

A COMPUTATIONAL MODEL FOR MULTI-CRITERIA DECISION MAKING IN TRAFFIC JAM PROBLEM

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Abstract

In this paper, we apply a computational model for multi-criteria decision making in traffic jam problems. First, we propose a system to determine the optimal shortcut road by reading the number of cars in each street using Radio Frequency Identification (RFID). Then, we have processed the data of traffic jam problems using Choquet integral with writing algorithm and computer program as a working procedure.

Keywords: Multi-Criteria Decision Making, Fuzzy Measures, Choquet Integrals, Traffic Jams

1 Introduction

Traffic jam is the worst problem that drivers are suffering in their daily lives, both in terms of delays in the traffic jams when going to work or the inconvenience caused by road jam in cars on public holidays. The problem of traffic congestion is not confined to regions without other regions, and thus countries always seek to address it in all kinds of solutions. The theory of multi-criteria decision-making has gained the emergence of several new paradigms in the second half of the twentieth century (for more details see e.g. [1]). There are several multi-criteria decision-making approaches that have been introduced to study the problem of traffic congestion (see e.g. [2]).

The aim of this paper is to apply a computational model for multi-criteria decision making in traffic jam problems, then use a system as a working procedure, to determine the optimal shortcut road using Radio Frequency Identification (RFID). The RFID system has already been adopted into various application areas (see, [3]-[6]).

In this paper, we propose a system that processed the data of traffic jam problems using Choquet integral to give the best result of the most appropriate road (optimal shortcut road) to go from the start point to the endpoint.

The structure of this paper is as follows. Section 2 introduces Multi Criteria Decision Making problem. In section 3, we propose a system to determine the optimal shortcut road in traffic jams. In section 4, we give a practical example. In section 5, we finish the paper with some conclusions.

2 Multi-Criteria Decision Making Problem

Consider a multi-criteria decision making problem that depends on n criteria (or points of view, attribute) described by the alternatives

G_1, \dots, G_n and a set of criteria $X = \{1, \dots, n\}$. An alternative is characterized by a value with respect to each criterion and is thus identified with a point in the Cartesian product G of the criteria, i.e. $G = G_1 \times \dots \times G_n$ is the set of potential alternatives.

The preference relation of the Decision Maker (DM) over alternatives is denoted by \geq . For any $g, h \in G$, $g \geq h$ means that the DM prefers alternative g to h . A classical way is to model \geq with the help of an overall utility function $z: G \rightarrow R$ [1]:

$$\forall g, h \in G, \quad g \geq h \leftrightarrow z(g) \geq z(h). \quad (1)$$

Clearly, z is a n dimensional function. An easy way to construct z is to consider one-dimensional utility function z_i on each criterion and then to aggregate them by a suitable operator:

$$z(g) = F(z_1(g_1), \dots, z_n(g_n)) \quad \forall g \in G \quad (2)$$

where, F is called an aggregation function.

Aggregation functions (AFs) are mathematical functions to collect helpful data in multi criteria decision making. The input of AFs is several numerical values and its output is a single value.

Based on the overall score by means of an aggregation function that takes into account the weights of importance of the criteria, the alternatives can be ranked and the best alternative selected. A special type of aggregation function is fuzzy integral with respect to non-additive measure. The fuzzy integral [7], [8] is an appropriate tool to represents the weights of criteria with non-additive measures. One of the fuzzy integrals is Choquet integral with respect to non-additive measure (fuzzy measure). The fuzzy integrals with respect to non-additive measures have been studied and applied in diverse fields (see, e.g. [9-17]). There are many types of non-additive measures, one of them is the λ -fuzzy measure. The definition of λ -fuzzy measure is as follows.

Definition 1: Suppose $P(G)$ be the power set of G , A set function is called λ -fuzzy measure if it satisfies the following axioms:

1. $g_\lambda: P(G) \rightarrow [0, 1]$
2. If $S, T \in P(G)$, $S \cap T = \emptyset$, then

$$g_\lambda(S \cup T) = g_\lambda(S) + g_\lambda(T) + \lambda g_\lambda(S)g_\lambda(T),$$

$$\lambda \in (-1, \infty) \tag{3}$$

In general, it can be shown that

$$g_\lambda(\{x_1, \dots, x_n\}) = 1 + \lambda \prod_{i=1}^n (1 + \lambda g_\lambda(x_i)) - 1, \lambda = 0 \tag{6}$$

This given a polynomial equation with respect to λ

$$1 + \lambda = \prod_{i=1}^n (1 + \lambda g_\lambda(x_i)). \tag{5}$$

The mapping $f: G \rightarrow R+$ corresponds to the value that the supply of the source (i.e., $f(x_i) = x_i$), using, as before, x_i to denote the i th input value and the fuzzy measure $(g_\lambda : P(G) \rightarrow [0, 1])$ assigns importance to subsets of G .

