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Engaging Undergraduates in the Thrill of Scientific Reasoning with Spatial Data

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Abstract:

Undergraduate introductory spatial data science curricula tend to first establish computational and statistical literacy, often resulting in students' exploration of data in an overly mechanistic way that is disconnected from the logic of scientific inquiry. This presentation summarizes early efforts to develop a framework and teaching examples for overcoming such mechanical applications by means of an effective integration of scientific reasoning within the spatial data exploration workflow -- with the goal of engaging undergraduate students in the thrill of exploring spatial data. The focus on scientific reasoning shifts attention to scientific explanations, falsification, and abduction, while leveraging the power of spatial analysis. The objective is to design and illustrate a spatial data exploration process that allows students to distinguish plausible from implausible explanations, test against errors and biases, and make it more likely to detect unexpected results. This presentation demonstrates a framework for such integration of exploratory spatial data analysis and scientific reasoning, with case examples for teaching.

Specifically, it highlights two examples we developed: One is to add spatial examples to existing course materials, in this case a spatialized version of some of the Jupyter notebooks developed for the labs of UC Berkeley's *Sense & Sensibility & Science* course. These labs let students explore the difference between correlation and causation, signal and noise, and identify false positives or negatives. We created interactive story maps that are integrated with the new open spatial platform *Matico* that we are developing.

The second example highlights a new course we are developing that integrates spatial data exploration with scientific reasoning using a history of science example that is covered in depth throughout the course. The example is based on the discovery of how cholera was transmitted in 19th century London, including John Snow's work. It illustrates how competing explanations, falsification and abductive reasoning (as theorized by Popper, Lakatos and Peirce) actually worked in practice. For instance, how evidence that supported Snow's waterborne hypothesis was incorporated by airborne theorists to protect them from falsification and what else was needed to tell which explanation was actually more plausible. Students take on the role of one of four groups of theorists to be tempted to fall prey to confirmation bias for their group and then analyze spatial data as they compare evidence across perspectives. We summarize the related paper, teaching materials, data, and software scripts that we developed for this course. We conclude with an overview of informal evaluations after using selected data and scripts of the cholera case in undergraduate and high school classes to teach spatial data analysis in the context of scientific reasoning.

The project seeks to change the way students think about analyzing spatial data by emphasizing the logic of scientific inquiry. By applying fundamental data science techniques, students learn to simultaneously practice a hard-to-obtain mindset where they become comfortable with experimentation, with not knowing (uncertainty), and with not being right (null hypothesis). In addition, we leverage exploratory spatial data analysis for scientific explanations, which is currently not prioritized in general spatial analysis courses. This is an important void to fill, especially in the social sciences, since advancement of knowledge depends on reliable explanations. Addressing this gap supports a data exploration practice that challenges findings until less plausible explanations are rejected, errors and biases are addressed, and more plausible explanations can be defended "beyond reasonable doubt."

References

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