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Mapping active frontages: a method for linking street-level activities to their surrounding urban forms

A case study of the city of Weimar, Germany

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ABSTRACT

In this paper, we discuss a few methods for mapping the location of urban activities. We focus on establishing the geometrical relationship between the frontages of urban activities and their morphological context. Frontages act as the interface between the users of the public space and the activities within its surrounding buildings. Studying how this interface connects to the surrounding is not a trivial task. It could give different results if we use different units or other mapping methods due to a known error caused by two main effects of the Modifiable Areal Unit Problem; the zoning effect and the scale effect. The first is concerned with the choice of sizes for the analysis area, and the second is the mapping method applied to the analysis unit. We introduce in this paper a few methods to facilitate the ease of establishing relations between frontages data for spatial queries and statistical inferential. It provides a platform to connect between different urban activities and urban forms like retail activity to a street or accessibility value to a specific type of service. Using this method on the street-level activities data collected in Weimar, Germany, we demonstrate how to bring together more detailed information on the urban retail centres and their connection to the local built environment.

KEYWORDS

Active Urban Frontages, Spatial data query

1 INTRODUCTION AND THEORY

The interaction between the public and private space in the city is encapsulated in the spatial organisation of active building frontages. Frontages are parts of the building façade that is visible

and accessible from the street level. And the active part refers to frontage status, either a solid wall or a windowed one where people can see the activity inside.

Frontages interface between the human and the city spaces through their street-level floors. Due to the horizontal nature of the human field of view, street-level frontages are more easily noticeable than any other building part. In addition to a distance constraint of around 100 meters, any object is less recognisable to the naked eye (Gehl 1987, Gehl & Svarre 2013). This renders the building frontage's importance inarguable, as it is of the highest value to the livelihood of the city streets (Alexander *et al.* 1977, Whyte 1988).

When a frontage has an active function visible from the street, it is called an active frontage. When an active frontage exists in a location, it indicates that there is a probability that another active frontage is nearby, and the opposite is true. Therefore, if more inactive frontages are present, then the frontages will become less the further we move away. This is mainly due to the geographical relationship between objects in nature, as similar things are found in closer proximity (Tobler 1970). This means that any reduction in active frontages is evidence of reaching the city's edge of the shopping zone (Jacobs 1961, 2016).

Kickert (2016) emphasises that we should categorise buildings according to their street frontages status. It encourages either side to interact with the public space (from inside to outside or the reverse). As ignoring the frontage attractiveness will reflect on the streets' privacy and walkability as the interaction between the buildings and the direct street frontage is disconnected (Karimi 2009, van Nes & Yamu 2021).

2 METHOD

When researching urban activities, the first category of information that should be collected is if the mapped activity is allocated on the street level or not. A building with one activity will result in one entrance and regular windows. And buildings with multiple activities will have a retail space with separate entrances and an entrance for the upper part of the building.
This upper part can also have multiple functions, favouring a hierarchy of information. For example, the building with multiple uses could host two retail spaces at the street level, one office space on the 1st floor, and the rest of the floors as residential.

Other buildings could have a single-use for residential or offices. Single-use that are not Retail, Food or Personal services does not usually try to attract the attention of the street visitors and, therefore, will typically be without a valuable façade. A Street-Frontage-Line could be accompanied by a percentage value to map the frontage ratio dedicated to a specific function. The method of mapping visible functions to the street segment is previously presented by Schneider *et al*. (2017). It was necessary to prove the correlation between local centrality and the number of commercial activities. But since our objective here is to map the relationship between

different shops and other shops, it became more challenging since the shop's location is governed by the access from a specific building façade to another shop on a particular building façade. Therefore, mapping building frontages became more crucial to this analysis.

The location of urban activities requires the understanding of relational data; since the location is directly connected to both the location it occupies and the context in which this activity exists (hence, surrounding streets, buildings, and other activities they host). This relation starts from the information available about the activity, then its location and ends with how this location is situated within its surrounding. This relative location of the activities here is called Positioning or Relative location, which includes distance or arrangement (Anselin 1988).

2.1 Acess to higher details of urban functions

Iacono et al. (2010) highlighted the need for easy access to higher resolution land use data. As most of the information about land use is hard to obtain, due to this information being collected by private investors. And since we have our own collected data, as well as the maps available from the state, it was crucial that we set up a system to facilitate the ease of access to higher detailed data. This presented multiple challenges regarding how the data should be formatted and mapped to the geometry?

