A FUZZY-BASED APPROACH FOR TRAFFIC JAM DETECTION

Ayman Hussein Abd El-Tawaba† , Tarek Abd El Fattah†, and Mahmood A. Mahmood††

† Information System Department, Faculty of Information Technology - Misr University for Science and Technology, Cairo, Egypt
†† Department of Information Systems, Faculty of Computer and Information Sciences, Jouf University, KSA

Summary

Though many have studied choosing one of the alternative ways to reach a destination, the factors such as average road speed, distance, and number of traffic signals, traffic congestion, safety, and services still presents an indisputable challenge. This paper proposes two approaches: Appropriate membership function and ambiguous rule-based approach. It aims to tackle the route choice problem faced by almost all drivers in any city. It indirectly helps in tackling the problem of traffic congestion. The proposed approach considers the preference of each driver which is determined in a flexible way like a human and stored in the driver profile. These preferences relate to the criteria for evaluating each candidate route, considering the average speed, distance, safety, and services available. An illustrative case study demonstrates the added value of the proposed approach compared to some other approaches.

Key words: *Transportation System Management; Geographical Information System (GIS); Global Positioning System (GPS); Traffic congestion; traffic jam; Traffic Fuzzy Logic.*

1. Introduction

Traffic congestion is one of the problems which almost all people face in their day-to-day life. Usually, drivers have their own subjective preferences concerning the roads they aim to use accordingly, there is a need for a flexible approach to help drivers of vehicles for setting their own preferences and finding the more suitable road respecting such preferences [1]. Moreover, some drivers prefer high speed roads despite their long distance [2]. In addition, ones like to ride roads with high safety measures regardless of some other road features like distance, average speed and number of traffic lights [3]. Commonly, car drivers vary when evaluating the suitability of a road. Accordingly, there is a need for a flexible approach that allows car drivers to define their preferences then search and evaluate alternative roads to reach a specified destination from a given source location respecting their predefined preferences. This paper proposes a flexible approach that enables drivers to get the most suitable roads starting from a given source to reach the specified destination. Then select, evaluation and ranking of the alternative roads take place respecting the driver preferences including Speed, Safety, Service, and others.

Almost, the selection for a road to be ridden to reach a destination from a source location is user dependent. Although some drivers prefer high speed roads despite their long distance, other ones like to ride roads with high safety measures regardless of some other road features like distance, average speed, and number of traffic lights. Commonly, car drivers vary when evaluating the suitability of a road. Accordingly, there is a need for a flexible approach that allows car drivers to define their preferences then search and evaluate alternative roads to reach a specified destination from a given source location respecting their predefined preferences [4].

The remainder of this paper is organized as follows. Section (2) gives related work. Section (3) introduces a proposed approach. Section (4) discusses a real case study. Section (5) summarizes the research as the conclusion.

2. Related work

Javed and Pandey [5] proposed a model for traffic light system using fuzzy logic. It has been proposed to dynamically regulate both the phase and green durations of traffic lights for a secluded traffic signals based on a two-stage traffic light system for real-time traffic monitoring with the objective of reducing the average vehicle delay in varying traffic flow rates as shown in fig. 1.

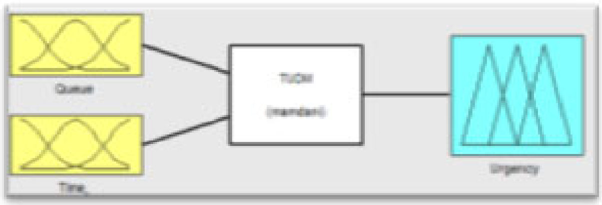

Figure 1: The design structure of TUDM using Mamdani Method [5].

Anwarul and Nazmul [6] proposed a real-time traffic control system using fuzzy logic-based edge detector for images. This paper proposes an image processing-based method for determining the density of vehicles on a

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specific lane of a road and controlling the signal accordingly. Screenshots from live feeds will be used to determine the traffic density of a road, and then a comparison analysis of traffic density will be performed using an efficient fuzzy logic-based edge detector system as shown in fig. 2.

