Feasibility analysis of open-government data for the automated calculation of the micro-climatic attributes of Urban Units of Observation in the city of Vienna

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ABSTRACT

A quantified analysis of the urban climate in general and the urban heat island phenomena in particular is a complex endeavor and requires a variety of data streams. Urban units of observations are meant to specify well-defined spatial domains within a city toward the representation and study of the microclimatic conditions (e.g., via simulation applications). The European Union generally mandates the implementation of open data interfaces. Administrative data is made publicly accessible to increase transparency and to support participation and collaboration. The present contribution analyses the feasibility of open government data for the automated calculation of the microclimatic attributes of urban units of observation in the city of Vienna. The proposed algorithms and framework are briefly introduced to explain which data sources are needed and how the data is classified. Suitable data sources include geo-referenced, two- and three- dimensional vector, raster as well as semantic data. A sample application scenario presents the results of aspect ratio calculation using the example of the inner city of Vienna.

KEYWORDS: Urban Heat Island, Algorithms, Automation, Microclimatic Conditions, Aspect Ratio

1 INTRODUCTION

The urban climate has a strong impact on a city’s quality of living. Vegetation, water, building materials and geometries influence the quality of the urban environments. However, empirical studies suggest that urban areas show significantly higher temperatures than their rural surroundings. This circumstance, referred to as the urban heat island (UHI) phenomenon (Oke 1982), has been the focus of a number of studies (e.g. Giridharan et al. 2004, Unger 2004). Beside the importance of geometry and vegetation (Memon et al. 2008, Santamouris 2007), seasonal changes (Gaffin et al. 2008) have a significant impact on the urban climate.

Related research conducted at our Department (Kiesel et al. 2012a, Kiesel et al. 2012b, Mahdavi et al. 2013, Kiesel et al. 2013) focused on the development of a systematic framework for the evaluation of UHI mitigation measures (Mahdavi et al. 2013). This framework included the definition of *Urban Units of Observation (U2O)* – bounded, coherent areas within an urban context – that represent potential spatial targets for the analysis of UHI mitigation measures. Within the scope of this research, a set of variables was identified that can be used to describe the built infrastructure by taking geometric and physical properties into consideration. These include properties such as built area fraction (ratio of building plan area to total ground area), unbuilt area fraction (ratio of unbuilt plan area to total ground area), pervious surface fraction (earth, vegetation, water), impervious surfaces (sealed surfaces), aspect ratio (height to width ratio of building canyons) and built surface fraction (ratio of exposed surfaces). Based on the sample U2Os in Vienna, which contain densely built areas in the city center as well as suburban areas at the city's boundaries, the previously introduced U2O variables were calculated manually using AutoCAD and visual analysis of satellite images. Applying this method to project areas with a total sum of $8.6×10^6$ m^2 proved to be a time-consuming and error-prone task.

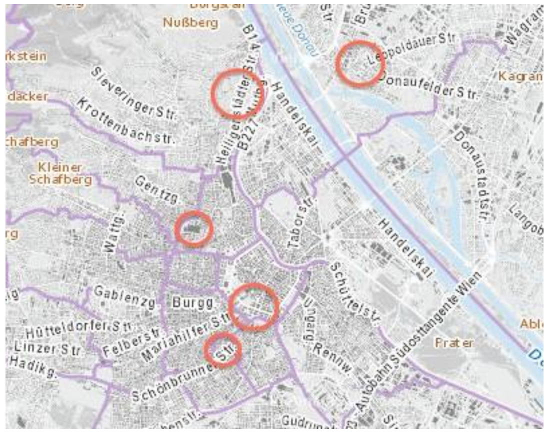

Figure 1: Sample U2Os in Vienna (Stadtplan Wien 2014).

1.1 Approach

The present contribution describes an approach toward the automated calculation of U2O variables at a large (urban) scale by incorporating geometric data from open data sources and Geographic Information System's (GIS) functionality. Based on open government data from Vienna, an automated workflow for the calculation of the introduced U2O variables was developed. This paper presents an overview of the framework and applied technologies using the example of aspect ratio calculation of a U2O located in the city center.

2 METHODOLOGY

2.1 Data

The idea behind the open data initiative is that certain data should be distributed without restrictions from copyright or patents. This mainly concerns data of public interest (e.g. environmental, ecologic, socio-economic, etc.) and includes geometric and typographic datasets within spatial contexts (for instance geometry of the built environment). The calculation of the U2O variables depends on vector, raster and semantic data. Urban geometries are available via point (e.g. trees), line and polygon (e.g. street segments, buildings), 2.5 and 3 dimensional vector data sets. Topographic information can be extracted from raster elevation and terrain models. Text-based attribute information defines properties such as number of building storeys, building age and building type that must be put into context with object geometries.

2.2 Framework

As it can be seen in Figure 2, the U2O-core module incorporates GIS functionality from the proprietary ArcGIS (ArcGIS 2014) arcpy core library. The functionality provided by the arcpy module is necessary to: (i) load geo-referenced data sources into a spatial context, (ii) create manipulable layers and (iii) to provide basic spatial analysis methods (e.g. distance calculations, comparing geometry with the help of logical operators, etc.). However, these core functionalities are also provided by open source software products and can be easily exchanged. Currently, the U2O-core module supports the calculation of the following U2O variables: (i) aspect ratio, (ii) pervious and impervious surfaces, (iii) built and unbuilt area fraction, (iv) built surface fraction, (v) mean building compactness and (vi) mean sea level. A detailed description of the algorithmic procedures is given in Glawischnig et al. (2014). For development purposes, the input data is currently loaded from local file sources. The geometric data is loaded into memory and combined with semantic data (if necessary) before the U2O indicators are derived. The U2O-core module produces geometric (maps) as well as semantic (text-based) output that is interpretable by map-viewer and GIS applications.

