A Route Selection Scheme for supporting Virtual Tours in Sites with Cultural Interest using Drones

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***Abstract*—Virtual tourism is a novel trend that enhances the experience the users perceive from touristic places, such as archaeological sites. Drones are equipped with 360^o video cameras and used for video capturing of the heritage sites. The video material is streamed to the users in real time, enriched with additional 3D, Augmented Reality (AR) or Mixed Reality (MR) material. Furthermore, the selection of the appropriate flying route for each drone should be performed, in order to provide a satisfactory tour experience to the user, considering his preferences about specific monuments. To address this issue, this paper describes a heritage route selection scheme for supporting real-time virtual tours in sites with cultural interest using drones. The proposed scheme applies a Fuzzy Multiple Attribute Decision Making (FMADM) algorithm, the Trapezoidal Fuzzy Topsis for Heritage Route Selection (TFT-HRS), to accomplish the ranking of the candidate heritage routes. The algorithm uses Interval-Valued Trapezoidal Fuzzy Numbers (IVTFN) for the representation of heritage routes evaluation values. Performance evaluation shows that the suggested method produces better results compared to the Fuzzy Topsis (FTOPSIS) by selecting the most appropriate flying route for the drone.**

I. Introduction

Virtual tourism [1] is a novel paradigm that reduces time or spatial limitations of real tourism and provides touristic experience to users. Services such as 360^o video streaming [2], 3D animation [3], Augmented Reality (AR) [4] and Mixed Reality (MR) [5] are used to construct a totally virtual world for the user. In this field, drones [6] equipped with 360^o cameras are used for the video capture of the touristic place. Thereafter, the video material is enriched with 3D, AR or MR material and streamed to users in real time [7] .

The application of virtual tour services to heritage sites [8] has obtained increased interest. Drones can provide us with real time images with a totally new perspective, the "bird's eye view", that is going to change not only what we see but also how we perceive and think about tangible heritage and physical environment. In recent implementations, the drone interacts with a Fifth Generation (5G) [9] mobile infrastructure to obtain access to plenty of networking, computational and storage resources. Indicatively, the enriched 360^o video is streamed to the user through a 5G Mobile Edge Computing (MEC) or Fog [10][11] infrastructure, which assures the satisfaction of its constraints in Quality of Service (QoS) related factors such as throughput, delay, jitter and packet loss. The 5G infrastructure could support heterogeneous network access technologies, such as the 3GPP Long Term Evolution Advanced (LTE-A) [12], the IEEE 802.11p Wireless Access for Vehicular Environment (WAVE) [13] RSUs and the IEEE 802.16 WiMAX [14].

Each drone is remotely controlled by the user or, in more advanced implementations, it is autonomous navigated [15][16] using its own Artificial Intelligence (AI) [17]. A critical task of the autonomous navigation service is the selection of the most appropriate flying route for the drone, while factors such as Points of Interest (PoIs) [18], user preferences or wireless networks availability could be considered. Specifically, in heritage sites where multiple monument types exist, the user preference for each type should be considered, in order the most appropriate flying route to be selected for the drone.

Virtual tours with drones can be used in numerous cases dealing with protection, preservation and enhancement of tangible heritage, as well as servicing special groups of people, i.e. elderly, children, persons with disabilities that can not reach the inaccessible monuments. Some of the potential uses of the proposed virtual tours in this paper are the following:

- Emergency, i.e. in case of fire, earthquake or flood the local administration can have a short-time check of the potentially harmed monuments
- Typical Control, i.e. regular control of the heritage sites dealing with everyday problems like checking the vegetation in archaeological sites or monitoring inaccessible monuments.
- Shared Experience, i.e. groups of visitors can be provided simultaneously real time experience either by accessing a monument or not.
- Selective Visit, i.e visitors will have the opportunity to visit virtually an amount of monuments of an area but due to time limit they will be able to choose a physical tour in one or two of them.

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- Educational Purpose, i.e. visitors of areas of natural beauty like lakes, rivers, and canyons will be able to have an holistic experience of the sites including inaccessible spots or monuments.