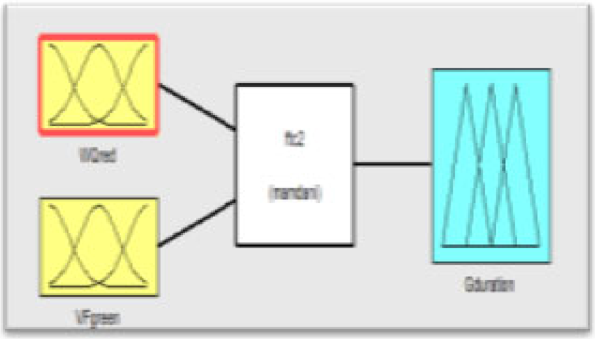

Figure 2: The FIS editor [6].

Deepak and Jitesh [7] introduced an algorithm for detection of hot spots of traffic through Analysis of GPS data. This paper describes how to find these regions, which it refers to as "Hot-Spots" in terms of road traffic and examines the influence of these "Hot-Spots" on traffic in both time and space. This goal is achieved using data from the Global Positioning System (GPS), which has proven to be a dependable, accurate, and cost-effective positioning technique for probe vehicles. This research presents strategies for detecting 'Hot-Spots' based on the probe vehicle's speed and a clustering (Fuzzy c-means algorithm) algorithm as shown in fig 3.

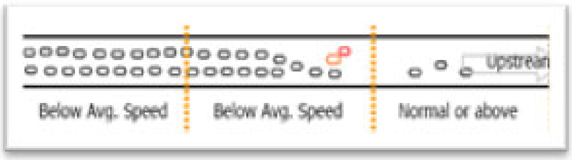

Figure 3: Segment of road causing congestion [7].

Shaimaa [8] proposed a fuzzy logic traffic signal controller enhancement based on aggressive driver behavior classification. It Integrated of driver behavior classification into the context of traffic signal control is difficult due to a lack of research in this area, which is made up of three primary modules: Vehicle data collection, either through video cameras and tracking programs or through roadside vehicle detectors, classification of driver behavior and fuzzy traffic signal control. The two modules of driver behavior classification and fuzzy traffic signal control are the focus of this study.

Social psychology concerns how our behaviors, thoughts and emotions affect, and affected by other people. It focuses on how groups of people make decisions, and the extent to which a person's attitudes towards a particular group of people influences his or her behavior towards them [9].

Another type of psychology is physiological psychology which is concerned with the relationship between mind and body. For example, physiological psychologists might investigate the electrical activity in the brain associated with behaviors, thoughts and emotions or they might be interested in the bodily changes associated with feeling stressed on the traffic jam. Hence, a psychological effect refers to negative consequences which have effects to the behavior, thoughts, or emotions of an individual.

Impacts of Traffic Congestion on the Economy Some studies put forward that the relationship between transportation and productivity is vital as a well-established transportation system triggers an economic development [10]. On the contrary, Eddington (2006) argued found that road congestion causes late arrival to workplaces, causing loss of output, missed deliveries, reduced productivity, and restricted economic growth. Choi et al. (2013) and Elisonguo (2013) stipulate that fuel consumption and depreciation of vehicles also tend to increase because of traffic congestion, thus leading commuters to spend more money on fuel. Businesses that have adopted the just-in-time system are more prone to be affected by traffic congestion as it is difficult to make just-in-time deliveries efficiently, thus reducing productivity and competitiveness [11,12].

An overwhelming body of literature has depicted that road congestion contributes to the aggravation of environmental conditions, including air pollution. Various authors have claimed that vehicular exhalations, triggered by traffic congestion, are the main causes of air pollution [13,14]. Based on the data collected through the questionnaires, it was found that traffic congestion induces a high level of stress and frustration in commuters, especially drivers, as they are required to be more attentive and focused while driving in challenging conditions. The results obtained from the survey also revealed that accidents endanger the safety of commuters. Likewise, the survey conducted for this study generated results that depicted those commuters suffering from asthma or other respiratory problems may be prone to more serious diseases because of polluted air caused by vehicular exhalations [15].

