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Point Patterns of Historical Landmarks in the Valley of Mexico

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Abstract. Point Pattern Analysis is already used in medical research, socio-economics and a huge number of related fields. Due to the nature of data on historical monuments is apparent to apply these methods in the context of analysing such monuments. The objective of this paper is, to propose explanatory approach to analyse point patterns using the example of historical buildings of Mexico City and Valley of Mexico. The focus of this work in progress, is on the examination of the underlying spatial pattern of historic monuments in Mexico Valley, and to evaluate if the emerging patterns match facts from scientific literature in the field of History. Key findings of this work in progress are, that the point patterns found can be explained by historic processes. Hence, this indicates that point pattern analyses can help to gain a deeper insight in historical data and processes alike.

Keywords. Point Pattern Analysis, Point Process, historical monuments, Mexico Valley, GeoHumanities

1 Introduction

Since the Spatial Turn (Soja, 1989; Finnegan, 2008) the Humanities are also utilizing the geographical domain as equal to the dimension time in order to analyse historic events and processes. During the recent years, historians are collecting spatial data concerning historic events in order to being able to analyse the spatial dimension (Grossner and Mostern, 2021; Stangl, 2018; Liceras-Garrido et al., 2019; Scholz et al., 2017).

Recently, the National Institute of Anthropology and History of Mexico collected and published the national catalogue of historical monuments in Mexico (Catálogo Nacional de Monumentos Históricos Inmuebles, 2022). The data collection can be accessed online via a web-based interface. The interface lacks a spatial analysis and an interactive map for the data on the historical monuments. In addition, the data only have coordinates of each historical monument in the database – which is not exploited any further (except for a link to Google Maps).

In this paper the authors attempt to analyse the historic monuments of the National Institute of Anthropology and History of Mexico, with the help of spatial analysis, in particular Point Pattern Analysis. The research question of this study is focused on whether point pattern analysis helps to identify patterns in the monuments and if so, whether those patterns are in line with findings from historical sciences." Due to limited resources, the study focuses on the study area of Mexico Valley (districts Morelos, Ciudad de Mexico., Estadio de Mexico).

The article is structured as follows. Section 2 elaborates on the methods and the datasets of this article. This is followed by the description of the exploratory data analysis of the data and presents the results in an integrated manner. Section 4 discusses the results obtained and evaluates if they can be verified with the help of historical science.

2 Methodology and Datasets

2.1 Methodological Background

Every dataset like events or objects with additional spatial information can be displayed as spatial point pattern. These events or objects are then reduced to their spatial attribute, which mostly are coordinates. The entirety of points in an area is mostly represented by a point process. If a point pattern is marked, additional information regarding the points is attached. In principle points can be distributed in three basic ways: random, regular, or aggregated (Illian et al., 2008). The distribution of randomly sampled points mostly follows a Poisson distribution. Meaning that the distance of two Points is a random variable. The distance of one point to its neighbouring points in regular point patterns tends to be as large as possible, which results in each point standing alone. Which is the contrary to aggregated point patterns, because the multitude of points is grouped around another point.

In order to analyse point patterns, they are transformed into descriptive statistics. This reduction of spatial data, consisting of the location of the Mexican monuments, can be carried out in two ways. One type of statistics is based on the distance between points, between points and randomly sampled points, or both in combination. The second approach is based on dividing the area of Mexico Valley into a regular grid and sampling the number of points in each cell. The results of these statistics are then compared with homogeneous Poisson Processes, which are also called "complete spatial random" point processes.

With the Poisson Point Process, points are randomly distributed in an area *B*. Therefore, it is suitable as a reference model, more specifically as null hypothesis in statistical tests (Illian et al., 2008). One fundamental property of the homogenous Point Process is homogeneity, meaning that the points follow a Poisson distribution and have no preferred location. The second quality of "Complete Spatial Randomness" (short CSR) is that the points of one region of the area are independent of another, which is CSR proposes a standard that would not appear in reality but constitutes a first approximation (Diggle, 2013).

2.2 Dataset of Historical Monuments in Valley of Mexico

Basis of this project is the national catalogue of historical monuments from the National Institute of Anthropology and History of Mexico. The data was kindly provided by Werner Stangl and Patricia Murrieta-Flores from Instituto Nacional de Antropología e Historia of Mexico. The dataset includes monuments of the districts "Morelos", "Ciudad de México" and "Estado de Mexico" from the 16th to the 21st century. Besides their location, additional information like their type and changes on the monuments were also provided. The data of 351 monuments in total could be used (see Fig. 1), 195 are situated in the area of "Ciudad de México", 136 in "Estado de México", and 20 in "Morelos".

