Producing a simplified and harmonised map of European local administrative units (LAUs): when “less” offers “more”

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Abstract
This article describes how a cartographic solution, originally implemented to circumvent copyright issues, has revealed collateral advantages, notably its capacity to efficiently convey cartographic message, its adaptability for web mapping and its diffusion potential.

Reference

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5.6. Producing a simplified and harmonised map of European local administrative units (LAUs): when “less” offers “more”

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Key words: thematic cartography, innovation, Voronoï polygons, mapping layer, LAU

i) Voronoï polygons: from origins to ESPON context

The use of Voronoï diagrams is not new in cartography. British physician John Snow for example famously applied a similar method in 1854. He used it to illustrate how the majority of people who died in the Broad Street cholera outbreak in London lived closer to the infected Broad Street pump than to any other water pump. Voronoï diagrams have also been used in climatology, as a way of improving precipitation estimates by interpolating punctual measures over large areas (Thiessen 1919). They are also called “Thiessen polygons” as in this work. However, their use in cartography remained limited until the 1970s, when computer algorithms made it possible to automatise their elaboration.

Nowadays, most geographical information systems (GISs) offer automatic functions that make it possible to transform a set of points into tiles that are delineated using Voronoï operators. As a result, a variety of applications emerged with regard to geographical issues. For example, Voronoï operators can be used for:

- **assessing imbalances** between institutional subdivisions and functional socio-economic spaces, an approach that was developed in the early 2000s in South Africa (Geyer et al. 2000);

- **creating maps of fine-grained** spatial information (e.g. municipalities) on a large scale: to compare long-term demographic trends in 17 European countries on the basis of municipal data, Hubert and Moriconi-Ebrard (1999) developed a mapping layer with Voronoï cells, at a time when seamless, pan-European maps of municipalities were not available for researchers.

Within the ESPON programme, the initial impetus in 2012 for elaborating a Voronoï local administrative unit (LAU) layer came from a practical concern: at that time, LAU mapping layers were protected by copyright. To continue capitalising on the results of the GEOSPECS project after its completion (Gloersen et al. 2013), the University of Geneva came up with an innovative way to circumvent copyright maps, producing its own LAU map built on Voronoï polygons and overlaying these with copyright-free delineations of the European coastline. Thus, generalisation and its related advantages were not the goals per se, but collateral consequences of the method.

When ESPON launched the MapKits 2020 project with the aim of providing the programme with a coherent set of mapping layers and a coherent layout, preliminary reflections highlighted that mapping layers are used for two distinct purposes: analysis and mapping. When assessing whether or not individual

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geographical layers may be suited to these purposes, a number of criteria need to be considered (Zanin and Ysebaert 2018), as follows:

- **For analyses**, the key criterion is precision. The ESPON LAU Census 2011 Map, based on a collection of various versions of the EuroBoundaryMap\(^70\) to fit the 2011 census nomenclature with a resolution corresponding to a scale of 1:100 000, is perfect for that purpose.

- **For mapping**, the key criterion is informational value. The objective is to convey the cartographic message in an efficient way. This implies that “noise” (i.e. unnecessarily detailed boundaries) must be eliminated. A coherent set of generalised mapping layers has been produced, including the Generalised Representation for European Areas and Territories (GREAT) and a Voronoi “twin” of the ESPON LAU Census 2011 Map. The appropriate degree of generalisation depends on the scales on which the mapping layer will be used. The Voronoi layer is primarily planned to represent local data at transnational level. However, the production of pan-European maps showing local data is also possible.

Altogether, these layers provide the ESPON community with structured and coherent sets of geographical layers for analytical use and thematic mapping on various scales, designed to support the multi-level approach supported by the ESPON programme (Figure 5.6.1).

