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Fuzzy modeling for route characteristic

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Abstract

Bicycling is gaining popularity as a form of urban transportation for environmental and health reasons. Despite the numerous research on the parameters influencing route choice, the characteristics of different segments/parts of a route is rarely studied. The route in a city is not a stable entity; the attributes being related to the bicycle facilities, road surface, traffic and topography are expected to change along the route line from origin to destination. In this paper a computational model is proposed to calculate and visualize the route in segments. Fuzzy logic is used as the methodology; where the inputs are chosen as (1) the type of bicycle facility, (2) slope and (3) vehicle flow. The output is the ride quality value that will fluctuate between 0 and 1. Fuzzy subsets enable granulation and provide a more real-like evaluation of the route. The result is a string of points on a city map, visually representing the bicycle ride quality in detail.

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Keywords: Bicycling; route; riding quality; fuzzy logic; visualisation.

1. Introduction

Besides its social and sportive usage, bicycling is an efficient form of sustainable transportation with both environmental and energy benefits. Most of the developed cities in the world promote bicycling and recognize the need to provide bicycle friendly environments. The efforts to do this involve understanding the travel decisions and preferences of the bicyclists.

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Depending on the purpose of a trip, bicyclists have a variety of factors to consider when choosing their routes. Hunt and Abraham (2007) and Casello and Usyukov (2014) list them as; facility characteristics (including type of bicycling facility, existence of on-street parking, pavement surface quality, grades, and completeness and directness of bicycling infrastructure), non-cycle traffic characteristic (including motor vehicle speeds and pedestrian interaction), individual and trip characteristics (including gender, age and level of bicycling experience), environmental/situational characteristics (including weather and aesthetics along the route). Bicyclists' route choice criteria can be destination based or more leisurely based (Yang and Mesbah, 2013); travel time and traffic volume are essential parameters for commuter cyclists, whereas recreational cyclists pay more attention to landscape and scenery (Sener et al., 2009, Chen and Chen, 2013). Bicycle route choice behavior is mostly analyzed by the data collected from stated preferences (SP) and revealed preferences (RP) surveys, also GPS based technologies (Menghini et al., 2010, Broach et al., 2012).

Current bicycle route planners (including the online planners e.g. Google Maps) are intended as spatial decision tools for everyday transport. However, most of them are functionally limited in terms of their single attribute optimization function (e.g. the shortest path) and make less usage of compensatory decision rules and eliminatory constraints (e.g. only the bike lanes) (Hochmair, 2005, Su et al., 2010). To remove the inefficiencies of existing planners, new analyzing and mapping models are developed using multi-objective decision-making techniques. Route selection is also modeled by new computational methods. Cosido et al. (2013) combined meta-heuristics and GIS techniques for bicycle route generation employed with city traffic and environmental data.

Despite the growing literature on route choice and bicycling behavior, route characteristic analysis is mostly ignored. Some attributes related to a route can be expressed with a single number -like the total distance between origin and destination. But, some attributes change along the route path in urban networks and cannot be explained with a single value –like traffic density. Due to the heterogeneous structure of the city network, a journey may be on steep sloping streets in some parts, while on a flat surface in other parts. So, inconsistencies along the roads in a city propel us to calculate and visualize the attributes of the segments of a route itself.

The objective of this study is to evaluate the riding quality (or similarly suitability) of a chosen bicycling route in segments. A computational model is proposed to calculate and visualize the route according to some predefined parameters - which are from the factors also effecting route choice. The calculation part uses fuzzy sets theory and takes the advantages of this method in dealing with vague and imprecise knowledge. Fuzzy logic enables the natural language expressions to be carried to the computational process, such as the subjective perception of grade. A fuzzy inference system (FIS) replicates the human decision-making process when it conceptually relates inputs to output.

A similar fuzzy approach is conducted by Kolisko (2013) to assess bike trail difficulty for the roads in the South Moravian Region in the Czech Republic. The slope and the quality of the road surface were chosen as inputs - impacts on difficulty. Two fuzzy subsets for input 1 are assumed; moderate and steep slope, while three subsets for input 2; paved (asphalt, pavement, concrete), maintained (unpaved, gravel) and other roads (forest and cart roads). The output is defined as small, intermediate and hard. Six rules are given between inputs and output: as "if it is a paved road and it has a moderate slope, then it is small difficulty," which is suitable for families with children, or "if it is an unpaved road and it has a steep slope, then it is hard difficulty," which is suitable for athletes.

Three parameters are used here in the model to evaluate bicycle ride quality. (1) Climb's gradient (or degree of incline) is a factor related to difficulty; higher gradients (%7 and more) become uncomfortable and challenging. The perceived risk level and safety is incorporated in the model as (2) Type of bikeway; whether mixed with traffic or separated bike lanes, and (3) Traffic condition; vehicle flow density. It is clear that there are various identified factors affecting bicycle ride quality ranging from weather to type of bicycle. The flexibility of the model enables us to analyze a route according to any selected mix of parameters for a certain context or condition. Here, in this study three major factors based on urban design and dynamics are chosen, in relation with the online city data retrieved from a web mapping and route planning service.