3. PROPOSED APPROACH FOR CANDIDATE ROADS SELECTION

The architecture of the proposed approach is shown in fig. 4. It aims mainly to reduce the traffic jam problem through supporting the users, vehicles drivers, with a set of ranked candidate roads respecting the user preferences. The proposed approach incorporates three operations. The first one is responsible for computing the average speed of the driver car as shown in Algorithm1. On the other hand, the second operation is responsible for defining and storing the user preferences represented as a set of human-like fuzzy rules. Finally, the third one is responsible for retrieving, evaluating, and ranking the candidate roads to reach the destination starting from the driver source as shown in Algorithm2. The architecture of the proposed approach contains the following main modules are (1) User Preference Setting, (2) Speed detection, (3) Candidate roads Determine Alternative, and (4) Candidate roads evaluation and ranking.

3.1. User Preference Setting Module

Commonly, this module allows the user to set his/her preferences in the form of fuzzy if-then rules. The user rules are stored in the user profile database on the server-side. This module, client sided, incorporates a user-friendly interface GUI that allows defining the user linguistic words for each underlined universe of discourse, like speed and distance, in a flexible manner

3.2. Speed detection module

This module is concerned with computing the average speed in each road ridden by a user. It receives ongoing messages periodically each slice of time from some users driving on the same road. Each message includes the user id, time and current location described by latitude and longitude. Consequently, such data is used to compute the user driving speed on the specified road. Hence, as shown in Algorithm 1, the average speed of each road is periodically updated in the database respecting the users computed speed.

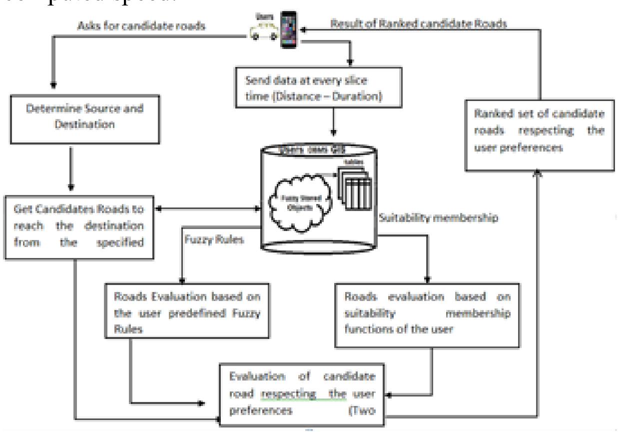

Figure 4: The architecture of the proposed approach for candidate road selection.

3.3. Candidate roads Determine Alternative module

This module is responsible for searching the database to retrieve all available candidate roads to reach the destination location starting from the specified source location. The retrieved data for each candidate road include the road id, name, distance, average speed, safety degree and degree of available services.

Algorithm 1: Computing the average speed for a specific road.
Input: Periodical signals indicating current time Tc, Current location latitude Lc and longitude Gc from each user Ui on the road Rj;
Output: The average speed Savg in road Rj
Process:
Foreach user Ui on road Rj
{ Foreach time slice T
{ Identify Tc , Lc and Gc values;
// Compute the passed distance PDi of user Ui through the time slice T;
PDi= acos(sin(Lp).sin(Lc)+cos(Lp).cos(Lc).
cos(Gp−Gc)).radius);
where c and p indicate current and previous locations respectively;
//Compute the speed for driver Ui on the road Rj
Si= PDi / T;
//Where T=Tc-Tp
} }
//Compute the average speed Savg in road Rj such that
Savg=(∑Si)/N;

