Spatial Multiscale Entropy in Cities

Barner Martin

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This is a description of the bigger picture ideas underlying my Master Thesis at CASA, "Multiscale Entropy in the Spatial Context of Cities"

Here, we first discuss the problem of uncertainty in urban planning and conduct a thought experiment for making planning decisions if we know nothing at all about cities. Then, more concretely, a case is made for a measure of uncertainty relating to urban life given by a city's morphology, and a multiscale approach to urban entropy is proposed. Finally it is mentioned how this measure could explain why cities are morphologically complex and why it could be useful in practice.

Uncertainty in Urban Theories

The way we have been trying to formulate objective principles for "good" urban planning and design throughout history comes with a set of fundamental difficulties.

First, the way of thinking is inevitably set within the framework of a larger sociological ideology of the time that determines what a good city should achieve. Second, the ideas on how to reach these goals are based on assumptions about how cities work, how people should or want to live and how society functions. Finally, predictions about the future are necessary because urban design, once realised, will impact people for a long period of time.

As a consequence, urban planning paradigms are always at risk to optimise for a flawed understanding of people, societies, cities and the future, in the framework of an ideology that is outdated by the time any plan or urban design paradigm is turned into reality.

Not Knowing Anything

To address this problem, we could use a framework of thinking to make reasonable planning decisions in the hypothetical extreme scenario of *not knowing anything at all about people, cities and society, in the present or the future.*

Imagine two cities. One in which all places are identical, and one with two types of places. We know nothing at all about how residents would want to use these cities and consequently what type of places they need. The second city allows more combinations of *what kind of place* any person could be in at any time. It is therefore statistically more likely to, by chance, meet the residents' needs. If we know nothing about cities at all, we can still make a rational decision to prefer the second city.

This general principle is useful because we can apply it to a more realistic situation in planning practice: If we believe to know a number of things with varying certainty, we can physically express that uncertainty in the structures we build. That way we increase the probability to have a useful result even if our assumptions or predictions were wrong.

A Measure of Multiscale Entropy

We can frame this idea more concretely in terms of information theory: Looking at a city layout, how certain can we be about how a randomly selected resident of the city uses it? We could call this an entropy measure of the *uncertainty about urban life inherent to the physical structure of the city.*

A first attempt to construct such a measure differs conceptually from existing approaches to entropy in cities.

First, places are individual observations, and the phase space dimensions reflect different characteristics describing those places.
Beyond that, we must recognise that while the Boltzman entropy assumes weak interactions between observations, we can not neglect the interactions between places in a city: If a building is on a high street that runs through a residential area, which itself is next to a big park, all in a city that lies next to the sea, we have to assume that these surroundings on multiple scales change the nature of how that building is being used. Theoretically, the state of a place should include its spatial relationship to all other places.

In my thesis, I implemented this idea as "spatial multiscale entropy". To take the surroundings of places into account, the phase space dimensions are defined so that they describe a point in space using aggregate values of observed characteristics at multiple radii around that point.

Results

Comparing different synthetic patterns (figure 1), we can show that with this phase space definition, complex patterns such as additive cascades display higher entropy than simple ones (figure 2).

This makes sense intuitively: We can imagine the black and white pixels in figure 1 denoting residential and commercial use. In the first pattern for example, all pixels lie in the same type of "mixed use area". As a result, they are more similar with respect to the environment they are in compared to a more complex pattern like the additive cascade to the right. In the additive cascade, there is a wide variety of different types of neighbourhoods on all scales, and hence more possible combinations of how they are used.

Consequences

These considerations could be a step towards explaining the observed structural complexity of cities, could build a different understanding of "multiplicity of choice" and help evaluate the adaptability of urban structures to changing circumstances.