In general, Multi Attribute Decision Making (MADM) methods are used to select the best alternative among candidate routes. MADM algorithms are able to evaluate different alternatives, sometimes even contradictory, using multi-criteria analysis. Widely used methods include the Analytic Hierarchy Process (AHP) [19] [20], the Analytic network process (ANP) [21], the Simple Additive Weighting (SAW) [20][22],the Multiplicative Exponent Weighting (MEW) [20], the Gray Relational Analysis (GRA) [20], the Distance to Ideal Alternative (DIA) [20], the Weighted Product Method (WPM) [23] and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [24]. Furthermore, various weighting methods are used, in order to provide suitable criteria weights for each alternative. It should also be noted that there is a rate of uncertainty in evaluating the monuments in each heritage route. Therefore, Fuzzy MADM (FMADM) methods have received the interest of many researchers in decision theory. In particular, several FMADM methods are proposed utilizing linguistic variables, triangular fuzzy numbers, trapezoidal fuzzy numbers etc. to evaluate heritage routes. Such methods include the Fuzzy AHP - SAW (FAS) [25], the Fuzzy TOPSIS (FTOPSIS) [26], the Fuzzy AHP - TOPSIS (FAT) [27], the Fuzzy AHP - SAW (FAS) [27], the Fuzzy AHP Mew (FAM) [27], as well as the Fuzzy AHP - ELECTRE (FAE) [28].

This paper describes a heritage route selection scheme for supporting real-time virtual tours in heritage sites using drones. It uses two algorithms, the Analytic Network Process (ANP) to model the user preferences about monument types and the Trapezoidal Fuzzy Topsis for Heritage Route Selection (TFT-HRS) to accomplish the ranking of the candidate flying routes, considering the aforementioned user preferences. The TFT-HRS algorithm uses Interval-Valued Trapezoidal Fuzzy Numbers (IVTFN) for the representation of heritage routes' evaluation values.

The rest paper is organized as follows: Section II describes the proposed scheme, while Section III presents the simulation setup and the evaluation results. Finally, section IV concludes the discussed work.

II. The Proposed Heritage Route Selection Scheme

A. The Analytic Network Process (ANP)

The Analytic Network Process (ANP) was introduced by Saaty [29] to deal with decision problems that criteria and alternatives depend on each other. ANP is actually the generalization of the AHP. A decision problem that is analyzed with the ANP can be designed either as a control-hierarchy or as a non-hierarchical network. Nodes of the network represent components (or clusters) of the system while arcs denote interactions between them. All interactions and feedbacks within clusters are called inner dependencies, while interactions and feedbacks between clusters are called outer dependencies. The ANP is composed of four major steps [30]:

a) Model construction and problem structuring: During this step the problem is analyzed and decomposed into a rational system, like a network .

b) Pairwise comparison matrices and priority vectors: During this step, the pairwise comparison matrix, as in AHP, is derived using Saatys nine-point importance scale (Table I).

TABLE I: Nine-point importance scale.

Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, 8	Intermediate Values

c) Supermatrix formation: During this step, matrix, supermatrix of the ANP model is constructed to represent the inner and outer dependencies of the network. It is actually a partitioned matrix, where each matrix segment represents a relationship between two clusters in the network. To contrust the supermatrix the local priority vectors obtained in Step 2 are grouped and placed in the appropriate positions in a supermatrix based on the flow of influence from one cluster to another, or from a cluster to itself, as in the loop. Then, the supermatrix is transformed to a stochastic one,the weighted supermatrix. Finally, the weighted supermatrix is raised to limiting powers until all the entries converge to calculate the overall priorities, and thus the cumulative influence of each element on every other element with which it interacts is obtained [31]. At this point, all the columns of the new matrix, the limit supermatrix, are the same and their values show the global priority of each element of network.

For example if we assume a network with n clusters, where each cluster $Q_k, k = 1, 2, , n$, and has m_n elements, denoted as $q_{k1}, q_{k2}, , q_{km_k}$, then the standard form for a supermatrix can be expressed as:

