method for the characterization of the spacing between urban elements based on the analysis of their spatial periodicity. The purpose of this method is to detect specific distances in the actual urban structure, potentially characteristic of ancient measurement units. This method is implemented in a GIS software, to facilitate its use by historians and archeologists, and is illustrated by an application on the ancient roman city of Amida (Diyarbakir, Turkey).

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1 Introduction

The characterization of urban morphology has been the subject of many contributions over the last 50 years. Numerous indicators have been proposed in different fields of application to characterize urban structures, based on the analysis of their constituent elements (e.g. road networks, or buildings). For example, in the domains of urban planning and transports, several indicators have been developed to characterize urban networks [4] [2]. In the field of cartography, indicators have also been proposed to orchestrate operations of cartographic generalization according to specific urban patterns [5]. If lots of indicators are available, some authors [6] consider that many of them are not appropriate to characterize urban structures, especially because they are not expressed in spatial units, which can be problematic in terms of interpretation or comparison between cities. In the domain of urban archeology, the use of indicators easily interpretable is an issue to characterize ancient urban structures. In this article, we propose a method for the characterization of urban structures based on the analysis of the spatial periodicity of urban elements in a particular orientation. The proposed method aims at determining specific spacings between urban elements (or topographic elements considered as a limit), potentially characteristic of ancient measurement units, which provide evidences of the persistence of ancient urban structures in the actual city plan. The proposed method, implemented in a GIS software, is applied on the city plan of Diyarbakir, to reveal and characterize relics of the ancient roman city of Amida.

2 Spatial periodicity analysis methods

The analysis of the distances between urban elements can provide pertinent information to characterize actual or ancient urban structures. For example, indicators of urban morphology can be constructed using the average distance between intersected streets along a road. In this article, we focus on the analysis of the most occurrent spacing between urban elements in a given orientation. These urban elements are not necessarily streets, but they can also be building walls or cadastral boundaries for example. To determine the most occurrent spacing between urban elements, the proposed methodology is established in two steps: (1) definition of a reference orientation of the studied urban elements, (2) analysis of the spatial periodicity of the elements inscribed in the specified orientation.

2.1 Orientation of urban elements

The definition of the orientation of geographic features can be a difficult task according to the geometric primitives and the level of complexity of the analysis. Indeed, for polylines, the orientation is generally defined according to the azimuth inscribed between the first and the last vertex of the geometry. However, in particular configurations, this simple definition of orientation does not necessarily reflect the heterogeneity of internal orientations of the polyline, which may be indicative of underlying urban structures. For polygons, the definition of the orientation is more complex and several measures can be proposed to determine it [3]. For example, the orientation of buildings can be defined using the longest side of the polygon, or the smallest bounding box. As a consequence, these different definitions of orientation can also generate inconsistencies for complex shapes. To overcome these problems for the definition of the orientation of urban elements, we propose to perform a disaggregation of polyline and polygon geometries into a set of segments, whose orientations will be measured separately. Once the geometry of urban elements is disaggragated into a set of segments, a selection of the segments following a particular orientation is performed. The reference orientation is computed with an angular tolerance, generally between 1° and 2°.

2.2 Analysis of spatial periodicity using the “paper band” method

When the orientation is defined, the most occurrent spacing between elements of a urban structure is determined by analyzing the spatial periodicity using the so-called “paper band” method. This method derives its name from the work of archaeologists who aimed at defining the most frequent spacing between urban elements with the help of a band of paper that they slid according to a defined orientation.

Methodology The “paper band” method works as exposed thereafter and in figure 1:

- Retrieving of a set of aligned segments according to a given orientation (a)
- Band initialization perpendicularly to segments, and pointing of intersected segments (b)

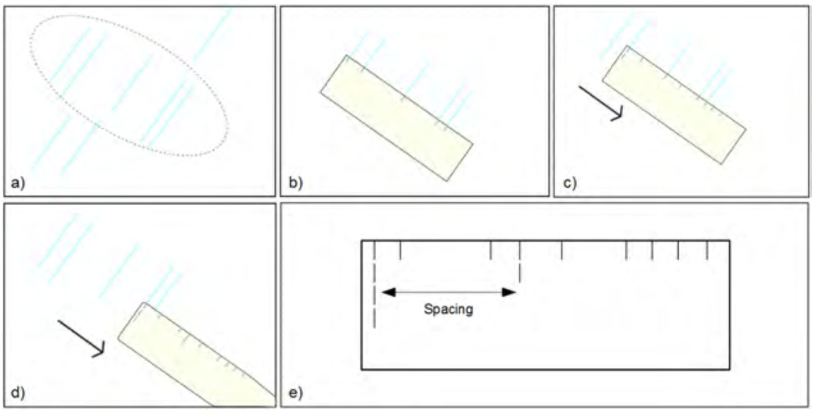

Figure 1 Measurement procedure using the paper band method.

