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# TOWARDS A QGIS-BASED GRAPH CARRIER OF URBAN INFORMATION AND SPOTTING WIND BEHAVIOR AT THE PEDESTRIAN LEVEL

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## 1. Introduction

In this communication, we present a research aiming at finding the correlation between urban spatial configuration and comfort conditions related to wind. We especially seek to highlight wind comfort and discomfort zones at a city scale through the study of urban layout. Our outcomes have to serve urban designers at an early stage of the urban planning. Therefore, we aim at finding a geometric descriptive that can help predicting discomfort zones with numerical models of future urban conceptions.

In literature, Computational Fluid Dynamics (CFD) are provided to give this kind of information. However, this method takes too much time to run the simulation, demands advanced technical support, and requires an accurate work for the urban numerical model and the mesh creation. All these requirements are necessary to end up with a reliable result, but are not compatible with the early stage of urban design.

An alternative to bypass this complicated step is the use of urban indicators or morpho-metric parameters. This kind of tools, which are quicker to apply, may help to cast, roughly, the wind behavior. For example, Oke (1988) and Beraneck (1984a) proposed empirical formulas based on built environment dimensions: buildings heights, buildings depth, street width... Oke used an aspect ratio for an urban canyon. He specified two thresholds for the canyon aspect ratio, according to which the turbulence regime changes in the street. Beraneck focused on isolated buildings, and proposed a formula to calculate the protected zone in the leeward side of the building. Although the idea of an urban indicator is attractive and well demanded, we still deal in these studies with cases too simplistic and away from the real complexity of the urban morphology. These last tools do not reveal the heterogeneity of the urban forms and its variety.

The question in our research is how to analyze quickly complex urban form for design purposes?

Our proposal is divided into two main stages, first, we have to define a method to characterize the urban fabric morphologies and to output their main geometric dimensions. Second, we have to manage correlations between the variety of dimensions and the air flow parameters.

## 2. Urban geometry analyzing tool

We aim at constructing a tool to characterize urban patterns regarding wind flow through a simplified representation. The simplified version of urban plan has to contain the specific geometrical information about the urban form, besides, it has to describe the planimetric aspect and the volumetric aspect to characterize it. For that purpose, we applied three levels of dimensions reduction to the geometry of the case study:

From 3D buildings to a 2D field-based modelling of the unbuilt space: we focused on the unbuilt space, the urban void and compared it to an urban vein (Fig.1b).

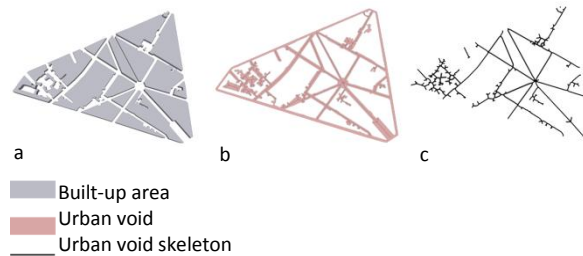


Figure 1: Dimensions reduction of an example (Paris - France)

From 2D unbuilt space to 1D graph of centerlines: We run a skeletonization operation. It is based on graph theory and has been used recently for urban studies, like the pedestrian path analysis done by Sarradin (2007). This technique shrinks the 2D form to a 1D form, reduces a polygon plan to lines. We end up with a set of centerlines for the sub-regions of the void complex form (Fig.1c). This straight skeleton is a tree graph that creates tessellation of a geometric shape, reduces its complexity to a refined set of centerlines, and transfers the main form features of the original shape. The last reduction dimension we apply, is from 1D centerlines to 0D skeleton sensors. Here, we transform the skeleton net into points by sampling the centerlines. In order to keep the 3D information about the urban case, we enrich sensors with morphological attributes (distance to the nearest building, SVF, aspect ratio, mean height, mean width, etc...). We also calculate the primary derivative (P.D.) and the secondary derivative (S.D.) of the carried information along the sections of the skeleton.

This combination of numerical and graphical urban information allows us to study thoroughly the street section form variation and as, for example, the vein enlargement and shortening (Fig.2).

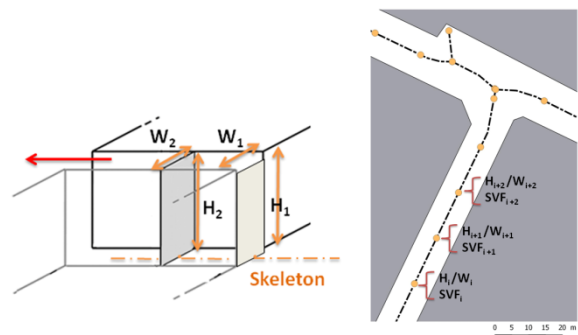
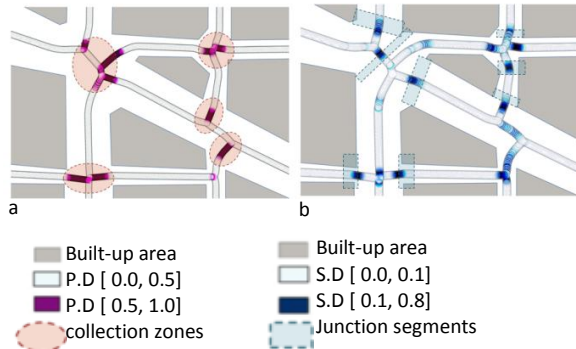