//Where N indicates the number of users on the specified road at a given time

Algorithm 2: Evaluate and rank the candidate roads respecting the user preferences
Input: User input the source and destination locations.
Output: A set of ranked candidate roads CR respecting the user preferences.
Process:
Rc = Get all candidate roads existed between the source and the destination.
Foreach candidate road Ri of Rc
{ Get distance RDi , safety degree SFi, average speed SPi and services degree.
SRi values of road Ri.
Evaluate the suitability of each candidate road respecting the user preferences.
Suitability (RDi)=μ(sdistance) (RDi);
Suitability (SFi) = μ(s_safty) (SFi);
Suitability (SPi) = μ(s_speed) (SPi);
Suitability (SRi) = μ(s_serviace) (SRi);
Suitability(Ri)= (W1*SPi + W2*SFi + W3*RDi + W4*SRi);
}
CR=Sort the resulted candidate roads respecting their suitability.

3.4. Candidate roads evaluation and ranking module

Generally, this module evaluates each candidate road, respecting the user predefined preferences stored in the user profile as depicted in Algorithm 2 and Figure 1. Accordingly, the evaluation process of candidate roads becomes human-like reflecting the user own subjective view. After the evaluation process takes place, a suitability degree is assigned to each candidate road indicates how much such road is suitable for the user to reach the specified destination. Obviously, suitability degrees of same road differ from user to user if their preferences are different. Finally, each user reaches a set of ranked candidate roads reflecting his/her preferences.

4. The Illustrative Case Study

Commonly, the proposed approach ranks the alternative roads based on any number of variables. This illustrative case study explains how much each user can consider any number of roads variables. Such roads variables include speed, safety, services, no of traffic lights, etc. Table 1 shows a snapshot of data for some variables that are considered for some roads linking Giza square to Alremaya Square at Giza-Egypt.

Table 1: Roads variables values

Road name	Safety	Services	Speed	Traffic Lights
Saft Roads	2	3	120	1
El Baher El Azem	7	6	70	3
Haram	6	5	70	6
Fiesal	9	8	60	4
Rabiea Giza	10	8	40	5

4.1. Setting the user preferences

This approach enables to construct the user preferences as a set of suitability membership functions defined over the user interesting roads linguistic variables. As shown in Table 1, the preferred suitable speed is defined as a trapezoid(60, 80, 100, 120). Accordingly, the roads with average speed ranging from 80 to 100 represent the most suitable roads with full matching degree. On the other hand, any other average speed has partial matching degree. Both of User1 and User2 set their preferences using trapezoidal membership function as shown in Table 2. Figure 5 and Figure 6 show mobile screen shots for defining suitability membership functions for speed and safety for user1 and user2 respectively. On the other hand, Figure 7 and Figure 8 show the defined suitability membership functions for each considered linguistic variables for user1 and user2 respectively. The Figures (5-8) shown the user#1 defined suitability membership functions for his/her considered linguistic variables.

Despite of enabling each user to define his/her preferences for any number of roads variables, the proposed approach allows him to consider some or all such variables on the time of searching for suitable road linking from the source to the destination locations. The Figures (9-12) shown the user2 defined suitability membership functions for his/her considered linguistic variables.

Table 2: Suitability membership functions for user1 and user2 using trapezoidal membership function.

Roads Linguistic Variable	User#1 control points					User#2 control points				
	A	B	C	D	Weight	A	B	C	D	Weight
Traffic Lights	1	2	3	3	0.3	2	3	4	4	0.2
Speed	60	80	100	120	0.5	20	40	60	60	0.3
Safety	5	7	6	10	0.7	7	8	10	10	0.65
Services	2	8	10	10	0.8	5	7	8	10	1

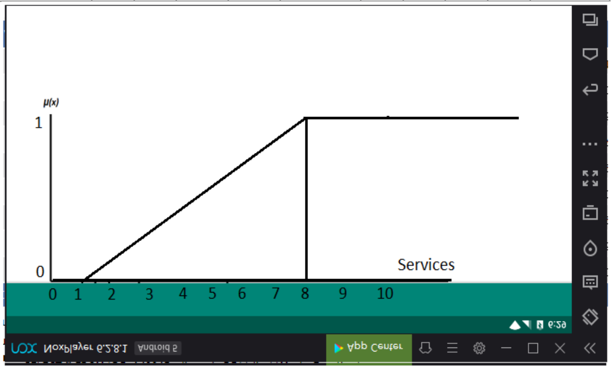

Figure 5: Suitability membership function for service linguistic variable.