$$W = \begin{array}{cc} & \begin{array}{ccccc} Q_1 & \cdots & Q_k & \cdots & Q_n \\ q_{11}\cdots q_{1m_1} & \cdots & q_{k1}\cdots q_{km_k} & \cdots & q_{n1}\cdots q_{nm_n} \end{array} \\ \begin{array}{cc} Q_1 & \begin{array}{c} q_{11} \\ \vdots \\ q_{1m_1} \end{array} \\ \vdots & \\ Q_k & \begin{array}{c} q_{k1} \\ \vdots \\ q_{km_k} \end{array} \\ \vdots & \\ Q_n & \begin{array}{c} q_{n1} \\ \vdots \\ q_{nm_n} \end{array} \end{array} & \begin{bmatrix} W_{11} & \cdots & W_{1k} & \cdots & W_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{k1} & \cdots & W_{kk} & \cdots & W_{kn} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ W_{n1} & \cdots & W_{nk} & \cdots & W_{nn} \end{bmatrix} \end{array} \tag{1}$$

d) Obtain the priority weights: If the supermatrix formed in Step 3 covers the whole network, then the priority weights of the alternatives can be found in the column of alternatives in the normalized supermatrix. Otherwise, additional calculations using matrix operations are required, in order to obtain the overall priorities of the alternatives.

B. The Trapezoidal Fuzzy Topsis for Heritage Route Selection (TFT-HRS)

The Trapezoidal Fuzzy Topsis for Heritage Route Selection (TFT-HRS) is used to accomplish the ranking of candidate heritage routes. Interval-Valued Trapezoidal Fuzzy Numbers (IVTFN) [32] are used for the representation of heritage routes' evaluation values. An IVTFN, is a general form of fuzzy number and can be represented as: $\tilde{a} = [\tilde{a}^L, \tilde{a}^U] = [(a_1^L, a_2^L, a_3^L, a_4^L, v^L), (a_1^U, a_2^U, a_3^U, a_4^U, v^U))]$ where: $0 \le a_1^L \le a_2^L \le a_3^L \le a_4^L \le 1$, $0 \le a_1^U \le a_2^U \le a_3^U \le a_4^U \le 1$, $0 \le v^L \le v^U \le 1$ and $\tilde{a}^L \subset \tilde{a}^U$. The operational rules of the IVTFNs are defined in [32].

The candidate heritage routes are ranked using the TFT-HRS method, which adjusts the TFT [33] network selection algorithm, in order route selection to be performed. Similar to TFT, TFT-HRS is based on the concept that the best alternative should have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. Also, it assumes that the linguistic values of criteria attributes (e.g. user preferences about specific monuments) are represented by IVTFNs. More specifically, suppose $AL = \{AL_1, AL_2, \dots, AL_z\}$ is the set of possible alternative heritage routes, $MT = \{MT_1, MT_2, \dots, MT_n\}$ is the set of monument types that exist in each route and $w_1, w_2, \dots, w_n$ are the user preferences of the respective monument types obtained from the application of the ANP algorithm. The steps of the method are as follows:

a) Construction of the decision matrix: Each $\tilde{g}_{ij}$ element of the $z \times n$ decision matrix $\tilde{D}$ is an IVTFN number expressing the evaluation value of alternative heritage route i for monument j, which refers to the percentage of the monument j covered by route i. Thus:

$$\tilde{D} = \begin{array}{c|ccc} & MT_1 & \dots & MT_n \\ \hline AL_1 & \tilde{g}_{11} & \dots & \tilde{g}_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ AL_z & \tilde{g}_{z1} & \dots & \tilde{g}_{zn} \end{array} \tag{2}$$

where $\tilde{g}_{ij} = \left[(g_{ij1}^L, g_{ij2}^L, g_{ij3}^L, g_{ij4}^L, v_{ij}^L), (g_{ij1}^U, g_{ij2}^U, g_{ij3}^U, g_{ij4}^U, v_{ij}^U)\right]$.

In the case that there are multiple monuments belonging to a specific monument type MT, the decision matrix includes the average of their evaluation values. Hence, assuming that for the x^{th} monument $\tilde{g}_{ijx}$ is its evaluation value in the heritage route i, the average of the evaluation values is given by formula 3.