Definition 2: Suppose that g_λ is fuzzy measures on G , whose elements are, refer to (x_1, \dots, x_n) . The discrete choquet integral of a function $f: G \rightarrow R+$ with respect to g_λ is defined by

$$\int_{C, g_\lambda} (f) = \sum_{i=1}^N (f(x_{(i)}) - f(x_{(i-1)})) g_\lambda(A_{(i)}) \tag{6}$$

where (i) denotes that the indices have been permuted so that

$$0 \leq f(x_{(1)}) \leq \dots \leq f(x_{(n)}), \text{ and } A_{(i)} := \{x_{(i)}, \dots, x_{(n)}\}$$

with $f(x_{(0)}) = 0$

3 A Computational Model for Multi-Criteria Decision Making in Traffic Jam Problem

3.1 A System for Solving the Problem of Traffic Jams

In order to solve the problem of traffic jams, we must first try to understand its causes. While the causes and may differ from city to city, there are some common factors. For example, the increase in the number of cars and narrow roads are obvious reasons. Hence the idea of the solution of traffic jams through which the street jam is identified by knowing the number of cars in each street of the city that the user wants to pass. This process is done using the Radio Frequency Identification (RFID) technique, through which scores every car entering and go out the specified road.

The procedure of statistical work for the proposed roads and choose the most appropriate road among these roads through the processing of data using multi-criteria decision making problems. Thus, the user can query the best road through an application designed for this purpose that is available for all smart mobile devices. Some countries use GPS technology to define the number of cars and regardless of the economic cost of this technology, where the cost of GPS is more than the cost of RFID. Furthermore, it is not available in all cars and it's difficult for the normal driver to install it comparing with the RFID technology used in our system.

3.2 Hardware Design of the System

The Hardware design of the system can be classified into the following.

Arduino. An electronic development board (as in Figure 1), can be used by both professionals and beginners, and it is used in different fields. Arduino can communicate with the surrounding environment through a number of sensors and can influence its surroundings by controlling small motors or lights and other electronic parts. Arduino's projects can be connected to its sensors and electronic parts only or can be connected to computer-based programs, such as Visual BASIC.

Radio Frequency Identification (RFID). RFID is one of the most common applications in the recent period (Figure 2). It is widely found in the security system and is done by sending electromagnetic waves to special cards (Figure 3).

The hardware design of the system for solving the problem of traffic jams is shown in the following figures (Figure 4 and Figure 5).



Fig. 1. Arduino Uno board

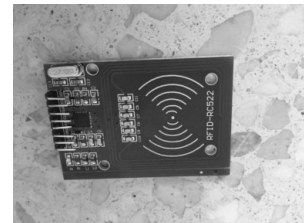


Fig. 2. RFID board



Fig. 3. Tags (RF Sender)

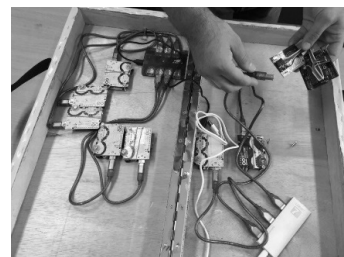


Fig. 4. Hardware for a small model

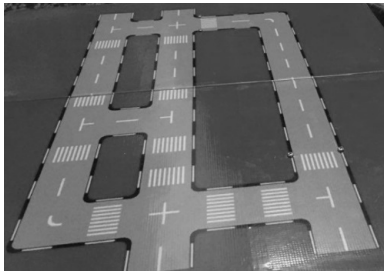


Fig. 5. A small city map

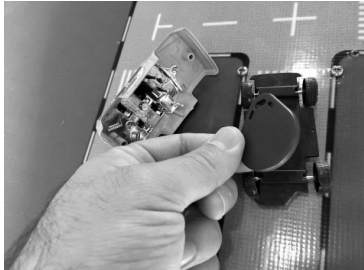


Fig. 6. A small car with tag inside

In the practical application will get the values of three criteria (Length, Time, and Traffic jam) automatically through the RFID reader (Figure 6, Figure 7) which will calculate the number of cars on the road, and calculate the rate of cars on the road by dividing the number of cars on the street capacity, and this value will represent the road jam. When the user wants to choose the best road, the application will draw the best streets on the map (Figure 10). The length of the street will be taken from the Google maps application, and the time will depend on the street length and the traffic jam. The hardware design of the system tools is showing in the following figures (Figure 6- Figure 9).

