

RESEARCH ARTICLE

Bananas and tangerines spilled on streets

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Abstract: 1-2 sentences basic introduction into field. 2-3 sentences more detailed background. 1 sentence clearly stating the general problem being addressed by this particular study. 1 sentence summarizing the main result (“here we show”). 2-3 sentences explaining what the main result reveals/adds. 1-2 sentences to put results into more general context. Optional - if accessibility is enhanced by this: 2-3 sentences to provide broader perspective.

Keywords: street networks, blocks, urban form, shape analysis, urban morphology, urban morphometrics, routing

1 Introduction

Many studies within urban science use the street network of a city as primary input. Recent examples are numerous and cover a wide range of applications: from transportation network design [4] to the classification of urban morphology [5]. The feasibility and broad applicability of quantitative urban science studies has greatly increased with open source GIS data becoming available on platforms like OpenStreetMap [1].

However, even when a data set of sufficient quality is available, the conversion of geospatial features into a street network, sometimes referred to as “network simplification”, still poses several unresolved methodological questions to the research community. The challenge, in a nutshell, is to reduce granularity of detail without loss of relevant information; in many cases, deciding which information to keep and which to aggregate is

easy for a human, but challenging for an algorithm (see Figure 1 [ref]). This is true both for studies that are concerned with the street network itself, and for studies that look at the polygons enclosed by the street network. Further complexity is added by the fact that the requirements towards the input network vary greatly depending on the use case. For example, traffic routing applications require adequately represented directionality of edges (street segments), while urban morphology studies are based on the shape of urban blocks, i.e., the polygons between the edges [3].

In this article, we work towards resolving one specific issue within the features-to-network conversion process, which arises from a transportation-focused encoding of urban networks and which we call “bananas”. The paper is organized as follows: In the next sections, we define the problem and formulate our research question, followed by a literature and terminology review. We then briefly describe the methodology and our workflow that we apply to X cities across the globe, and present an overview of our results. The fully documented workflow, all input data and all results are made available in open source format on GitHub: <https://github.com/martinfleis/bananas>. We conclude with a discussion of implications and potential further steps.

Problem description

Each geospatially encoded street network comes with a certain level of granularity. A detailed look at the polygons enclosed by the edges (street segments) of a given network often reveals artifacts of transport-focused geometry. An illustration is found in Figure 1 [ref].

[Description of Figure 1: A close-up look at [city, location]. The black lines are network edges (street segments). Grey polygons are correctly identified urban blocks; the red polygon is a “banana” that should not be identified as urban block.]

Unlike its grey-colored neighbors, the polygon colored in red is not an urban block enclosed by streets; rather, it appears in the network due to the representation of a bidirectional street as two separate edges, one in each direction of traffic flow. The “banana” in Figure 1 [ref] poses a twofold problem. First, for studies concerned with urban form, it introduces a false signal into the distribution of urban shapes and distorts the actual shape of its neighboring polygons. Second, for any study that is concerned with the properties and pattern of the street network rather than with routing, the “banana” introduces a superfluous network edge, and it does so in a frequently inconsistent matter – not for all, but only some bidirectional and/or multilane streets. The extent to which “banana” artifacts distort results depends on the analysis conducted, and cannot be quantified without prior “banana” identification. Thus, no matter whether one is interested in the network or in shapes enclosed by the network, the “banana” should be removed as part of data pre-processing, and replaced by a single network edge. Human manual processing would be unambiguous, but prohibitively costly. We therefore pose the following research question:

How can “bananas” in an urban street network be computationally identified?

Literature review and terminology

First off, a disclaimer: One of the present challenges of “bananas” is the lack of a coherent terminology of the problem description, which makes it substantially more difficult to conduct a comprehensive literature review on the topic. We therefore apologize for any



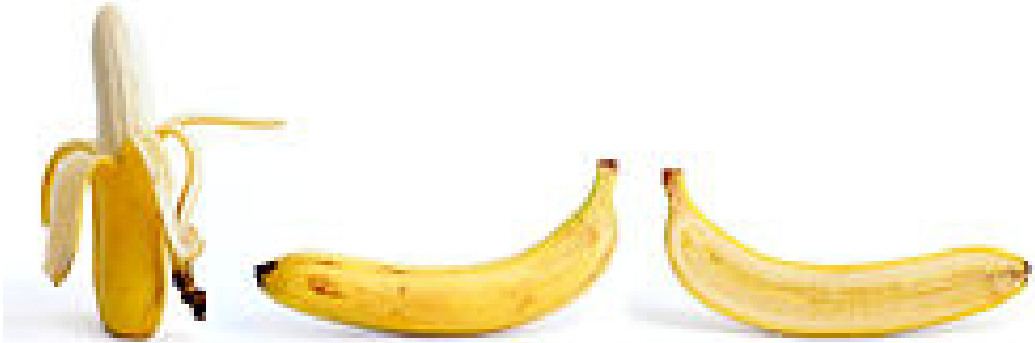


Figure 1: Banana

involuntary omissions of previous work on “bananas”, and hope to contribute to a future homogenization of the problem discussion.