Moreover, How can this data be used in different contexts while still keeping the integrity of the information?. Talen and Jeong (2019) pointed to a large gap in detailed information about the relation between urban function and urban form. As most of the data urban planners have are large scale zoning data. This is also a crucial of urban studies as it can support a better sustanible life for the city inhabitants (Bobkova el al. 2019).

2.2 Modifiable Areal Unit Problem (MAUP)

Openshaw (1983) and Wong (2004) have pointed to a common problem in any spatial analysis process in Physical Geography. Since different studies could be applied to the same area over time, some problems in the analysis units would need to be addressed. Two main effects were gathered under the Modifiable Areal Unit Problem (MAUP). First is the problem of defining the study area boundary called the zoning effect. And second is the change of the analysis unit design or type called the scaling effect. (Clark and Scott 2014, Brownson et al. 2009, Handy 2005). Brownson et al. (2009) have found that different scales of the unit of analysis will lead to different information about the study. We will evade this problem by connecting the data to all the possible units of analysis available for the study. Therefore all the streets will be connected to the Blocks, Plots, and buildings, including their related attributes.

A particular hierarchy should be considered to facilitate this transfer to transfer the information about the location between the relevant geometries. The method used is inspired by the work of

Lee and Hardy (2005), in specific, the topological relationship among urban geometry features like ensuring shared geometry and considering interfering features.

2.2.1 The zoning effect

Each research defines the area of research, which can differ between studies. In our study, we simply connect all the geometries to each other. This facilitates the transfer of information between different geometries, as well as documents the information inside each element. Which facilitates easy information retrieval.

2.2.2 The scale of the unit

We are starting with the location of the functions within buildings and passing through different scales of the units, from the smaller to the larger ones. We consider a shop space as a starting area within the building. Still, since any information about the internal configuration or occupied area is challenging to obtain, we decided to use the frontage as the smallest unit of analysis.

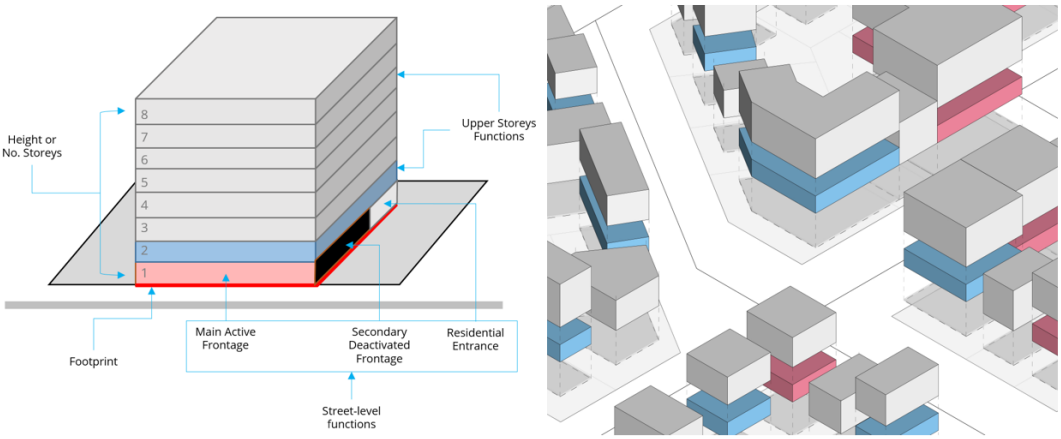

Figure 1: Built environment units and their corresponding information

First, we define the frontage as a building edge that can be seen from the street directly in front of the building.

Each frontage is then categorised into Activated and Deactivated frontages as the following:

- A frontage could be activated or deactivated. A deactivated frontage is a rule-governed by the street type (if a building has a deactivated frontage, it will deactivate based on the information from the street).
- A frontage that overlooks a neighbouring plot is considered deactivated.

Due to the nature of frontages and their relation to the street, other conditions should be considered when selecting the functions of frontages:

- A building could have a ground floor with either residential or functional activity.