**Figure 5.6.1.**
**Voronoi within the multi-level layers supply strategy of the ESPON 2020 MapKitx**

<table>
<thead>
<tr>
<th>Territorial level</th>
<th>GREAT World</th>
<th>GREAT Europe</th>
<th>Voronoi LAU</th>
<th>ESPON LAU Census 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUTS 0</td>
<td><img src="image1.png" alt="Layer 1" /></td>
<td><img src="image2.png" alt="Layer 2" /></td>
<td><img src="image3.png" alt="Layer 3" /></td>
<td><img src="image4.png" alt="Layer 4" /></td>
</tr>
<tr>
<td>NUTS 2</td>
<td><img src="image5.png" alt="Layer 5" /></td>
<td><img src="image6.png" alt="Layer 6" /></td>
<td><img src="image7.png" alt="Layer 7" /></td>
<td><img src="image8.png" alt="Layer 8" /></td>
</tr>
<tr>
<td>NUTS 3</td>
<td><img src="image9.png" alt="Layer 9" /></td>
<td><img src="image10.png" alt="Layer 10" /></td>
<td><img src="image11.png" alt="Layer 11" /></td>
<td><img src="image12.png" alt="Layer 12" /></td>
</tr>
<tr>
<td>LAU</td>
<td><img src="image13.png" alt="Layer 13" /></td>
<td><img src="image14.png" alt="Layer 14" /></td>
<td><img src="image15.png" alt="Layer 15" /></td>
<td><img src="image16.png" alt="Layer 16" /></td>
</tr>
</tbody>
</table>

\(^70\) https://eurogeographics.org/products-and-services/ebm/
ii) Production of ESPON Voronoï LAU layer

A Voronoï cell, also sometimes referred to as a Thiessen polygon, is the basic unit of a Voronoï diagram. A Voronoï diagram divides – tessellates – a two-dimensional set of points into areas, so that the borders of the resulting areas are equidistant from the nearest points. It means that, within a Voronoï cell, every location is closer to the point around which the cell is drawn than to the centre point of any other cell.

Details on steps leading to a pan-European LAU Voronoï mapping layer can be accessed in the MapKits creation process and data report (Gloersen et al. 2017). They can be synthesised as follows:

1. **produce a set of NUTS 0 polygons** covering all ESPON countries;
2. **generate centroids** out of the ESPON LAU census 2011 layer to ensure one-to-one compatibility between the two layers;
3. **adjust national borders**: some of the centroids appear on the “wrong side” of the terrestrial border (in black in Figure 5.6.2a); the adjusted border is shown in white;
4. **generate the Voronoï diagram** via an appropriate GIS command;
5. **make manual adjustments to preserve significant contiguities** such as coast, national border or lake (Figure 5.6.2b);
6. **make manual adjustments to preserve geographical coherence** for very large LAUs, e.g. in Sweden or French Guyana (Figure 5.6.2b);
7. **make manual adjustments for remaining errors** such as sliver polygons resulting from the clipping of the Voronoï polygons with the coastline;
8. **assemble the countries into a single shapefile**: the ESPON LAU Voronoï layer (Figure 5.6.2c);
9. **clean topological errors**: essential for further processing, such as aggregation, R automated treatments and running cartogram software.

An exciting alternative would be to automate parts – or the whole – of the creation and adjustment processes, e.g. using R or Python scripts. Given that all methodological steps have now been extensively described, their translation into computerised routines seems achievable. This does raise a series of methodological and technical issues, as some of the manual steps described above require geographical expertise. However, automation remains an option to be explored, e.g. within the framework of the updates of the EU LAU reference layer.

iii) “Less”: specifications of the Voronoï mapping layer

The Voronoï mapping layer possesses a number of advantages related to the methodological choices made for its construction. The ESPON LAU Voronoï layer distinguishes itself in terms of the following:

- File size: while the size of the ESPON LAU census 2011 map layer, which is based on the EuroBoundaryMap, is 311 071 KB, the size of the Voronoï layer is only 796 KB. This makes its ".shp" file 800-times smaller than its detailed equivalent.
- The method offers an easy solution to producing a seamless map without the particular efforts required by the harmonisation of precise national layers. These layers are however necessary input material for generating centroids.
- Using exclusively open-source material, it is possible to customise it to meet the specific needs of the ESPON MapKit in terms of generalisation.
- It provides a very simplified pattern that offers real complementarity to the EuroBoundaryMap when mapping LAU statistics, or geographical objects based on LAU aggregation (e.g. urban objects, mountain massifs).
**Figure 5.6.2.**
Creation and adjustments, and the resulting mapping layer

a. Creation process

b. Adjustment processes

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Adjusting national borders  
Generation and clipping of Voronoï diagram

Preserving significant contiguities  
Preserving geographical coherence

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c. Voronoï layer, seamlessly embedded into Natural Earth 50m

© Administrative boundaries: University of Geneva  
Natural Earth
iv) “More”: innovative perspectives as the result

The Voronoï layer offers several advantages, in terms of both mapping (i.e. effectively and efficiently conveying cartographic messages) and processing (i.e. computer processing of spatial data). These advantages are linked to the small file size of the mapping layer file and to the high level of the generalisation of its boundaries:

▪ The Voronoï mapping layer is not only internally seamless. It also seamlessly integrates with boundaries of countries outside the ESPON space, as represented in the Natural Earth 50 m layer71. This makes the Voronoï layer particularly well suited to elaborating and running spatial models. Furthermore, this particular feature would allow the easy creation of LAU layers for countries that may join the ESPON space in the case of EU enlargement.