$$\begin{aligned} \tilde{g}_{ij} &= \frac{1}{X}\sum_{x=1}^{X} \tilde{g}_{ijx} = \\ &\Bigg[\left(\frac{1}{X}\sum_{x=1}^{X} g_{ijx1}^L, \frac{1}{X}\sum_{x=1}^{X} g_{ijx2}^L, \frac{1}{X}\sum_{x=1}^{X} g_{ijx3}^L, \frac{1}{X}\sum_{x=1}^{X} g_{ijx4}^L, v_{ijx}^L\right), \\ &\left(\frac{1}{X}\sum_{x=1}^{X} g_{ijx1}^U, \frac{1}{X}\sum_{x=1}^{X} g_{ijx2}^U, \frac{1}{X}\sum_{x=1}^{X} g_{ijx3}^U, \frac{1}{X}\sum_{x=1}^{X} g_{ijx4}^U, v_{ijx}^U\right)\Bigg] \end{aligned} \tag{3}$$

b) Normalization of the decision matrix: Considering that Γ is the set of monuments, the elements of the normalized decision matrix are calculated using formula 4, where $b_j = \max_i g_{ij4}^U$ for each $j \in \Gamma$.

$$\tilde{g}'_{ij} = \left[\left(\frac{g_{ij1}^L}{b_j}, \frac{g_{ij2}^L}{b_j}, \frac{g_{ij3}^L}{b_j}, \frac{g_{ij4}^L}{b_j}, v_{ij}^L\right), \left(\frac{g_{ij1}^U}{b_j}, \frac{g_{ij2}^U}{b_j}, \frac{g_{ij3}^U}{b_j}, \frac{g_{ij4}^U}{b_j}, v_{ij}^U\right)\right] \tag{4}$$

c) Construction of the weighted normalized decision matrix: The weighted normalized decision matrix is constructed by multiplying each element of the normalized decision matrix $\tilde{g}'_{ij}$ with the respective weight w_j according to the formula 5.

$$\begin{aligned} \tilde{u}_{ij} = \Big[&\left(g_{ij1}'^L \cdot w_j, g_{ij2}'^L \cdot w_j, g_{ij3}'^L \cdot w_j, g_{ij4}'^L \cdot w_j, v_{ij}'^L\right), \\ &\left(g_{ij1}'^U \cdot w_j, g_{ij2}'^U \cdot w_j, g_{ij3}'^U \cdot w_j, g_{ij4}'^U \cdot w_j, v_{ij}'^U\right)\Big] \end{aligned} \tag{5}$$

d) Determination of the positive and negative ideal solution: The positive ideal solution is defined in 6, where $\bigwedge_i \equiv \max_i$. Correspondingly, the negative ideal solution is defined in 7, where $\bigvee_i \equiv \min_i$.

$$\begin{aligned} \tilde{G}^+ &= \left[\left(g_{ij1}^{+L}, g_{ij2}^{+L}, g_{ij3}^{+L}, g_{ij4}^{+L}, v_{ij}^{+L}\right), \left(g_{ij1}^{+U}, g_{ij2}^{+U}, g_{ij3}^{+U}, g_{ij4}^{+U}, v_{ij}^{+U}\right)\right] \\ &= \Bigg[\left(\bigwedge_i u_{ij1}^L, \bigwedge_i u_{ij2}^L, \bigwedge_i u_{ij3}^L, \bigwedge_i u_{ij4}^L, v_{ij}^L\right), \\ &\quad \left(\bigwedge_i u_{ij1}^U, \bigwedge_i u_{ij2}^U, \bigwedge_i u_{ij3}^U, \bigwedge_i u_{ij4}^U, v_{ij}^U\right)\Bigg] \end{aligned} \tag{6}$$

$$\begin{aligned} \tilde{G}^- &= \left[\left(g_{ij1}^{-L}, g_{ij2}^{-L}, g_{ij3}^{-L}, g_{ij4}^{-L}, v_{ij}^{-L}\right), \left(g_{ij1}^{-U}, g_{ij2}^{-U}, g_{ij3}^{-U}, g_{ij4}^{-U}, v_{ij}^{-U}\right)\right] \\ &= \Bigg[\left(\bigvee_i u_{ij1}^L, \bigvee_i u_{ij2}^L, \bigvee_i u_{ij3}^L, \bigvee_i u_{ij4}^L, v_{ij}^L\right), \\ &\quad \left(\bigvee_i u_{ij1}^U, \bigvee_i u_{ij2}^U, \bigvee_i u_{ij3}^U, \bigvee_i u_{ij4}^U, v_{ij}^U\right)\Bigg] \end{aligned} \tag{7}$$

e) Measurement of the distance of each alternative from the ideal solutions: The distances of each alternative heritage route from the positive ideal solution are evaluated using formulas 8 and 9. Likewise the distances of each alternative from the negative ideal solution are estimated using formulas 10 and 11.