- A residential frontage could also host an office or a service function like a clinic, and both do not require a frontage on the street and therefore are treated as residential.
- A mixed-use building with residential has a frontage located on the address street regardless of the deactivation condition,
- It is observed that the building entrances are located far from the centre of the frontage (closer to the building edge/corner).

Bielik (2020) highlights that by mapping the building function to the directly accessible street, we lose some part of the information due to the type of the mapping method. This error is due to the nature of spatial data and the method used for aggregation.

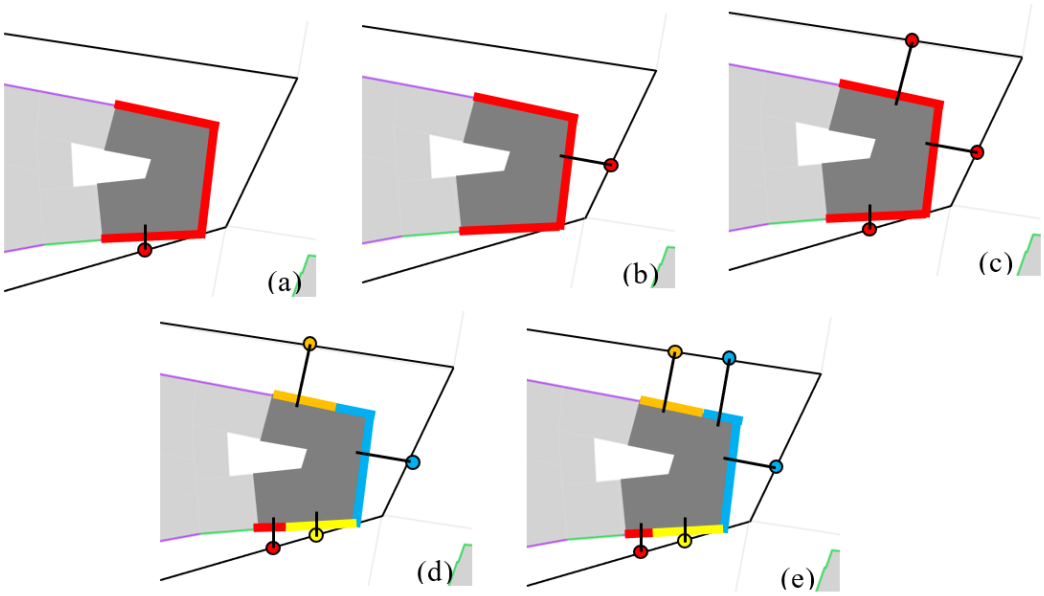

Figure 2: Aggregating building functions using front building edges a) Building address b) Frontage edge centre c) Each Frontage edge to its nearest street d) Function-based edge separation e) each edge to its street function-based (Adopted from Bielik, 2020)

For the case of aggregating frontages, we have found five scenarios in total. First in figure 2a is the address aggregation; this is based on the city given location identifier for each building in the city. This method locates the main entrance to the building, specifically the residential entrance. Figure 2b highlights the closest street aggregation where all the frontage edges are accessed from the average location. Third, figure 2c is the normalised frontages based on their access to their closest entrance. Fourth in figure 2d where we detail the frontage edges by the functions behind them, we normalise the aggregation by the total frontage length of each function. Finally, figure

2e shows another version of normalising the frontages by the function, but this also maps each edge of each function to their corresponding closes street segment.

2.3 Transferring information between units

In the following, we discuss some remarks that need to be considered when connecting the city geometry to facilitate transferring information between them. To connect the function of the building to other geometries, we consider the following conditions:

- A function is a space on the ground floor of the building and has an entrance from the street, not through shared access with the residential/upper functions.
- Each function has a unique ID and street ID/s of the entrance/s.
- A function could have a frontage on many streets.
- Each street is considered secondary except the main entrance street, even if there are multiple entrances.
- A frontage could be mapped to the street in three methods: each frontage to its corresponding street, each frontage with an entrance to the entrance street or all the frontages to one main entrance street.
- A function could exist in many buildings; we use the function ID to combine relative function information.

3 DATASET AND RESULTS

The data collected comes from two sources, the open Geodata of the Thuringian state in Germany and empirical data from mapping the city geometry and the activities within them. We first collect the basic geometrical data about the city using two sources of open Geodata, the street network from the crowdfunded OpenStreetMap and the buildings and plots from the Open Official Geodata of the state Thuringia, Germany. Then we merge both data as the difference in quality does not affect any later analysis of them (Krenz 2017).