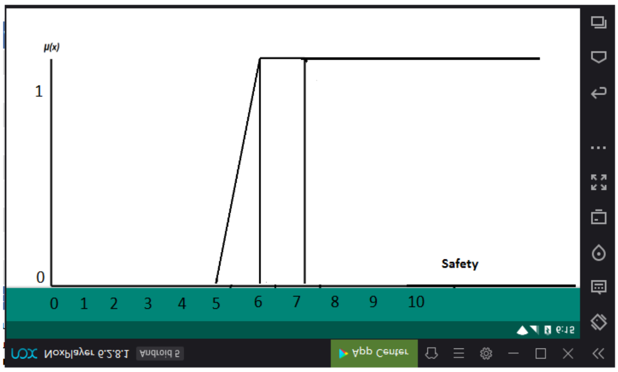

Figure 6: Suitability membership function for Safety linguistic variable.

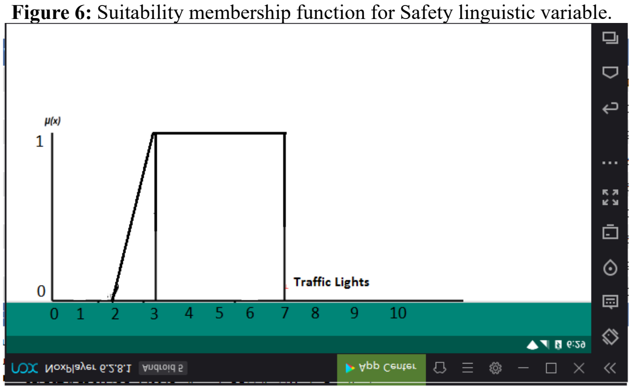

Figure 7: Suitability membership function for Traffic Lights linguistic

variable.

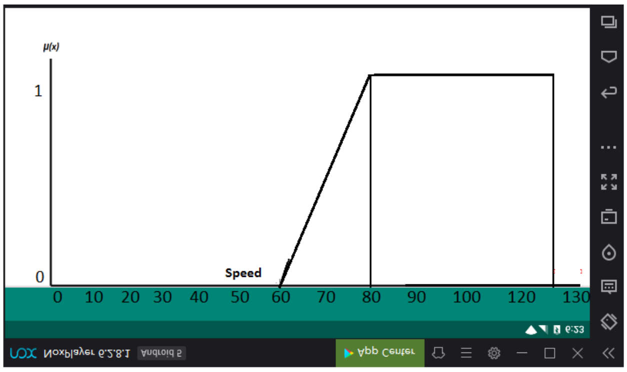

Figure 8: Suitability membership function for Speed linguistic variable.

Figure 9: Suitability membership function for Safety linguistic variable.

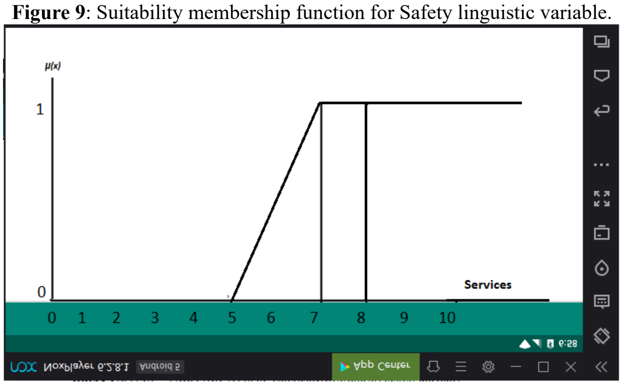

Figure 10: Suitability membership function for service linguistic variable.