Let us assume that, as complexity theory suggests, a city's morphology is an emergent phaenomenon from individuals' actions and interactions. Then a city layout that allows a larger number of activity combinations should also have a larger number of ways to develop, and therefore should be more likely to occur. *This means that we might be able to explain the complex spatial patterns we observe in cities as simply the configuration with the highest entropy, and therefore the most probable one.*

Simultaneously, the greatest multiplicity of choice for residents could be given for complex spatial configurations of different functions rather than in a homogeneously mixed city as proposed by Jane Jacobs.

Finally, complex spatial patterns would be most likely to, by chance, still be "suitable" after random changes in how cities work, how they are being used or what is generally considered a good city.

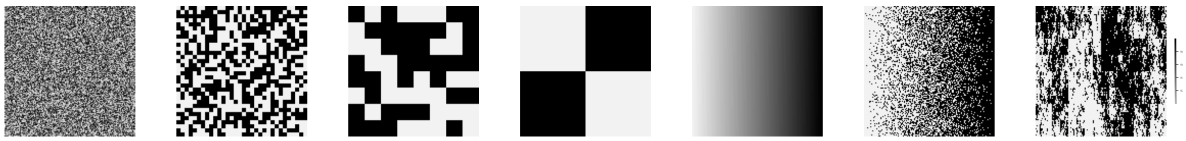

Figure 1: examples of spatial patterns. From Left to right:
1-4: patches of varying size distributed randomly.
5: Sorted. 6: 1/f noise. 7: Additive Cascade

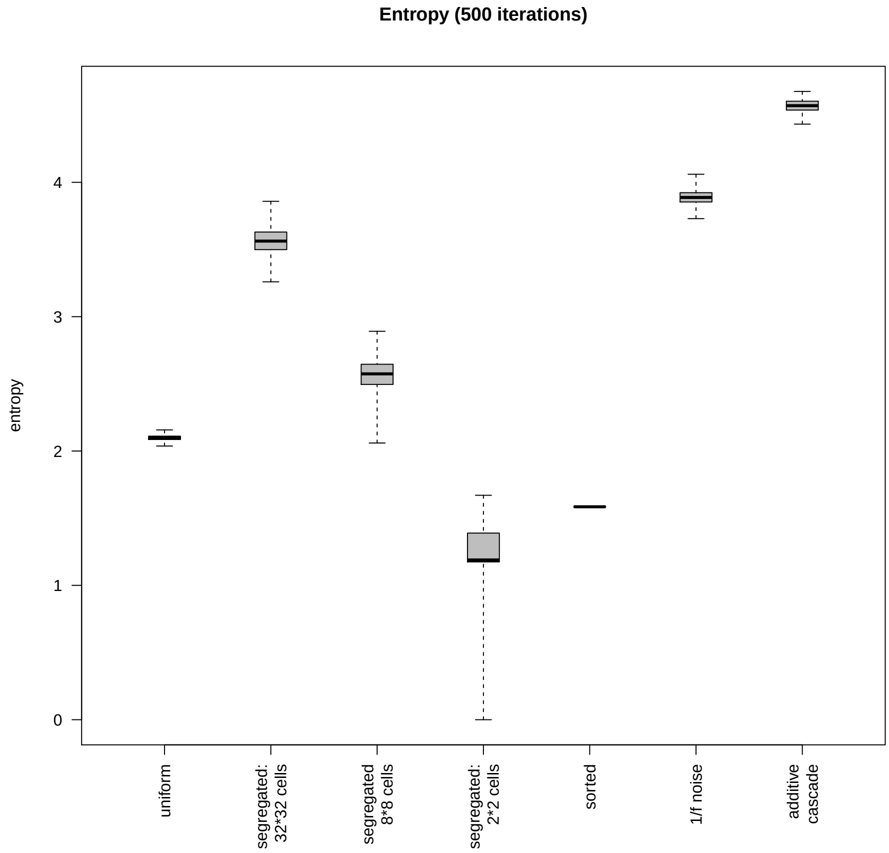

Figure 2: multiscale entropy of patterns in figure 1