On the Use of Grey Information Theory as a Conceptual Framework for Treating Uncertainty in Spatial Systems

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1. Introduction

Developing effective means of theorizing and dealing with uncertainty continues to attract a great deal of interest in GIScience (Brown 1998, Rashed and Weeks 2003, MacEachren et al. 2005, Klugl et al. 2006, Lilburne and Tarantola 2009). During the last few decades, grey information theory has emerged in the engineering sciences as a means of better understanding uncertain information and processes in human and physical systems (Liu and Yi 2006). This paper explores the potential implications of grey information theory for conceptualizing uncertainty in GIScience, emphasizing its possible role in spatial modelling and geocomputation.

2. Background

Many spatial problems consist of both known and unknown elements. For example, in spatial models of facility location, candidate sites for prospective new retail stores are often known, but the demand for sited facilities' goods or services may not be certain (Hale and Moberg 2003, Snyder 2006). Similarly, when modeling urban land use change, base year land use (known) is subjected to a host of hypothesized processes (some unknown) to estimate future land characteristics (Li and Yeh 2000, Al-Ahmadi et al. 2009). In other situations, such as emergencies or extreme weather events (Elsner et al. 2006), there simply may not be sufficient historical spatial information to model a particular human behavioral response using traditional statistical approaches (Liu and Yi 2006).

One approach to deal with such situations is to treat uncertain problem constructs as 'grey' information. In this regard, grey information theory may be a useful way to ascertain uncertainty and provide an overarching formal organizational framework in many GIScience arenas. Essentially, grey information theory recognizes that some systems may consist of both completely known information and unknown information. It differentiates such information in terms of white (known) and black (unknown) information and their interrelationships (Huang and Fan 2005). A key idea in grey theory is the identification of the 'whitenization function,' with the purpose of improving the level of uncertainty of a particular system parameter, process, or data instance. When this concept is extended to spatial systems, grey theory could be used to guide the design of new geocomputational tools intended to address and resolve uncertainty in modeling situations.

More broadly, the implications of grey information theory for GIScience are quite numerous, including the possibility of developing new ways of formalizing uncertainty in spatial problems and the logical decomposition of spatial problems into known and unknown components. A scan of recent research reveals there is relatively little exploration of grey concepts in the GIScience literature, with the few papers in

existence focussing on empirical and computational applications of selected grey concepts. (Yeh and Li 2001, Yang et al. 2009, Horner 2010). The present paper will comprehensively analyze some of the potential linkages between grey information theory and GIScience.

3. Overview

This paper consists of three major components. First, a more complete background on grey information theory is given, including providing general formulations for grey systems concepts including the whitenization functions and their possible instances in GIScience. Secondly, an effort is made to compare grey information theory with other related but different conceptualizations of uncertainty in GIScience, particularly those involving fuzziness (Fisher 2000; Rashed and Weeks 2003; Silvan-Cardenas et al. 2009), stochasticity (Sahinidis 2004; Lilburne and Tarantola 2009), as well as notions of complexity in general (Manson 2001; Ligmann-Zielinska and Jankowski 2007). Third, examples of grey systems are drawn from the author's work in spatial modelling for hazard management (Horner and Widener 2009), network uncertainty (Horner 2010), and household energy conservation behaviour (Horner et al. 2010). In these cases, grey information theory is critically discussed as a possible organizing principle for conducting uncertainty experiments and simulations of human behavioural response.

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