



Fuzzy interval-valued multi criteria based decision making for ranking features in multi-modal 3D face recognition

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Abstract

This paper describes an application of multi-criteria decision making (MCDM) for multi-modal fusion of features in a 3D face recognition system. A decision making process is outlined that is based on the performance of multi-modal features in a face recognition task involving a set of 3D face databases. In particular, the fuzzy interval valued MCDM technique called TOPSIS is applied for ranking and deciding on the best choice of multi-modal features at the decision stage. It provides a formal mechanism of benchmarking their performances against a set of criteria. The technique demonstrates its ability in scaling up the multi-modal features.

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Keywords: 3D face recognition; Multi-modal features; Interval values; Evidential reasoning under uncertainty; Fuzzy fusion; TOPSIS; MCDM

1. Introduction

Face recognition systems benefit from multi-modal feature (MMF) sets and their performance can outway that of individual modalities [1]. Multi-modal systems utilise multiple information sources enabling increased performance, reliability and filling in missing information. MMFs play a key role in fusing information towards decision making in a face recognition system. In situations where several modalities may be identified such as multiple sensor configurations or combinations of feature sets, the problem becomes that of selecting the right modality for the application. The Cumulative Match Curve (CMC) which is a set of performance plots typically used in biometric systems may exhibit similar responses of the modalities under the same environmental conditions or the number of parameters to deal with are large making the feature selection process a difficult task. In such cases, subjective judgements that do not have a 100% certainty or due to lack of data or incomplete information lead to decision making under uncertainty [2].

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Table 1

Decision matrix represented as a table.

Alternatives	Criteria			
	C_1	C_2	$\dots$	C_n
	W_1	W_2	$\dots$	W_n
A_1	r_{11}	r_{12}	$\dots$	r_{1n}
A_2	r_{21}	r_{22}	$\dots$	r_{2n}
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
A_m	r_{m1}	r_{m2}	$\dots$	r_{mn}

1.1. Multi Criteria-Based Decision Making (MCDM)

Evidential reasoning (ER) denotes a body of techniques specifically for reasoning from evidential information [3]. ER requires two parameters namely a structure to encompass the collected evidence and a framework for evidence accumulation using fusion techniques [4]. Multi-Attribute Decision Making (MADM) or otherwise known as Multiple Criteria-based Decision Making (MCDM) refers to making decisions in the presence of multiple, usually conflicting set of criteria. Operations Research (OR) models have the capability of making decisions in the presence of multiple, usually conflicting criteria. They use mathematical programming techniques in a continuous decision space. MCDM techniques are a branch of the OR techniques except that they deal with discrete spaces where the set of decision alternatives is pre-determined. A key characteristic of MCDM techniques is that they use both qualitative and quantitative attributes for evidential reasoning which is ideal for modelling uncertainties dealing with incomplete and vague information [5–7]. MCDM techniques share certain common terminology as follows:

- **Alternatives:** Alternatives relate to the available options from which ranked selections are made.
- **Criteria or Attribute:** The MCDM is associated with a set of criteria or attributes that will impact the selection of the alternatives. An attribute is a property; quality or feature of alternatives being considered. Multiple criteria are typically organised into a set of sub-criteria or sub-attribute.
- **Weights** – Weights provide relative importance of criteria provided by decision makers.
- **Decision Makers (DMs)** – a set of experts providing weights to each criterion.
- **Decision Matrix** – a matrix that is used to make objective decisions from several options. DMs rate each criterion of each alternative.

An MCDM problem may thus be described by a decision matrix $\mathbf{D}$. Suppose that there are m alternatives that are assessed by n attributes or criteria, then $\mathbf{D}$ is an $m \times n$ matrix. An MCDM problem is typically described as a decision matrix as follows [8]:

$$\mathbf{D} = r_{ij} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix} \quad (1)$$

The set of alternatives is denoted by $A_1, A_2, \dots, A_m$ and the criteria denoted by $C_1, C_2, \dots, C_n$ and x_{ij} represent the rating of alternative A_i with respect to criteria C_j . When the ratings are described in linguistic terms, x_{ij} is replaced by r_{ij} . From a performance evaluation perspective, r_{ij} indicates the performance of alternative A_i when evaluated against the criteria C_j . The decision maker DM determines the weights W_j of relative performance of C_j . W_j may also be described linguistically. This information is as shown in Table 1. The MCDM problem then becomes that of determining the optimal alternative A_i given the set of criteria C_j that are to be met.

Popular MCDM techniques include ELECTRE (Elimination et Choice Translating Reality) [9], SAW (Simple Adaptive Weighting) [10], TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [8], AHP (Analytical Hierarchy Process) [8], ANP (Analytic Network Process) and SMART (Simple Multi Attribute Rating Technique) [11] to name a few. Some of these techniques have been benchmarked for a rigorous classification problem in [12]. Amongst the MCDM techniques, TOPSIS has the unique advantage of incorporating preferential group decision making given a set of alternatives. It defines a set of ideal solutions called *ideal positive* and *ideal negative* solutions which are used as reference points and with respect to which distance measures are computed as a logical process of ranking

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