$$\begin{aligned} p_{i1}^+ = \sum_{j=1}^{n} \Bigg\{\frac{1}{4}\Big[&\left(u_{ij1}^L - g_{ij1}^{+L}\right)^2 + \\ &\left(u_{ij2}^L - g_{ij2}^{+L}\right)^2 + \left(u_{ij3}^L - g_{ij3}^{+L}\right)^2 + \left(u_{ij4}^L - g_{ij4}^{+L}\right)^2\Big]\Bigg\}^{\frac{1}{2}} \end{aligned} \tag{8}$$

$$\begin{aligned} p_{i2}^+ = \sum_{j=1}^{n} \Bigg\{\frac{1}{4}\Big[&\left(u_{ij1}^U - g_{ij1}^{+U}\right)^2 + \\ &\left(u_{ij2}^U - g_{ij2}^{+U}\right)^2 + \left(u_{ij3}^U - g_{ij3}^{+U}\right)^2 + \left(u_{ij4}^U - g_{ij4}^{+U}\right)^2\Big]\Bigg\}^{\frac{1}{2}} \end{aligned} \tag{9}$$

$$\begin{aligned} p_{i1}^- = \sum_{j=1}^{n} \Bigg\{\frac{1}{4}\Big[&\left(u_{ij1}^L - g_{ij1}^{-L}\right)^2 + \\ &\left(u_{ij2}^L - g_{ij2}^{-L}\right)^2 + \left(u_{ij3}^L - g_{ij3}^{-L}\right)^2 + \left(u_{ij4}^L - g_{ij4}^{-L}\right)^2\Big]\Bigg\}^{\frac{1}{2}} \end{aligned} \tag{10}$$

$$\begin{aligned} p_{i2}^- = \sum_{j=1}^{n} \Bigg\{\frac{1}{4}\Big[&\left(u_{ij1}^U - g_{ij1}^{-U}\right)^2 + \\ &\left(u_{ij2}^U - g_{ij2}^{-U}\right)^2 + \left(u_{ij3}^U - g_{ij3}^{-U}\right)^2 + \left(u_{ij4}^U - g_{ij4}^{-U}\right)^2\Big]\Bigg\}^{\frac{1}{2}} \end{aligned} \tag{11}$$

Consequently, the alternatives distance from the positive and negative ideal solutions are expressed by intervals such as

$[p_{i1}^+, p_{i2}^+]$ and $[p_{i1}^-, p_{i2}^-]$, instead of single values, while in this way less information is lost.

f) Calculation of the relative closeness: The relative closeness of the distances from the ideal solutions are calculated using formula 12 and 13. Subsequently, the compound relative closeness is obtained using formula 14.

$$RC_{i1} = \frac{p_{i1}^-}{p_{i1}^+ + p_{i1}^-} \tag{12}$$

$$RC_{i2} = \frac{p_{i2}^-}{p_{i2}^+ + p_{i2}^-} \tag{13}$$

$$RC_i = \frac{RC_{i1} + RC_{i2}}{2} \tag{14}$$

g) Alternative heritage routes ranking: The alternative heritage routes are ranked according to their RC_i values, while the best alternative is that with the higher RC_i value.

III. Simulation Setup and Results

In our experiments, we consider a 5G architecture (figure 1) which includes a Cloud and a Fog infrastructure. The Cloud infrastructure includes a set of Virtual Machines (VMs), while each VM hosts a set of 3D, AR and MR heritage models. Accordingly, the Fog infrastructure includes LTE and WiMAX Macrocells and Femtocells, as well as WAVE RSUs, with additional computational and storage resources. Additionally, inside the area of the Fog, a number of Ancient [34], Byzantine [35], Modern [34] and Natural Beauty [36] monuments exist. A Software Defined Network (SDN) controller provides centralized control of the entire architecture.