▪ Far from adding accuracy, an excessive level of detail generates visually counterproductive “noise” to maps above a certain level. For example, on maps covering all of Europe, a full surface of the colour of unit outlines appears on the west coast of Norway, while the colours of small German NUTS 3 units become illegible. In that sense, the Voronoï diagram is appropriate for conveying cartographic messages.

▪ Because of its high level of generalisation, only a small amount of computing power is required when processing these files in GISs or in editing programs such as Adobe Illustrator. This makes the production of maps faster and easier.

▪ The aggregation of LAU seamless units to produce maps of functional urban areas (FUAs) and all types of geographical objects is relatively easy. NUTS, FUA and core city delineations are already embedded in the Voronoï “.dbf” file of the ESPON 2020 MapKit, allowing the aggregation of LAU units into higher level territorial subdivisions. Similarly, users can incorporate their own territorial objects according to their needs (Map 5.6.1: LAU delineation of Alpine perimeter).

▪ In turn, simplified units that require less computing power facilitate the creation of innovative maps from classical GISs, for example the generation of cartograms or smoothing maps with tools such as ScapeToad and Magrit (Map 5.6.1).

▪ The small file size, in association with Creative Commons72 licensing, makes the “on the fly” production of maps using interactive mapping portals feasible, even for pan-European maps. Meeting this specification is particularly relevant, as interactive cartography via web-based tools is becoming increasingly the norm for the dissemination of maps and data.

▪ Based on the Creative Commons license, the mapping layer can be widely disseminated, and used and updated by users such as European institutions, students and academics. In that sense, a seamless geographical layer, adapted to cartographic needs and matching EU statistics, fills a recurring need.

71 https://www.naturalearthdata.com/
72 https://creativecommons.org/
v) Synthesis in view of ESPON 2020 objectives

With regard to the specific ESPON 2020 objectives – to (1) improve territorial observation and provide new tools for territorial analyses and (2) support researchers and policy-makers with innovative perspectives on the EU territorial structure – the Voronoï LAU mapping layer clearly meets the need for alternative spatial observations, which in turn support related policy discussions:

The opportunity to map LAU statistics at the transnational and European levels without having to handle mapping layers with a large file size and the possibility of drawing cartograms or smoothing maps should stimulate researchers to produce innovative territorial evidence on a local scale. As a result, a better understanding of specific territorial patterns and associated development issues is likely to support policymaking in terms of a place-based approach and integrated territorial investments.

- The possibility to aggregate LAU units so as to represent a variety of larger territorial objects provides a real alternative to traditional NUTS analyses. As demonstrated by the ESPON GEOSPECS73 project and by the ESPON European Territorial Monitoring System (ETMS)74 tool, it is, for example, possible to explore social, economic and environmental patterns and trends in a variety of functional areas, in mountain ranges, islands, sparsely populated areas and coastal zones. This makes it possible to produce evidence to support, for example, metropolitan strategies, community-led local development (CLLD) and integrated territorial investments (ITIs).

The production of the Voronoï mapping layer echoes wider debates on how institutional actors, researchers and analysts may relate to some key challenges:

- Facilitating access to geographical data, and their use, may help to promote territorial approaches to addressing social, economic and environmental issues.
- The storage of data at the local level, and of information on corresponding nomenclatures, is a key challenge.
- By producing “open data”, and making their availability known to relevant organisations, institutions such as ESPON may trigger major changes in policy-making practices.
- As discussed at the ESPON conference held in London on 14 November 2018, these highly simplified maps can be disconcerting for some users, who are used to traditional detailed representations of boundaries. Such simplified representations of spatial patterns must therefore be accompanied by explanatory statements.

The decision to opt for the Creative Commons licensing of the GREAT and Voronoï layers relates to the objective of the ESPON programme to realise a wider outreach and uptake of territorial evidence. Indeed, the idea is that, if more users access mapping layers and related datasets, the ESPON 2020 programme will have a greater impact on policy practices across Europe.

These fascinating perspectives are novel; therefore, there is a need to publicise the findings and for the ESPON programme to have a diffusion strategy to disseminate the tool to wider communities of users, outside the actual network of researchers and policy-makers. To draw all possible benefits from open-source mapping layers, relevant actors need to be made aware of their existence.

vi) References