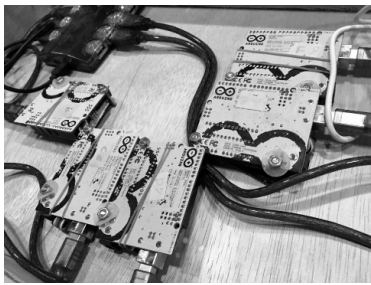


Fig. 7. Arduino connection

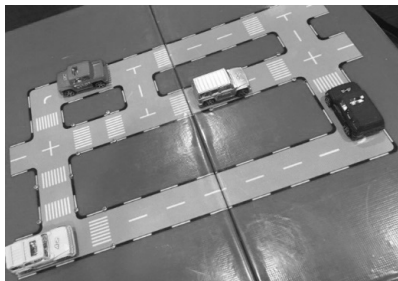


Fig. 8. Small city simulator

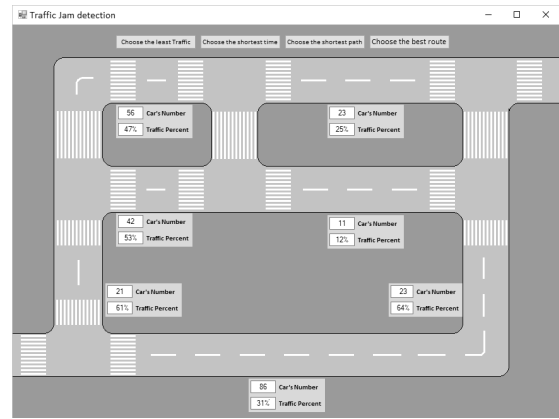


Fig. 9. Before choosing a path

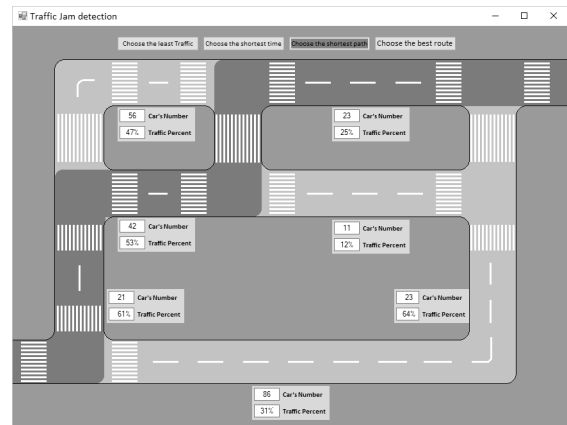


Fig. 10. The shortest path

3.3 Algorithm

To simplify the notation in the algorithm, we use the following equation to calculate the discrete Choquet integral that is equivalent to the equation (6):

$$\int C_{g_s}(f) = \sum_{i=1}^n [x_{(i)} - x_{(i-1)}] g_s(A_{(i)})$$

where $x_{(0)} = 0$ by convention, and $A_{(i)} = \{1, \dots, n\}$

Consider the vector of pairs $((x_1, 1), (x_2, 2), \dots, (x_n, n))$, where the second component of each pair is just the index i of x_i . The second component will help to keep track of all permutations. Therefore, we use the following procedure for the calculation of the discrete Choquet integral $Cg_s(f)$.

Step 1: Sort the components of $((x_1, 1), (x_2, 2), \dots, (x_n, n))$ with respect to the first component of each pair in non-decreasing order.

We obtain, $((x_{(1)}, i_1), (x_{(2)}, i_2), \dots, (x_{(n)}, i_n))$, so that $x_{(j)} = x_{i_j}$ and $x_{(j)} \leq x_{(j+1)}$ for all i . Let also $x_{(0)} = 0$.

Step 2: Let $T = \{1, \dots, n\}$, and $S = 0$.

Step 3: For $j = 1, \dots, n$ do
 a) $S := S + [x_{(j)} - x_{(j-1)}] g_s(T)$;
 b) $T := T \setminus \{i_j\}$

Step 4: Return S .