- Band translation at the following segment, and pointing of intersected segments (c)
- Band translation at the following segment, and pointing of intersected segments (d)
- ...
- Stop translation at the last segment and measurement of the most frequent distance (e)

Goals and issues. This method can be used to determine specific spacings between urban elements in a particular (or dominant) direction. In the field of urban archeology, the detected spacings can correspond to ancient measurement units fossilized in the actual urban structure. Nevertheless, the manual application of the "paper band" method remains problematic when dealing with large volumes of data, such as entire urban plans. Indeed, this method is redundant and time-consuming, and in addition, it is exposed to inaccuracies related to human intervention, which can be detrimental for a good restitution of specific spacings. Therefore, an implementation of this method in a GIS tool is proposed to facilitate the automation of these tasks.

3 GIS Implementation

In order to automate the periodicity analysis method presented in the previous section, an extension of the QGIS GIS software has been developed. The QGIS GIS software has been selected because of its large community of users and its rich documentation, as well as its facility to implement plug-ins using the QGIS Python API and the PyQT library for the development of user interfaces. The developed plug-in, called "paper band", automates the study of the spatial periodicity of a set of input segments, according to a given orientation.

Input parameters. The parameters necessary for the analysis of spatial periodicity are: the input segment layer; the orientation (in degrees); the angular tolerance (in degrees); the number of bands (i.e. the resolution of the analysis); the maximum spacing between elements.

For example, in the figure 2, the analysis relates to the buildings having walls oriented between 9° and 11° (10° with an angular tolerance of +/- 1°). The analysis is carried out using 20 bands, and the maximum allowed spacing between walls is 100 meters.

Output results. Once the extension is executed, a layer of points is generated, corresponding to the intersections between search bands and segments of the input layer, as exposed in

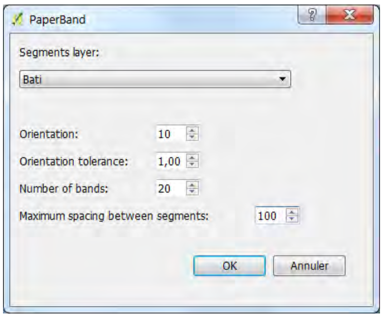

Figure 2 User interface of the “paper band” plug-in.

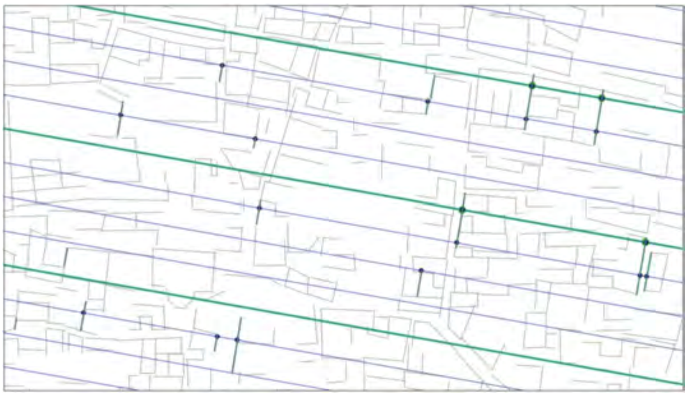

Figure 3 Impact of the resolution of the analysis (with 20 or 80 bands).

figure 3. The distances between intersected points are iteratively computed for each band, and the most occurrent spacing is determined.

Figure 3 illustrates the impact of the resolution (i.e. the number of bands configured) on the input segments used for the periodicity analysis. If a high resolution may be time consuming, a too low resolution can ignore numerous reliable elements for the periodicity analysis, which could affect final results. One solution is to perform the analysis using various resolutions to study the sensibility of the spacings between elements according to the chosen resolution.

As a result, the plug-in finally generates a diagram representing the distribution of distances between urban elements (figure 4). A spreadsheet containing the computed distances is also generated. For instance, in figure 4, it is found that the most frequent spacing is about 10 meters.

4 Application to the characterization of the ancient city of Amida

The proposed method for the characterization of the spacing between urban elements is applied on the urban structure of the city of Diyarbakir, which is built on the site of the ancient roman city of Amida.

Study area. The city of Diyarbakir is the main kurdish city of southeastern Turkey. Its site is established on the ancient roman city of Amida, which presents the characteristics of an ideal roman city: the city presents a quadripartite plan, and is surrounded by a wall. Indeed, in a roman city, the urban structure is built on two axes: the *quardo* (oriented North-South) and the *daecumanus* (oriented East-West).

