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Essay 1

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## Uncertainty in GIScience

Technological advancements in recent decades have facilitated the availability of large amounts of spatial data while also improving the ability to quickly extract and process that information for research and industry purposes. However, uncertainty is almost always inherent in spatial data and can lead to incorrect conclusions and results if ignored (Fisher, p. 191).

Uncertainty in data can appear in many forms because there are so many applications of spatial data across different fields. For example, problems of definition arise in classification maps of soils, ground cover, vegetation, and other natural features in the environment (Fisher, p. 195).

Uncertainty also affects cell phone tracking data (spatial big data) which can be used to help determine population sizes and human behaviors, but can face many uncertainties including those related to temporal discrepancies between user location and online content generation (Shi et al). Uncertainty can also arise from errors in data collection, management, or generalization.

For example, GPS devices can usually achieve accuracy to within 10 meters, but this could be reduced due to factors such as proximity to trees, buildings, atmospheric conditions, and overhead satellite positions (Goodchild, p. 3). These are just a few examples of how prevalent uncertainty can be in geographic data. Ignoring uncertainty can cause serious errors and incorrect results, meaning that it's very important for GIS researchers and analysts to understand, mitigate, and account for uncertainty in their work.

Within the study of uncertainty, the term “vagueness” is commonly used when there is “poor definition of class”, and many features in geographic data are susceptible to this problem (Fisher p. 192). The sorites paradox can be used to illustrate this, where incremental changes of a classification category gradually morph into another category with no clear boundaries (Fisher p. 197). This creates a paradoxical situation where the boundaries between different classifications cannot be precisely defined due to vagueness of definition. An example of this can be found in vegetation classifications. For example, when defining a forest, it may at first appear simple to claim that a large area of densely clustered trees is a forest. However, complexity increases when considering a situation where trees are cut down one by one. At what threshold is the area no longer a forest? It would be illogical to claim that the area is no longer a forest if only a few trees are cut down. Yet if this logic is continued, all the trees could be cut down and the definition of a forest would still hold, yet that would be an illogical definition. A real-world example of this problem of definition is found in a vegetation classification scheme created by the United States Federal Geographic Data Committee (FGDC) which further backs up this argument that classifying vegetation is vague/uncertain. The report stipulates that due to “differing definitions and protocols” the method provided may not directly align with other classifications.

Ambiguity, another type of uncertainty, occurs when there is disagreement about the appropriate class for a particular object which can be a result of *discord* or *non-specificity*. Discord occurs when objects are clearly defined, but are placed into different categories in different classification methods/interpretations. Non-specificity occurs when assigning an object to a class may be up to interpretation (Fisher, p. 192). These different forms of uncertainty underscore its complexity, showing that it’s influenced by a variety of factors and can occur in many ways.

There are many approaches for dealing with uncertainty, all dependent on the scenario and data. One approach is to create an uncertainty model that aims to predict possible outcomes and their likelihood (Fisher, p. 199-201). However, some argue that these models have limitations for situations where data is not as easily measurable, particularly for spatial issues within social and environmental sciences (political, economical, human behaviors, environmental-policy making) (Brown, p. 376). Another approach by the FGDC aims to reduce uncertainty by creating strong definitions based on a large group of professional opinions (p. 2). Others point out that uncertainty is a “norm and not an anomaly” within geographic research, meaning that uncertainty should be expected in a wide range of issues and managed using professional opinion across several overlapping fields of study (Senanayake, et al).

Uncertainty is an essential part of working with spatial data, and its complex nature necessitates a broad range of approaches for its management. As technology continues to advance, and spatial data grows, a clear understanding of uncertainty will remain essential for accurate and reliable spatial analysis.

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