4 Practical Example

We consider the problem of evaluation of traffic jams on roads with respect to three criteria, Length (L), Time (T), and Traffic Jam (J). This is usually done through a simple weighted amount, in which weights are coefficients of the importance of different criteria. Let us take some areas on the map that contain five roads (R1, R2, R3, R4, R5) to move from point (A) to point (B). The data of the five roads are given in the following table (Table 1).

Tab. 1. The data of the five roads (R1, R2, R3, R4, R5)

	Length (L)	Time (T)	Traffic Jam(J)
R1	200	100	55
R2	300	180	55
R3	150	70	90
R4	150	60	80
R5	150	50	70

We can solve this problem by using a suitable fuzzy measure and the Choquet integral as follows.

1. The Length and Traffic jam criteria are more important than Time, we put the following weights on criteria taken individually.

$$g_s(\{\text{Length}\}) = 0.7, g_s(\{\text{Time}\}) = 0.5, g_s(\{\text{Traffic Jam}\}) = 0.6.$$

Using equation (5), we get

$$1 + \lambda = (1 + 0.7\lambda)(1 + 0.5\lambda)(1 + 0.6\lambda)$$

Then, the solutions of this equation are $\lambda = -0.9103$, $\lambda = -4.1849$, and $\lambda = 0$. The only acceptable value is $\lambda = -0.9103$, but the other values are violated of constraints of λ -fuzzy measure.

2. Since length and traffic jam are redundant, the weight attributed to the length and the traffic jam should be less than the total weights of the length and traffic jams. By applying equation (3), $g_s(\{x_1, x_3\}) =$

$$g_s(\{x_1\}) + g_s(\{x_3\}) + \lambda g_s(\{x_1\})g_s(\{x_3\}),$$

$$g_s(\{x_1, x_3\}) = g_s(\{\text{length, traffic jam}\})$$

$$= 0.8 + 0.5 + (-0.9439 * 0.8 * 0.5) = 0.917674$$

$$g_s(\{\text{length, traffic jam}\}) = 0.917674 < 0.8 + 0.5.$$

Similarly, the weight attributed to the time and length should be greater than the sum of individual weights (also, the same for time and traffic jam).

$$g_s(\{x_1, x_2\}) = g_s(\{\text{length, time}\}) = 0.881395 < 0.8 + 0.6,$$

$$g_s(\{x_2, x_3\}) = g_s(\{\text{time, traffic jam}\}) = 0.82691 < 0.6 + 0.5,$$

$$g_s(\emptyset) = 0, g_s(\{\text{length, traffic jam, time}\}) = 1.$$

3. By applying λ -fuzzy measure and Choquet integral for the first road (R1) we get the following result for (R1). $0 \leq f(x_3) \leq f(x_2) \leq f(x_1)$,

$$\int C_{g_s}(f) = \sum_{i=1}^N (f(x_{(i)}) - f(x_{(i-1)})) g_s(A_{(i)})$$

$$\int C_{g_s}(R1) = [f(x_3) - f(0)] g_s(x_1, x_2, x_3) + [f(x_2) - f(x_3)] g_s(x_1, x_2) + [f(x_1) - f(x_2)] g_s(x_1)$$

$$\int C_{g_s}(R1) = [55 - 0] * 1 + [100 - 55] * 0.88139 + [200 - 100] * 0.7 = 164.66$$

Other results for the remaining roads (R2, R3, R4, R5) are shown in Table 2.

Tab. 2. Choquet integral for the roads (R1, R2, R3, R4, R5)

	Length (L)	Time(T)	Jam (J)	Global evaluation (Choquet integral)
Road 1	200	100	55	164.66
Road 2	300	180	55	249.17
Road 3	150	50	70	124.35
Road 4	150	60	80	127.35
Road 5	150	70	90	130.35

The interpretation of Choquet integral with respect to scoring (from lower to above) on the road ranking confirms that the preference relation of the Decision Maker is $R3 \geq R4 \geq R5 \geq R1 \geq R2$.

Therefore, Road 5 is the optimal shortcut road according to the ranking roads. Thus, we get the predictable solution of the traffic jam problem for the appropriate road (optimal shortcut path) to go from the start point to the endpoint.

5 Conclusion

In this paper, we have described a computational model of the problem of multi-criteria decision making in traffic jams. Then, we have proposed in this model a system for solving the Multi-Criteria Decision Making Problem of traffic jams. The application of this system is high speed in data collection and processing, also the mechanism of the system is automatic. In the future, we plan to test our model in many areas, such as service, commercial, and security fields.

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