Validating the data after the organisation is crucial, even if the effort is minimal, either by a site visit or by other online sources like google streetview (Law *et al.* 2017, Serra-Coch *et al*. 2018). Since our access to the city location is more feasible, all our notes and edits were driven mainly by the result of the site visits.

Figure 3: Information to note when selecting the unit of analysis (a1&2) shows a plots/block boundary defining problem that prevents a path and a function on that path from being detected due to being under a building. (b1&2) showing a street with no active frontages directly attached to a very active street.

3.1 Looking at Frontage information

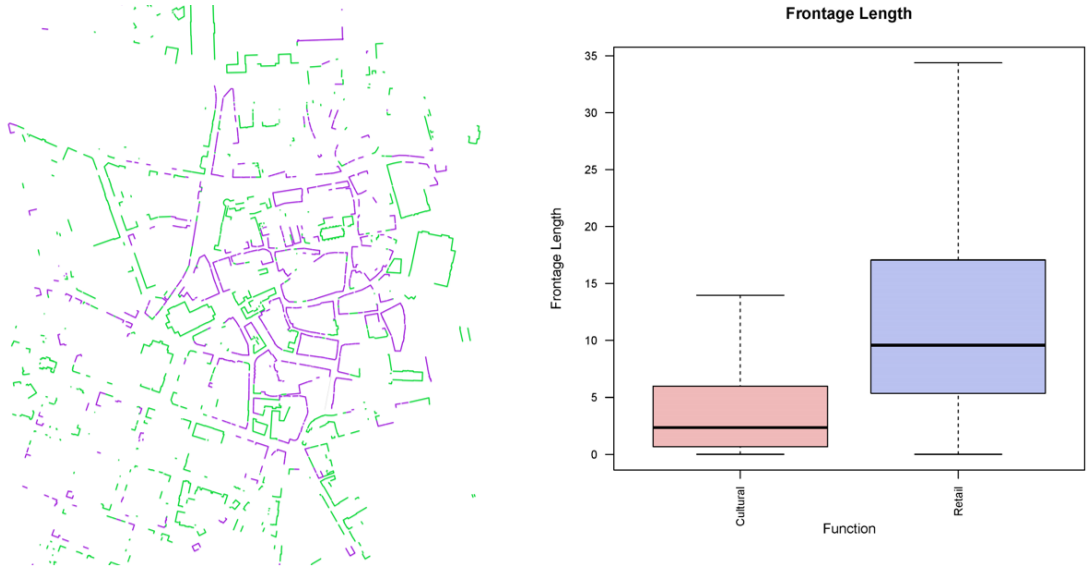

Figure 4 Frontage's length (Left) Retail frontages in Purple, and Cultural and service frontages in Green. (Right) Boxplot of the length of frontage of both the retail and cultural/services.

3.1.1 Frontages of Weimar

By selecting two types of frontages based on their street visibility, we can compare them using maps visualisation or statistical plots, as shown in figure 4.

In figure 5, we can also access all the information regarding the frontages and compare all the types of activities to their surrounding ones.

Figure 5 All frontage types Residential only (Red), Residential entrance (lite red), Service and Cultural (Green), Service and Cultural entrances (lite green), retail (Gradient purple for the same buildings)

3.1.2 Frontages Accessibility (Gravity and Betweenness)

What accessibility components (Attraction and impedance) can explain. Gravity measures distance as impedance (activity/distance)(Bielik, 2020 and Bhat *et al*, 2002).

$$A_i = \sum_{j,i\neq j,d_{ij}<r}^{n} \frac{O_j}{f(d_{ij})} = \sum_{j,i\neq j,d_{ij}<r}^{n} \frac{AFL_j}{e^{\beta d_{ij}}}$$

Where A_i is the Gravity-based accessibility at the location I, O_j is the opportunity/attractivity of the destination within a range of r, in our case, is the Active Frontage Length at destination (AFL_j), the distance decay function is the negative exponential function with the beta coefficient for the city of Weimar is $\beta = 0.00138$ (Bielik, 2020). The d_{ij} is the metric or Euclidian distance between the origin i, and the distention j.