As it concerns the Hellenic territory, the category of Ancient monuments consists of prehistoric antiquities, monuments of Classical, Roman and Hellenistic Era and all of their subcategories. In the group of Byzantine monuments, we refer to the antiquities between 330 AD and 1830 AD, including the subcategories Early Byzantine, Middle Byzantine, Post Byzantine monuments (in Western Europe, the term Byzantine could be replaced by the term Medieval). With the term Modern monuments, we refer to artifacts after 1830 AD, i.e. exceptional buildings constructed according to Neoclassic, Art Nouveau and Bauhaus style, well preserved traditional complexes, industrial buildings, statues etc. In the category of Natural Beauty there are landscapes with special features, remarkable and sensitive ecosystems, i.e. rivers, lakes, forests, canyons, etc.

The case where 5 users need to perform a virtual tour using a drone is considered. Initially the preferences of each user for each type of monument are modeled as presented in table II, which includes the corresponding pairwise comparisons. Subsequently, using the ANP method, the weights that concern the users' preferences for each monument type are estimated. As can be observed in figure 2, the estimated user preferences are proportional to the aforementioned pairwise comparisons. Indicatively, user 1 mostly prefers the Ancient monuments, user 2 prefers the Byzantine monuments, user 3 prefers the Natural Beauty monuments, user 4 prefers both Ancient and Byzantine monuments and, finally, user 5 prefers

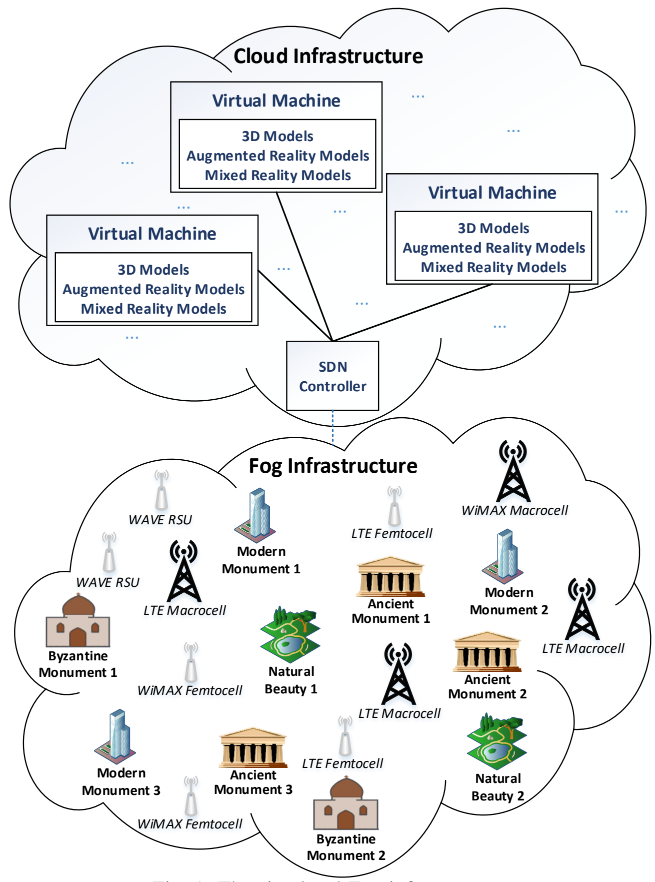

Fig. 1: The simulated Fog infrastructure.

TABLE II: The pairwise comparisons between the monument types for each user.

User		Ancient	Byzantine	Modern	Natural Beauty
User 1	Ancient	1	3	7	9
	Byzantine	1/3	1	5	7
	Modern	1/7	1/5	1	3
	Natural Beauty	1/9	1/7	1/3	1
User 2	Ancient	1	1/9	1/5	1
	Byzantine	9	1	5	9
	Modern	5	1/5	1	5
	Natural Beauty	1	1/9	1/5	1
User 3	Ancient	1	1	1	1/9
	Byzantine	1	1	1	1/9
	Modern	1	1	1	1/9
	Natural Beauty	9	9	9	1
User 4	Ancient	1	1	5	9
	Byzantine	1	1	5	9
	Modern	1/5	1/5	1	5
	Natural Beauty	1/9	1/9	1/5	1
User 5	Ancient	1	5	9	1
	Byzantine	1/5	1	3	1/5
	Modern	1/9	1/3	1	1/9
	Natural Beauty	1	5	9	1

Ancient and Natural Beauty monuments. Furthermore, table III represents the linguistic terms and the corresponding interval-valued trapezoidal fuzzy numbers used for the definition of the evaluation values of each monument in each flying route. Accordingly, table IV presents the corresponding value that each monument obtains in each route.