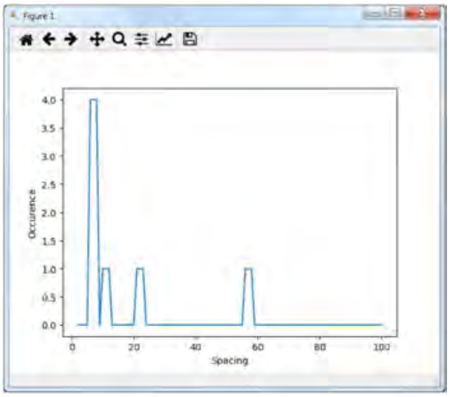

Figure 4 Graphic representation of spatial periodicity.

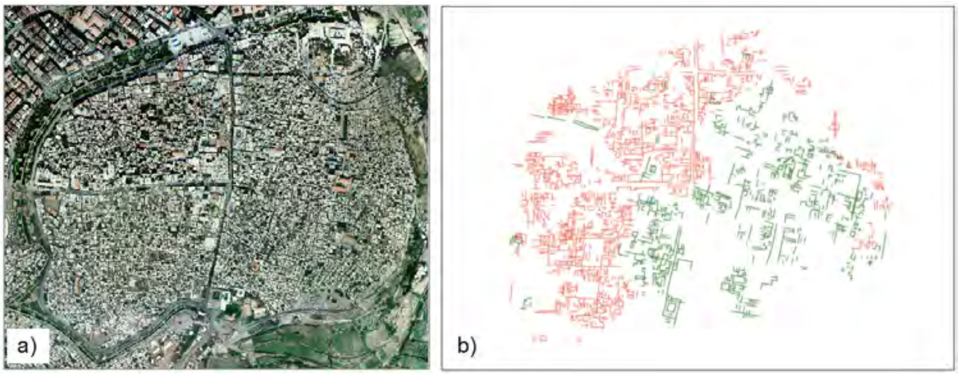

Figure 5 Aerial photography (a) and the two urban structures (b) of the city of Diyarbakir.

Assumptions. The date of the founding of the roman city of Amida remains controversial [1]. Indeed, a first foundation would date from the time of the Sévères (green plan on figure 5b), and a second would date from Constance II (red plan on figure 5b). Each of these two foundations remain in the actual city plan, through two characteristic structures, one oriented North-South, and the other one with an angle of about 10°.

Despite its successive occupations (e.g. Byzantines or Ottoman Empire), the city of Diyarbakir retains the relics of these two plans in its current urban structure. So, it seems possible to identify ancient urban structures inherited from the antiquity through the constituent elements of the current city, such as streets, walls, monuments, or parcel alignments for example.

Objectives. In order to confirm the assumptions concerning the existence of two different structures in the current city plan of Diyarbakir, we seek to characterize the spacings between their constituent urban elements. In this paper, we only focus on the characterization of the inherited urban structure from the roman city of Amida funded during Constance II (oriented in a North-South direction). More particularly, the analysis of the spacing between urban elements will seek to reveal the use of roman measurement units.

So, the analysis of the spatial periodicity was carried out using the cadastral plan of the city of Diyarbakir, using an orientation of 0°, with a tolerance of +/- 2°. The analysis was performed with a resolution of 80 bands.

First results. The results show that the distribution of spacings between urban elements has two peaks: one between 3 and 4 meters and the second between 8 and 10 meters. The first measure could correspond to the distance of streets and secondary roads, which were about 3.5 meters in roman period, but it could also correspond to an old unit of measure called the "roman perch", equivalent to 2.964 meters or 10 roman feet. This unit of measure could also explain the second peak of the distribution, which would be equivalent here to 30 roman feet, since this measurement was used for the sizing of rooms in the roman period. These results are obviously preliminary, and need to be established on other orientations, and to be enriched with the help of other urban elements, such as excavated buildings for example.

5 Conclusion and further works

This article has presented a method of morphological characterization of urban structures, by analyzing the spatial periodicity between its constituent elements. The proposed method, known as the "paper band" method, is used to determine the most occurrent spacing between the elements of a urban structure, according to a specific orientation. This method is particularly relevant in the field of urban archeology, in order to characterize spacings corresponding to ancient measurement units. More generally, the proposed method provides additional metrics to characterize spatial distances in urban structures. The application of this method on the cadastral plan of the city of Diyarbakir offered opportunities to illustrate the persistence of the roman city of Amida in the actual urban structure, by revealing characteristic distances corresponding to ancient roman feet. This work obviously remains to be extended, especially by studying spatial periodicity on complementary elements, such as buildings for example, and in a larger range of orientations. To conclude, this study is all the more justified because the city of Diyarbakir is currently the subject of important destructions of its buildings, which are as many relics of the ancient roman city of Amida.

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