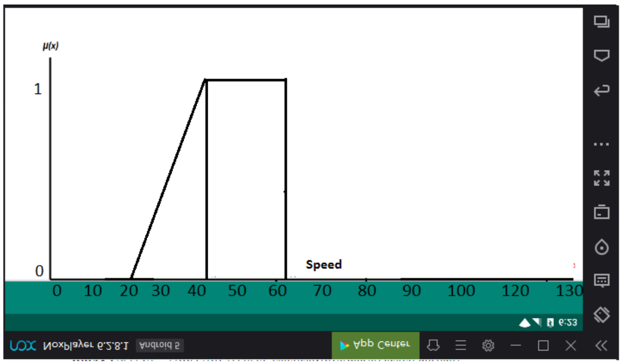

Figure 11: Suitability membership function for Speed linguistic variable.

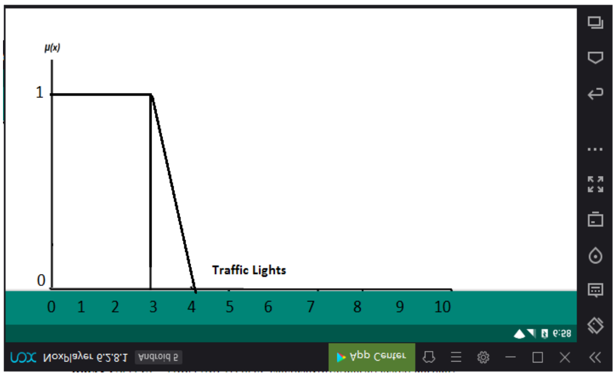

Figure 12: Suitability membership function for Traffic Light linguistic variable.

4.2. Query for Alternative Roads

Both users ask for alternative roads for driving from El Giza Squar as a source location to reach Al Remaia Square as a destination location. The criteria specified for evaluating the roads vary from user to user respecting their subjective views. Different criteria for both users are presented in the following queries:

- Query1: both users ask for alternative roads respecting their predefined preferences concerned with Speed for both user1 and user2. The results of responding to this query is shown in Figure 13. The results of responding to Query1 for both users with respect to applying the proposed roads-suitability approach.
-

Alternative roads	Roads Linguistic Variable	Crisp Value	Candidate Roads variables Suitability				Over all Road Suitability	
			User#1		User#2			
			Consider	Suitability	Consider	suitability	User# 1	User# 2
Feisal	Traffic Light	4					0	1
	Speed	60	✓	0	✓	1		
	Safety	9						
	Services	8						
Rabee Elgiza	Traffic	5					0	1
	Speed	40	✓	0	✓	1		
	Safety	10						
	Services	8						
El Baher Alzem	Traffic	3					0.5	0
	Speed	70	✓	0.5	✓	0		
	Safety	7						
	Services	6						
Haram	Traffic	6					0.5	0
	Speed	70	✓	0.5	✓	0		
	Safety	6						
	Services	5						
Saft Ring	Traffic	1					1	0
	Speed	120	✓	1	✓	0		
	Safety	2						
	Services	3						

Figure 13: Results of responding to Query 1 for both users

- Query2: both users ask for alternative roads respecting their predefined preferences concerned with road Safety for user1 and road Services for user2. In this query, although each user profile includes a set of suitability membership functions for some roads variables, both users consider just one variable at the time of query, The result of responding this query is presented in Figure 14.