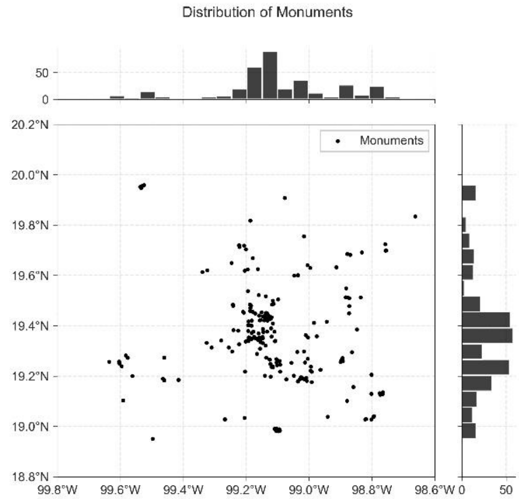

Figure 1. Distribution of monuments.

By taking into consideration, that buildings are manmade and Mexico Valley was rebuilt in the 16th century by the Spaniards on the grounds of Aztec ruins, it is not surprising that the Point Pattern of the historical monuments seems clustered around the historical city centre.

3 Exploratory data analysis

The analysis of point patterns can be structured into two categories. The analysis of the first order properties of a point process or the second order properties. While the analysis of first order properties focuses on the spatial density of the point pattern, the second order properties deal with distances between points and therefore reflect the three basic distributions of points (Bivand et al., 2008). In order to detect local spatial clusters in the dataset, we use Local Moran statistic visualized in the form of cluster maps (i.e. LISA maps) – which are a standard methodology in literature (Anselin et al., 2006; Anselin, 2010).

3.1 Global autocorrelation

With global autocorrelation, spatial and attributive similarities are compared. In the case of the number of monuments per municipality the number is the attribute. The number of monuments in their according municipality is depicted in Fig. 2.

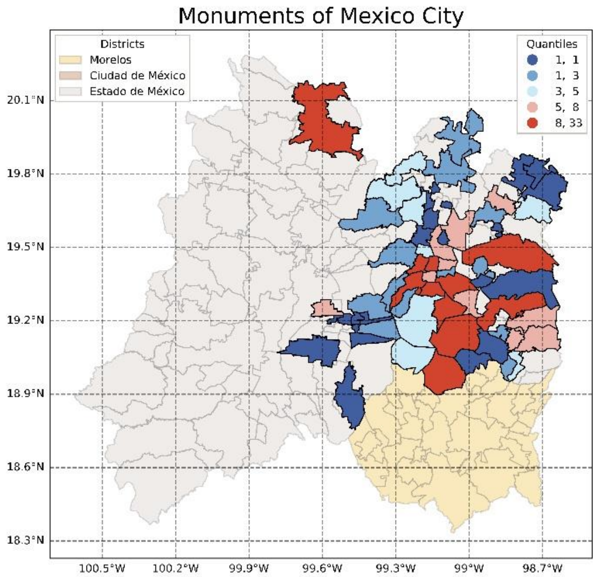

Figure 2. Municipalities and their respective number of monuments from the colonial period.

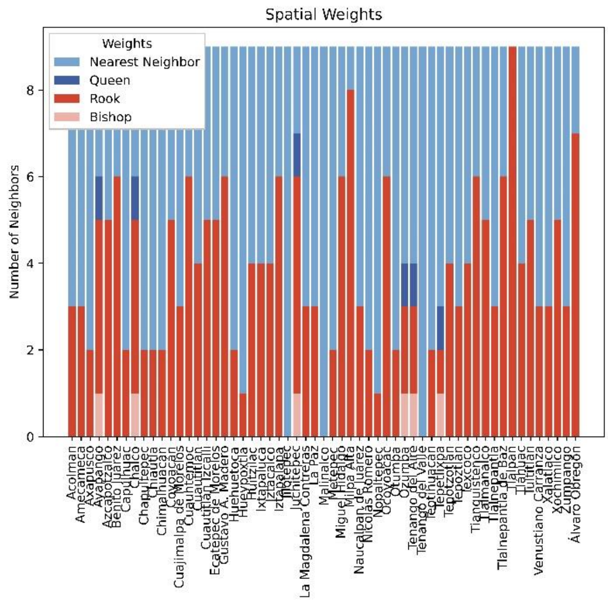

Figure 3. Histogram depicting the spatial weights of the polygons.

Spatial similarity is calculated through spatial weights and depending on the choice of neighbours. Weights are defined through their distance to the objects *i* an *j*.

$$W_{ij} = d_{ij}^{-\alpha} \quad (1)$$

The inverse distance, reduced by a factor α results in the weight *W* (Getis, 2010).