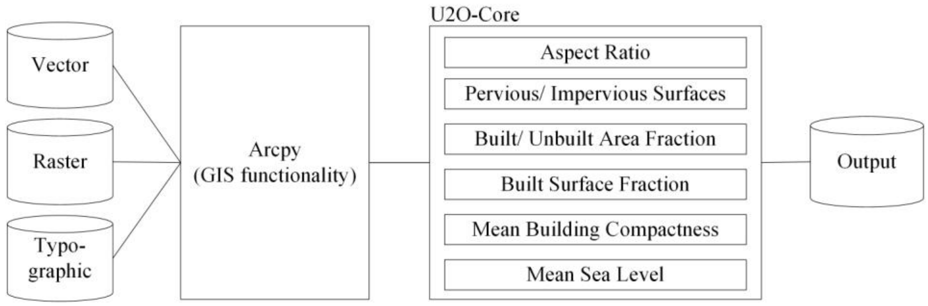

Figure 2: Proposed framework for automated calculation of U2O variables.

3 APPLICATION SCENARIO

The discussed sample U2O is located in the center of Vienna. To illustrate the framework processes, the calculation of aspect ratio is introduced. Aspect ratio is defined as the height-to-width ratio of street canyons (Oke 1981). Unfortunately, the topology of the Vienna base map is not sufficient enough to automatically calculate a representative aspect ratio value for an entire street canyon. As it can be seen in Figure 3, street canyons are not clearly defined. Streets are not represented as discrete polygons. Instead, the definition consists of various street types (e.g. street lights, walkways, crossroads, etc). Furthermore, there is no standardized procedure on how to handle junctions, differing street widths or differing building heights. In case a consistent theoretical definition can be found that considers semantic data (for instance boundaries derived from the street name) and geometric data (building and street geometry), a feasible solution can be derived even for large-scale data. However, this procedure includes many iterative steps and would require immense calculation costs. To minimize algorithmic costs, the procedure presented in this paper does not focus on an accurate definition of street canyons (both semantic and geometric), but on a superimposed more or less uniformly distributed array of spatial units.

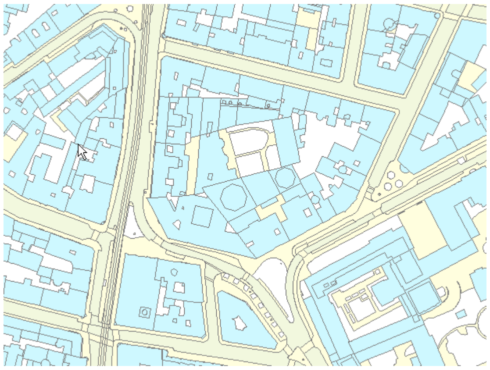

Figure 3: Typical urban Viennese setting. (Streets green, buildings blue)

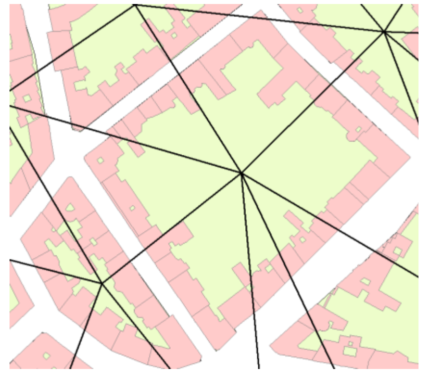

Figure 4: Delaunay triangulation with building blocks centroids (Glawischnig et al 2014).

These units are identified by reusing well-established spatial concepts. Instead of modifying the base data to derive street canyons, a Delaunay-triangulation is generated that connects the centroids of building blocks (Figure 4). A building block is defined as the number of buildings that are logically and spatially encapsulated by roads. Subsequently, the street facing buildings are identified within each triangle. For each possible building combination, the distances (street canyon width) and average building heights are calculated. Given the varying widths of street segments (Figure 3, 4), the aspect ratio can be computed using either the minimum, mean or median width of street canyons. The following pseudo code expresses the relevant processes (for the extended version, see Glawischnig et al. 2014):

```
Float buildingHeight, canyonWidth
tempBuildingMatrix  = list()
calculateTIN()
For i < getTinList().length  :
      For j < getBuildingBlocks.length  :
         If buildingBlock(j)  is inside getTinList(i)  :
                  selectBoarderBuildings()
                  updateTempBuildingMatrix()
                  updateBuildingHeight(calculateHeight(mode))
                  updateCanyonWidth(calculateCanyonWidth(mode))
                  removeTriangleFromTinList()
      setAspectRatio(getTinList(i),  getBuildingHeight  / getCanyonWidth)
```

As it can be seen in Figure 5, applying the introduced algorithm to a reference area (1.16×10^6 m^2) results in an aspect ratio range of r = [0 to 3.4].

Figure 5: Automated aspect ratio calculation for the city center of Vienna.

4 CONCLUSION

We presented an overview of an ongoing research effort to automatically calculate microclimatic attributes at an urban scale by incorporating open data and GIS functionality into a python based framework. The introduced methods use well-established spatial concepts, for instance Delaunay triangulation to develop efficient algorithms that can be applied on an urban scale. Future work will focus on the inclusion of open data services instead of using native datasets. For development purposes discussed in this paper, the datasets were provided by municipal departments and loaded from local data sources instead of using open data services.

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