Each user interacts with the Fog infrastructure and requests to perform a real-time virtual tour using a drone. Thereafter, the Fog interacts with the SDN controller, in order the most appropriate flying route to be selected for the drone, using the TFT-HRS algorithm which considers the user's preferences about each monument type. Also, the Fog retrieves the corre-

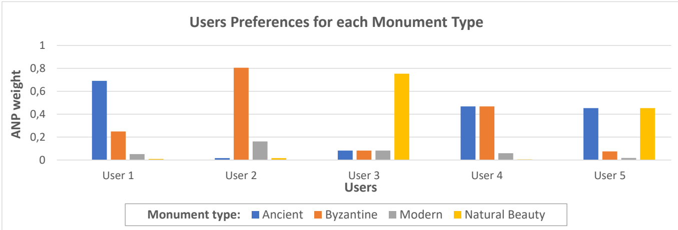

Fig. 2: The ANP weights which concern the users' preferences for each monument type.

TABLE III: Lingustic terms and the corresponding IVTFNs used for the definition of the evaluation values of each monument in each heritage route.

Linguistic term	Interval-Valued Trapezoidal Fuzzy Number (IVTFN)
Absolutely Poor (AP)	[(0.0, 0.0, 0.0, 0.0, 0.9), (0.0, 0.0, 0.0, 0.0, 1.0)]
Very Poor (VP)	[(0.01, 0.02, 0.03, 0.07, 0.9), (0.0, 0.01, 0.05, 0.08, 1.0)]
Poor (P)	[(0.04, 0.1, 0.18, 0.23, 0.9), (0.02, 0.08, 0.2, 0.25, 1.0)]
Medium Poor (MP)	[(0.17, 0.22, 0.36, 0.42, 0.9), (0.14, 0.18, 0.38, 0.45, 1.0)]
Medium (M)	[(0.32, 0.41, 0.58, 0.65, 0.9), (0.28, 0.38, 0.6, 0.7, 1.0)]
Medium Good (MG)	[(0.58, 0.63, 0.8, 0.86, 0.9), (0.5, 0.6, 0.9, 0.92, 1.0)]
Good (G)	[(0.72, 0.78, 0.92, 0.97, 0.9), (0.7, 0.75, 0.95, 0.98, 1.0)]
Very Good (VG)	[(0.93, 0.98, 1.0, 1.0, 0.9), (0.9, 0.95, 1.0, 1.0, 1.0)]
Absolutely Good (AG)	[(1.0, 1.0, 1.0, 1.0, 0.9), (1.0, 1.0, 1.0, 1.0, 1.0)]

sponding 3D, AR and MR models from the Cloud and informs the drone about the selected heritage route. Subsequently, the drone flights along the selected route, while the captured 360^o video is enriched with the aforementioned 3D, AR and MR models and streamed to the user in real-time. Figure 3 illustrates the entire process.

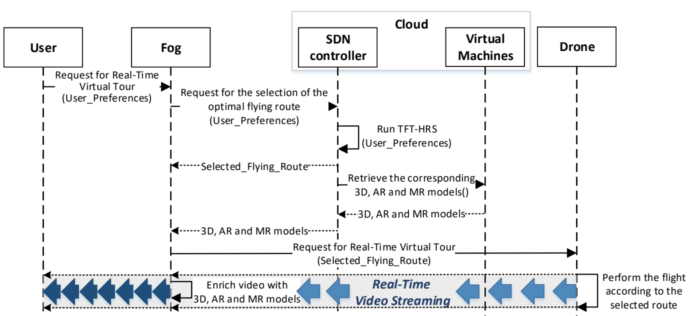

Fig. 3: The sequence diagram about the entire procedure.