With "Rook" weighting all polygons with a shared edge are considered. With "Queen" weights polygons connected by an edge or node are neighbours. "Bishop" weights only include those polygons connected by nodes (see Fig. 3). In this case we use a distance-based calculation of weights, because not all municipalities adjoin. With "k-nearest neighbour" weights the polygons with the least Euclidean distance are used for the calculation.

The attributive similarity is determined with the "spatial lag" and is calculated with the cross product of *W* and *Y* (see Eq. 2).

$$\Gamma_{ij} = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} Y_{ij} \quad (2)$$

Depending on the values in W and Y the spatial autocorrelation can either be positive, when municipalities with similar attributes are neighbouring, or negative, if the case is the opposite. This can be easily displayed with Moran statistics, which essentially is a cross-product of the spatial lag of and the deviation from the mean (Anselin, 2010). The deviation from the mean of a variable is conducted through the autocovariance with $\bar{y}$ being the mean of the observation y at the location *I* (Getis, 2010) in Eq (3).

$$y_i = (y_i - \bar{y}). \quad (3)$$

The elements of the weight matrix are introduced as W_{ij} (Eq. 1), and the sum of the weights as S_0 are defined in Eq. (4).

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}. \quad (4)$$

With n observations this results in Eq. (5).

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} y_i y_j}{\sum_{i=1}^{n} y_i^2}, i \neq j \quad (5)$$

Graphically the results can be displayed in form of a scatterplot (see Fig. 4). The original values are plotted on the x-axis and the spatial lag of the variables on the y-axis. The value of "Moran's I" (see Eq. 5) represents the slope of the linear fit of the values.

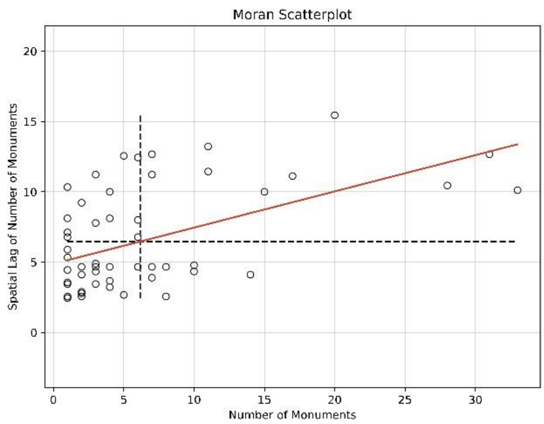

Figure 4. The Moran Scatterplot of the number of monuments with an indication of the autocorrelation.

As depicted in Fig.4, the mean values divide the observations into four quadrants, which coincide with the spatial association: the first and third quadrant indicate a positive form of autocorrelation and the other quadrants a negative. The overall spatial autocorrelation is positive as is indicated by "Moran's I" (Anselin et al., 2006).

3.2 Local autocorrelation

"Local Moran" is utilized in finding hot and cold spots or spatial outliers. In comparison to "Moran's I" in local Moran statistics only the components in the sum - in Eq. 5 - that correspond to *i* are used, therefore the value is calculated through Eq. (6).

$$I_i = \frac{n}{S_0} \frac{\sum_{i=1}^{n} w_{ij} y_i y_j}{\sum_{i=1}^{n} y_i^2}, i \neq j \quad (6)$$

Statistical significance is based on a conditional permutation method. While one value is fixed at a location *i*, the remaining observations are randomly interchanged, resulting in a reference distribution. The null hypothesis for the permutation is "CSR". With the combination of significance with the results from the local Moran statistics significant spatial associations (Anselin et al., 2006). Therefore, municipalities with a positive significant correlation are spatial clusters, like High-High (Hot Spots) or Low-Low (Cold Spots) and those with a negative significant correlation like High-Low (Diamonds) or Low-High (Doughnuts). The confidence interval is 95%.

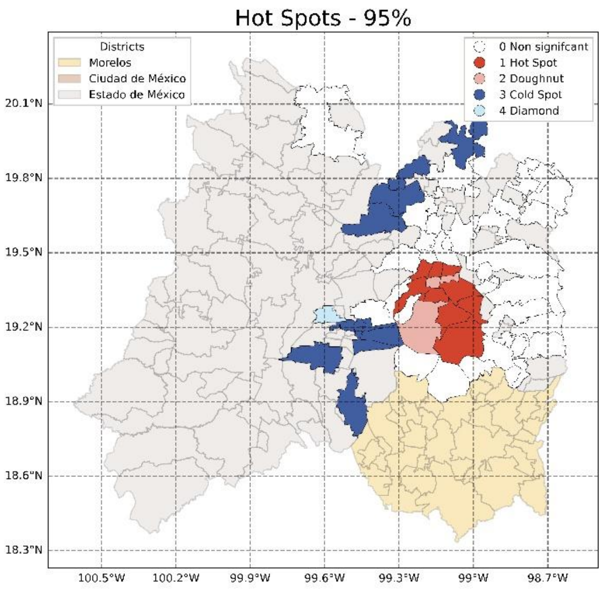

Figure 5. Significant spatial clusters and Hot Spots with a confidence interval of 95%.