Peponis et al. [10] conduct an analysis of urban spatial profiles and point out that their input data includes street center lines, but lacks street widths, hence street surfaces are merged into urban blocks. In a related, but methodologically different approach, Hermosilla et al. [8] develop a method to derive so-called urban block related street areas (abbreviated by the authors as “UBRSA”), defined as the street area surrounding an urban block. This method, however, requires urban block boundaries as input. Grippa et al. [7] classify polygons derived from OpenStreetMap street network data into “urban blocks” and “sliver polygons” and present a semiautomated workflow, partially in PostGIS, for sliver polygon removal from the data set. Ludwig et al. [9] take up this approach within the context of land use classification, but additionally filter out all polygons based on a size threshold. A recent study by Shpuza [13] describes elongated urban blocks that are delimited either by a street or another type of obstacle (e.g. a waterbody), and that contain no buildings, as “edge blocks”. Vybornova et al. [15] refer to the network pattern that creates “bananas” as “parallel edges” and present a network shortest path-based approach for their identification, but no solution to effectively remove these from the network.

Some recent studies describe the “banana” phenomenon as sliver polygons [7, 9, 12]. However, “bananas” arise as consequence of a context-dependent redundancy of mapped line features, while sliver polygons stem from mismatching boundaries in vector overlays of polygon features [2, 6, 11]. In addition, “bananas” are, in line with our problem definition, confined to the specific context of urban street networks. Therefore, in spite of some degree of geometric similarity between the two, we refrain from applying the term “sliver polygon” in the “bananas” context.

2 Method

This is method. And the figure 1 shows the banana.

Many, though not all, shape index frequency distributions for the analyzed FUAs reveal a common feature of two prominent peaks (see figure [INSERT FIG REF]). Through

visual analysis, we find that these peaks represent two different types of polygons. Most of the polygons from the first (leftmost) peak can be attributed to “bananas” in the street network, whereas most of the polygons from the second (rightmost) peak represent true urban blocks. Therefore, for FUAs that show a pronounced two-peak pattern in their shape index frequency distribution, the minimum *between* the two peaks can be used as shape index threshold: polygons with a shape index below the threshold will most likely be “bananas”; polygons with a shape index above the threshold will most likely be true urban blocks. To derive the minimum, we approximate the shape index frequency distribution with a Gaussian kernel density estimation. For bandwidth selection, we use the parametric Silverman method [14] and find that it gives satisfactory results; non-parametric bandwidth selection methods might be a subject for future work (see section [REF]).

Next, comparing the positions of peak 1, peak 2, and shape index threshold for different FUAs with pronounced two-peak patterns, we find that maxima positions vary to a considerably greater extent than minima positions. In other words, shape index thresholds for “banana” identification from morphologically different FUAs lie within a relatively narrow range. We therefore hypothesize that applying a shape index threshold within the range identified from FUAs whose polygons follow a two-peak distribution will allow the identification of “bananas” polygons even for those FUAs whose distributions do not show a two-peak pattern. Applying the ... [TBD: lower boundary/median/average/higher boundary] of the empirically derived shape index threshold range to the rest of FUAs indeed reveals “bananas” polygons in all/most FUAs (see Figure [REF]).

3 Results

- area vs shape plots - use all cases together and show multiple shape indices - Reock as an optimal index (?) [I think it will be the optimal one but we need to verify that] - 1-dimensional index formula (if we use Reock it is the one from the banana notebook) - shape-index plots with cut-off values - plots based on geographical location - distributions, Reock-area scatters - describe the differences - formalise the detection workflow

4 Discussion

How could this be used?

how to move forward? (sneak preview of google summer of code) - the simplification problem can be seen as a problem of the elimination of banana

incorporate further data (ideas: directionality; street names; angles; land use; ...) use network formalism: on dual approach (intersections = edges): jiang 2004, yang 2022, rosvall/sneppen; barthelemy paper on shortest path shape

end with a call to action & ‘towards open urban data science’

include in future work:

- analyze other regularities in distribution
- !! once banana has been found: how to replace it?
- non-parametric bandwidth selection



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To be added. Remember to include ESRC/ATI funding covering initial experiments.

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