Chapter 10
Modeling Spatial Evolution: Review of Methods and Its Significance

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ABSTRACT

Geographic features in the real world are represented by spatial entities such as point, line, and area in two-dimensional surfaces. These features tend to evolve in time, thereby characterizing change in their physical identity, evolution into new species, thus describing geomorphological change of geographic features. These phenomena can be formalized using spatio-temporal relations. Formal representation of changing geographic (spatial) features is the interest of this chapter. Formal methods for representing the event and process that causes geomorphological change are presented. The formalization of geographic entities that are temporally and spatially related in a two-dimensional plane using the interval logic and spatial logic would facilitate the understanding of how modeling of space-time using spatio-temporal relations represents spatial evolution over time. Representation of temporal dynamism can be accomplished using various models. Modeling using spatio-temporal graph is more apt as it contributes to the cause-effect analysis.

INTRODUCTION

Human cognition by nature systematically deduces knowledge that would pave the way for incidental solution. Cognitive thinking towards understanding of physical phenomena on earth such as epidemic disease spread, drought, deforestation, evacuation, migration of settlements etc., imparts knowledge to human beings. Information gathered to attain this knowledge transforms an individual to domain knowledge expert. Artificial Intelligence (AI) is a subject of cognitive science that governs the development of computational algorithms and tools that would act like human beings in solving complex tasks. Automated reasoning through inference engine, a knowledge based approach, is the foundation of such systems (Elaine Rich, 2009). Knowledge based systems contribute to Geographical Information System

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(GIS) and can increase the computational efficiency of GIS. Thus, engineering real-world fact can be done by employing systematic Knowledge Engineering (KE) processes (Patterson, 2005) namely (1) Data Acquisition (2) Data pre-processing and transformation (3) Domain knowledge Representation and Reasoning. The final outcome of such is an expert system. The source of knowledge for automated reasoning systems like spatio-temporal knowledge based system consists of spatial and temporal facts that are coded using formal principles of KE. These systems are called expert system as they automate the discovery of knowledge that would further update the facts in the knowledge base to ensure real-world dynamism. The resources on the earth are enormous in its type, physical appearance, size, variety and are geographically distributed in wide range of space. Each of these resources is identified in a location of space at distinct time period (seasonal), within specified time interval or in a moment of time. These resources tend to change over time. Thus, space-time evolution of earth is the motivation behind this study.

Modeling space-time is the foundation for both knowledge-based reasoning and probabilistic reasoning approaches, in which spatial locations like land use, land cover regions, forests, urban settlements and their temporal activities are parameterized, empirically formulated to qualitatively reason spatio-temporal events like deforestation, forest fire, migration of habitats etc., (Jayanthi and Uma, 2016b). Moreover, this approach has motivated researchers towards reasoning about the events that cause phenomenal changes such as earthquake, landslides, drought etc., (Jayanthi and Uma, 2016a; 2016b; 2016c; 2016d and 2017). Thus, modeling of evolution considering the spatial and temporal factors is the interest of this chapter. Spatial entities representing geographic features are identified by their spatial and aspatial properties. Universally, geographical entities are related with respect to space and time. The physical locations of such features and their spatial extension over time in various forms are related in a moment of time, over an interval or at regular intervals (time period) (Campelo, 2013; Hornsby and Egenhofer, 2000 and Mondo, 2010). Thus, temporal, spatial and spatio-temporal relations that are intrinsically formed, dynamically associate or disassociate spatial entities over time (Mondo, 2010). Geographic feature captured in a moment of time is a static scenario, which is a snapshot of real-world entity. A distinguishable change as a resultant of process is identified when captured over an interval (Campelo, 2013, Hornsby and Egenhofer, 2000; Jayanthi and Uma, 2016d; 2017). In this perspective, researchers have shown interest towards modeling of spatio-temporal evolution using graph structure (Mondo, 2010) in which nodes represents spatial locations and edges are links that relate spatial location at different time instants. The spatial analytics based on dependencies between spatial locations at various temporal scales is applied in forecasting weather, rainfall, traffic flow etc., (Box, 2012; Cohn, 1995 and 1997; Egenhofer, 1994a and 1994b; Galton, 2008 and 2009).

Evolution of spatial structures over time emerges into a connected spatio-temporal network, a graph structure formed through association of spatio-temporal relations. The structural properties of graph structure are (1) reflexive and its complement irreflexive (2) symmetry and (3) transitive. These properties are applied in analyzing membership, homogeneity, heterogeneity and relational hierarchy (Mondo, 2010). Thus, modeling of evolution considering the spatial and temporal factors using graph structures has its significance in dynamic knowledge representation wherein connectivity and reachability of geographic features on geo-spatial network are analyzed using spatial topological relations formalized through RCC-8 (Randell, 1992) and temporal relations (Allen, 1981 and 1983). Nevertheless, potential researches are in progress towards the optimization of computational methods wherein linear complexity is highly demanded along with highly expressive knowledge based systems.

The objective of the proposed chapter is to explain the formalization of geographic entities that are temporally and spatially related in a two-dimensional plane using the interval logic and spatial logic.
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