Figure 2: Informative skeleton

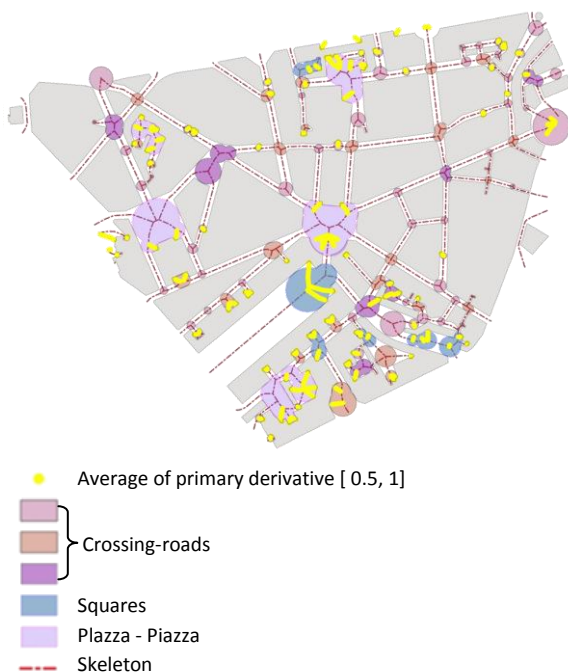
### 3. Urban geometry analyzing tool results for the urban typology characterization

Fig. 3a shows a primary result for the skeleton tool. It helped distinguishing streets (canalization) from squares (collection zones). Furthermore, Fig. 3b shows how it also helps differentiating the transition zones between two urban components (streets or crossing-roads), whether they are of similar type or of different type. It picks out void sections where we come out from a street to another street, or from a street to a square and backwards.



**Figure 3: Primary derivative and secondary derivative results**

Fig.4 is a cartography of results developed from the previous ones: the urban typology recognition. Here we cut the skeleton into segments when the second derivative was at its maximum, thus locating different urban components, and the primary derivatives help to qualify the type of zone: collection zones, streets, square, big plaza, crossing roads (with the number of roads meeting at that point), the dead-end streets...



**Figure 4: Urban recognition**

### 4. Correlation between urban wind, urban informative skeleton

In this part, we present a first attempt to treat how we can manage to link a spatial information (average wind velocity represented by vectors) to a 0D information (morphology information stored in points, skeleton sensors). Simulations were made using a CFD code (Code Saturne), but as we intend on working in a unique context, QGIS, we transferred the CFD simulation result to the QGIS environment. We generated a point-based presentation of the wind velocity between buildings at the pedestrian level, instead of a mesh presentation.

Then, we applied the principle of the nearest neighborhood to group the points where wind was calculated according to their distance to the skeleton sensors. We obtain cells gathering the nearest "wind" points to each skeleton sensor. The calculation of the standard deviation in each cell allowed us to analyse the homogeneity or heterogeneity of wind velocity in each cell and to select sets of cells with a low standard deviation [0.0, 1.9], located in the center zone of the case study, which is more eligible for the correlation phase than in the outlying zones.

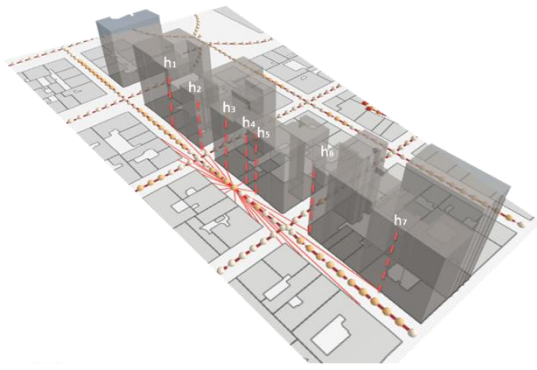
### 5. Results

Tab.01 shows first results confirming a weak correlation between wind velocity and values of urban indicators carried by the skeleton sensors. Two higher values of correlation coefficient correspond to the SVF and the distance between points and the nearest building. From this stage, we conclude that it is necessary to seek for more representative urban indicators for wind, which means that our geometrical descriptive tool, the informative skeleton, has to carry out more sensitive indicators to the wind characteristics like orientation, and has to be more sensitive to the 3D variation in the field.

	Aspect ratio	SVF	Radius (LIB)	Primary derivatives	Secondary derivatives
Average velocity m/s within cells	-0.16	0.40	0.32	-0.017	0.037
Standard deviation of the average velocity	-0.07	0.24	0.10	-0.02	-0.01

**Tableau 1: Correlation coefficient**

As a response, we enhanced our method by changing the source zone of the indicators. The skeleton sensor only captures dimensions of buildings located in the source zone. We change consisted of stretched this zone so as to consider morpho-metric dimensions of the built form upstream, at the direct proximity and the skeleton sensors downstream (Fig.5). This approach is panoptic, calculated on 360° around the sensor. Results are shown in Tab02. We obtain an increase in the correlation coefficient for the panoptic aspect ratio compared to the sectional aspect ratio, for both the average velocity and the standard deviation of the average velocity. This encourages us to continue with the same method for the rest of the urban indicators and parameters.



**Figure 5: Panoptic approach for the aspect ratio**

	<b>Sectional Aspect ratio</b>	<b>Panoptic Aspect ratio</b>
Average velocity m/s within cells	-0.16	-0.31
Standard deviation of the average velocity within cells	-0.07	-0.20

**Tableau 2: Correlation coefficient for the panoptic approach**

## 6. Conclusion

Skeletons included in the GIS context are useful and powerful tools to analyze the urban form quickly. But in order to reach our purpose we need more sophisticated indicators, taking into account the directionality and both local global geometrical information, so as to obtain stronger correlations with wind characteristics. Indeed, our study has to be applied on more case studies and simulations data to have a more robust approach.

## 7. Bibliography

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