Alternative roads	Roads Linguistic Variable	Crisp Value	Candidate Roads variables Suitability				Over all Road Suitability	
			User#1		User#2			
			Consider	Suitability	Consider	suitability	User#1	User#2
Feisal	Traffic Light	4					0.33	1
	Speed	60						
	Safety	9	✓	0.33				
	Services	8			✓	1		
Rabee Elgiza	Traffic	5					0	0
	Speed	40						
	Safety	10	✓	0				
	Services	8			✓	0		
El Baher Alzem	Traffic	3					1	0.5
	Speed	70						
	Safety	7	✓	1				
	Services	6			✓	0.5		
Haram	Traffic	6					1	0
	Speed	70						
	Safety	6	✓	1				
	Services	5			✓	0		
Saft Ring	Traffic	1					0	0
	Speed	120						
	Safety	2	✓	0				
	Services	3			✓	0		

Figure 14: Results of responding to Query 2 for both users

- **Query3**: both users ask for alternative roads respecting their predefined preferences concerned with Safety and service. As shown in Figure 15, the overall suitability is computed using the conjunction operator defined as the average of the considered roads variables for each user.
-

Alternative Roads	Roads Linguistic Variable	Crisp Value	Candidate Roads variables Suitability				Over all Road Suitability	
			User#1		User#2			
			Consider	suitability	Consider	suitability	User#1	User#2
Feisal	Traffic Light	4					0.68	1
	Speed	60						
	Safety	9	✓	0.33	✓	1		
	Services	8	✓	1	✓	1		
Rabee Elgiza	Traffic	5					0.53	0.39
	Speed	40						
	Safety	10	✓	0	✓	1		
	Services	8	✓	1	✓	0		
El Baher Alzem	Traffic	3					0.824	0.30
	Speed	70						
	Safety	7	✓	1	✓	0		
	Services	6	✓	0.67	✓	0.5		
Haram	Traffic	6					0.73	0.0
	Speed	70						
	Safety	6	✓	1	✓	0		
	Services	5	✓	0.5	✓	0		
Saft Ring	Traffic	1					0.0	0.0
	Speed	120						
	Safety	2	✓	0	✓	0		
	Services	3	✓	0	✓	0		

Figure 15: Results of responding to Query 3 for both users

- Query4: user1 asks for alternative roads respecting his/her predefined preferences concerned with speed only while user2 considers both of service and speed. As shown in Figure 16, the overall suitability is computed using the conjunction operator defined as the average of the considered roads variables for each user.
-

Alternative roads	Roads Linguistic Variable	Crisp Value	Candidate Roads variables Suitability				Over all Road Suitability	
			User#1		User#2			
			Consider	suitability	Consider	suitability	User#1	User#2
Feisal	Traffic Light	4					0.615	1
	Speed	60	✓	0	✓	1		
	Safety	9						
	Services	8	✓	1	✓	1		
Rabee Elgiza	Traffic	5					0.615	1
	Speed	40	✓	0	✓	1		
	Safety	10						
	Services	8	✓	1	✓	1		
El Baher Alzem	Traffic	3					0.603	0.38
	Speed	70	✓	0.5	✓	0		
	Safety	7						
	Services	6	✓	0.667	✓	0.5		
Haram	Traffic	6					0.5	0.0
	Speed	70	✓	0.5	✓	0		
	Safety	6						
	Services	5	✓	0.5	✓	0		
Saft Ring	Traffic	1					0.487	0.0
	Speed	120	✓	1	✓	0		
	Safety	2						
	Services	3	✓	0.167	✓	0		

Figure 16: Results of responding to Query 4 for both users

5. Conclusion

The proposed approach aims to support the users, vehicles drivers, with a set of ranked candidate roads respecting the user preferences. The proposed approach incorporates a set of operations. The first one is responsible for computing the average speed of the driver car. On the other hand, the second operation is responsible for defining and storing the user preferences represented as a set of human-like fuzzy rules. The third one is responsible for retrieving, evaluating, and ranking the candidate roads to reach the destination starting from the driver source.

An application has been developed based on the proposed approach. This application interacts with the users through mobile devices that enables them defining their own preferences concerning Speed, Safety, Service and Distance and save it in the user profile. Accordingly, when a user attempt to drive his car from a source location to a specified destination, the application starts finding, evaluating, and ranking all alternative roads to reach the specified destination.

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