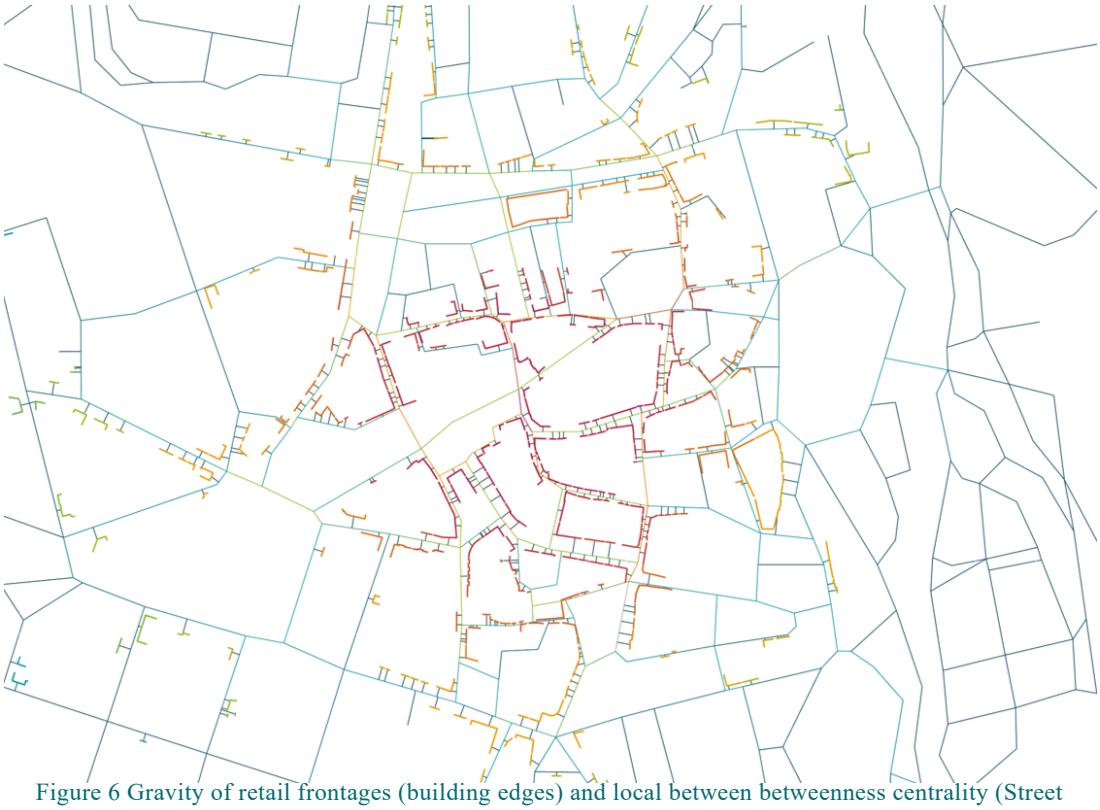

Figure 6 Gravity of retail frontages (building edges) and local between betweenness centrality (Street Segments)

4 CONCLUSION AND OUTLOOK

In this paper, we demonstrate how the frontage data could be used to bring together more detailed information on the urban retail centres and their connection to the local built environment. Due to

also being in a parametric environment, this method provides direct access to many types of information from both the result and the different parts of the process.

In addition, since the data is structured in a hierarchy that could be reversed, all the information from the detailed to the larger scale of the model could be reversed and mapped from the larger parts to the smaller ones. Considering the mapping method in the analysis, this could facilitate the ease of accessing and relating the same information on many scales of the city geometry, which can lead to more room for detailed research about the nature of urban retail spaces in the city.

This method has some challenges and obstacles that will need further development. For example, the data supplied by the state have a lot of missing information about the state of ground floor activities in a building that does not have access to the streets. This is due to them being merged in reality but still having separate geometry in the city database. This is manageable to overcome in smaller cities like Weimar but might be difficult in larger ones. Another example is the private streets and under paths of the street networks. Although some of this information was available in the city, something like private paths could introduce some conflicts if the research question is about the public accessibility of the spaces.

Finally, we are looking forward to using the connected data generated in more advanced spatial statistics applications. This could add more significant information about the microeconomics aspects of the retail frontages and their local relations. This could be done using the Spatial Autocorrelation analysis using the available frontage parameters as features and their linkages as weights.

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