The analysis results in ten Hot Spots which are stated below. All significant Hot Spots are situated in the district "Ciudad de Mèxico" except "Tepoztlán" which is assigned to the district "Morelos".

- Coyoacán
- Cuauhtémoc
- Iztapalapa
- Miguel Hidalgo
- Milpa Alta
- Tepoztlán
- Tláhuac
- Venustiano Carranza
- Xochimilco
- Álvaro Obregón

Additional information like the changes at the monuments throughout the different centuries can be analysed with spatial autocorrelation, specifically with local autocorrelation. In the case of the alterations at the monuments in the 17th century, the number of alterations is the attribute, regarding the attributive similarity. In the 17th century 114 monuments were altered in "Ciudad de México", 65 in "Estado de México" and three in "Morelos". The results of the local autocorrelation are three Hot Spots which are depicted in Fig.6. and listed below.

- Cuauhtémoc
- Xochimilco
- Milpa Alta

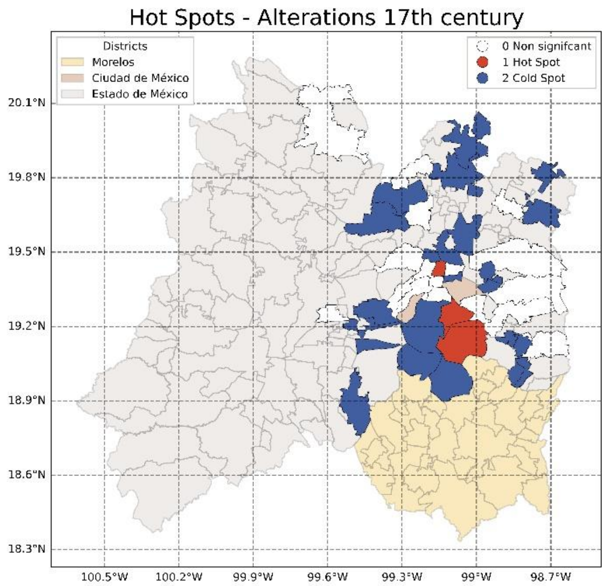

Figure 6. Significant clusters of monuments respective their alterations like renovation, extension or restoration. The Hot Spots are calculated with a confidence interval of 95%.

In comparison with the significant clusters of the number of monuments, three Hot Spots with high alteration activities remain. The high degree of architectural improvements and alteration fits with the considerable overall development of colonial society in Xochimilco, as recorded in parish registers and administrative sources like criminal lawsuits (Conway, 2014). Similar activities are observed in "Milpa Alta", where the dominant mendicant order was the Franciscan. While the local Indian population became reticent, the number of ecclesiastics increased, concomitant with the increase of building alterations (Gibson, 1964).

4 Discussion and Conclusion

A plausible explanation for a higher number of monuments belonging to hot spots is the lake "Texcoco". The majority of the modern city would have been taken up by the lake. The capital of the Aztec empire

"Tenochtitlan" was built on an island in the middle of the lake (Biar, 2020; Stangl and Austrian Science Fund, 2019). The Spaniards conquered the local population in 1521 and razed the city. They rebuilt their new capital of the viceroyalty on the grounds of the Aztec ruins. Therefore, it is not surprising that the Aztec symmetric city grid remained in its essential features (Kubler, 1948). The municipality "Cuauhtémoc" which is one of the ten Hot Spots, includes the ancient capital "Tenochtitlan". While Cortés raided, razed and rebuilt "Tenochtitlan" he resided in the town of "Coyoacán", another Hot Spot. Records show that the city provided many laborers for private or public work, which is evidence for the importance of the municipality. The Dominicans built an important monastery in the city and many smaller churches followed (Kubler, 1948). All Hot Spots were prehispanic sites, razed and rebuilt by the Conquistadors, accompanied by building of monasteries, churches, and chapels by Dominicans or Franciscans.

The paper – still ongoing work – shows that spatial analysis can help to detect patterns in data on historical monuments. The cross-check with literature from the field of History and existing data (Stangl and Austrian Science Fund, 2019) reveals, that the point patterns are well justified and are well aligned to historical processes.

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