Table V compares the results of the proposed scheme with the ones obtained using the FTOPSIS algorithm. A critical weakness of the FTOPSIS is that it does not support the existence of multiple monuments of the same monument type. Consequently, the FTOPSIS method considers only the first monument of each type, namely the Ancient Monument 1, the Byzantine Monument 1, the Modern Monument 1 and the Natural Beauty Monument 1, for the Ancient, Byzantine, Modern and Natural Beauty monument types, respectively. Both algorithms provide similar results for users 1 and 2, by selecting the route 7 and the route 4, respectively. However, for the rest of the users, the TFT-HRS outperforms the FTOPSIS, by selecting more appropriate heritage routes considering the evaluation values for multiple monuments of the same type that exist in each route. Specifically, in the case of user 3, who mostly prefers the Natural Beauty monuments, the TFT-HRS selects the route 8, which provides AG and VG for Natural Beauty 1 and Natural Beauty 2, respectively. On the contrary, for the same user, the FTOPSIS selects the route 7, which provides AG for Natural Beauty 1 but AP for Natural Beauty 2. Accordingly, in the case of user 4, who prefers both Ancient and Byzantine monuments, the TFT-HRS selects the route 7, which provides AG, AG, VG, G and AG values for Ancient Monument 1, Ancient Monument 2, Ancient Monument 3, Byzantine Monument 1 and Byzantine Monument 2, respectively. On the other hand, the FTOPSIS selects the route 3, which provides VG instead of AG for Ancient Monument 1, while the offered values for the rest of Ancient and Byzantine monuments are similar. Finally, in the case of user 5 who prefers Ancient and Natural Beauty monuments, the TFT-HRS selects the route 3, which provides AG for Natural Beauty 2, while the FTOPSIS selects the route 7, which provides similar values for the most Ancient and Natural Beauty Monuments, but AP for the Natural Beauty 2 monument.

IV. Conclusion

This paper proposes a scheme for the selection of drone navigation to support virtual tours in sites with cultural interest using drones. The proposed scheme is called TFT-HRS and selects the most appropriate heritage route for the drone, in order the user preferences about specific monument types to be satisfied. Thereafter, the drone flights along the selected route and captures video about the corresponding monuments. The video is transmitted to the user in real time, enriched with 3D, AR and MR material. The scheme is applied to a 5G architecture which includes a Cloud and a Fog infrastructure. Performance evaluation showed that the proposed scheme outperforms the FTOPSIS algorithm in terms of selecting the most appropriate drone navigation considering the users preferences about each monument type.

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TABLE IV: The available monuments for each heritage route.

Heritage Route	Ancient Monument 1	Ancient Monument 2	Ancient Monument 3	Byzantine Monument 1	Byzantine Monument 2	Modern Monument 1	Modern Monument 2	Modern Monument 3	Natural Beauty 1	Natural Beauty 2
Route 1	AG	G	VG	P	MP	AP	G	P	MG	MP
Route 2	VG	G	G	MG	AG	G	VP	M	AG	AP
Route 3	VG	AG	G	VG	AG	AP	AP	P	VG	AG
Route 4	AP	P	MP	VG	AG	AG	VG	MG	G	G
Route 5	P	MP	AG	G	MG	MG	VG	G	VG	AG
Route 6	G	MG	AG	AG	VG	MG	MG	AG	G	VG
Route 7	AG	AG	VG	G	AG	G	G	MG	AG	AP
Route 8	VG	AG	AG	VP	VG	P	AG	AG	AG	VG
Route 9	P	VP	VP	MP	MG	G	G	MG	VG	AG
Route 10	VG	AG	AP	P	AG	G	MG	MP	P	VG

TABLE V: Routes' classification in respect of TFT-HRS and FTOPSIS results.

	User 1		User 2		User 3		User 4		User 5	
Routes \ Method	TFT-HRS	FTOPSIS	TFT-HRS	FTOPSIS	TFT-HRS	FTOPSIS	TFT-HRS	FTOPSIS	TFT-HRS	FTOPSIS
Route 1	6	6	10	9	10	9	9	7	7	6
Route 2	5	3	6	6	9	2	4	4	6	2
Route 3	2	2	4	4	3	3	2	**1**	**1**	3
Route 4	9	8	**1**	**1**	6	8	7	6	10	10
Route 5	8	9	5	5	2	4	6	9	5	7
Route 6	3	4	2	2	5	7	3	3	3	5
Route 7	**1**	**1**	3	3	7	**1**	**1**	2	4	**1**
Route 8	4	7	9	10	**1**	5	5	8	2	4
Route 9	10	10	8	7	4	6	10	10	9	8
Route 10	7	5	7	8	8	10	8	5	8	9

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