Using MDS to Compute the Contribution of the Experts in a Delphi Forecast Associated to a Naval Operation's DSS

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Abstract. The Portuguese Navy gave financial support to THEMIS project under the aim of the development of a decision support system to get optimal decisions in short time in a disaster context, optimizing the decision chain, allowing to get a better performance of tasks execution allowing a reduction of costs.

In [14,17], the authors have considered the facilities and high qualified staff of Portuguese Navy and proposed a variant of the Delphi method, a method that is exceptionally useful where the judgments of individuals are considered as an important information source. They proposed a system that prioritize certain teams for specific incidents taking into account the importance of each team that acts in case of emergency.

In the present work we propose a distinct method of computing the weights that represent the importance given to experts opinion in the Delphi method used in [14,17] under the idea that shall not depend on the years of experience of each expert exclusively but also shall be considered the kind of expert experience. To justify this suggestion we have used hierarchical classification, allowing to identify different padrons for experts with the "same experience". Also discriminant analysis and multidimensional scaling revealed to be adequate techniques for this issue. We can classify the experience of each expert evaluating the similarity/distance between the individuals in the group of proposed experts and compare with the number of consensus presented.

In this manuscript we propose an alternative way of weighting the experts experience that contributes to a decision support system capable to prioritize a set of teams for certain disaster incidents involving maritime issues. The decision support system is still been tested but, with this work, we hope to have given an improvement to its optimization.

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1 Introduction

The decision support systems (DSS) appear as consequence of the new technologies and the urgency of optimal decisions in a short interval of time. We can observe DSS where there exists a decision chain so it can be optimized allowing to improve the performance of tasks, for example, in medicine, teaching, engineering, transportation [6,15,16]. Also it can be found in a maritime environment. In the case of a catastrophe, a DSS for naval operations would allow to improve all stages of intervention: reception of information on the incidents, tasks to execute, navigation orientation to incidents and advice how to perform the tasks.

The project THEMIS, promoted by Portuguese Navy has as purpose the construction and implementation of such DSS that will allow to handle with disaster relief operations, under naval context. Some contributions to THEMIS project can be found in [10–13] where the approach was performed some recent techniques such as augmented reality or user experience design.

We are particularly interested to build and implement a DSS with the ability to prioritize certain teams for specific incidents taking into account the importance of each team that acts in case of emergency, the sequence of tasks that should perform all possible orders to be given.

As the author of [15] says, the Delphi method is a method that is exceptionally useful where the opinions of individuals are needed to dilute the lack of agreement or incomplete state of knowledge. This method is particularly important due its ability to structure and organize group communication. In [5,8,18] we can find numerous examples of Delphi method applications. Some examples that illustrate the importance of Delphi method: transportation [6], in paper pulp production [7], the construction of an index in automotive supply chain [2,3], education [5], natural sciences [15], social policy [1].

We have applied the Delphi method to facilities and high qualified staff of Portuguese Navy [14,17].

Data collection is already complete. The obtained results depend on the weighting of experts experience. In the [14,17], the considered weights depend on the time of the expert service. In the present work, we evidence that these weights shall take into account not only the time of experience but the similarity of the experts opinion.

In Sects. 2 and 3 we describe some details about the proposed methodology and the previous work. The evidence of the improvement issue need is provided in Sect. 4. Also are done some conclusions and suggestions.

2 Multidimensional Scaling

The Multidimensional Scaling (MDS) is a multivariate technique that explores a set of multivariate measurements of individuals attributes, representing them in a reduced

dimensional system, identifying distinct latent variables associated to the individuals perception [4,9]. The main objective of MDS is the representation of attributes or individuals in a map of proximities (similarities) with a reduced dimension. We can notice that the data in MDS are similarities/dissimilarities, either measured or perceived or else computed from a set of attributes. The more general application of MDS is the classical MDS. When the data measure some attributes or characteristics, it is necessary to determine a distance between these attributes. When we have quantitative measures the usual distance is the Minkovski distance. In other case, it is usual to use the chi-square statistics for the contingency tables or the correlation coefficient.

Summarizing, the basic steps of MDS are: Assign a number of points to coordinates in a n-dimensional space (can be a 2-dimensional space, a 3-dimensional space, etc); Computation of distances for all pair of points (can be the Euclidean distance - a particular case of the Minkovski distance); Comparison of the similarity matrix with the original input matrix by evaluating the stress function (statistics that evaluates the differences of the actual distances and the estimated distances; The adjutment of coordinates, when necessary so can be minimized the stress.

3 Delphi Method - Round I

In this section, we will describe shortly the first round of Delphi method approach performed in [14,17].

To proceed with Delphi method, in a preliminary stage to first round of questionnaires, the potential group of experts were inquired about some individual characteristics of their profile: age, gender, professional rank, training class, type of experience in response to disasters (real versus train exercise) and the total ship boarding time (less than 1 year, 1–3 years, 3–5 years, more than 5 years).

With the objective of identifying the degree of priority that which each team should carry out each task, the same group also performed a questionnaire classified in a Likert scale of importance from 1 (Not Important) to 6 (Extremely Important) all possible tasks to be carried out during a humanitarian disaster relief operation for each existing team that can provide its service in the concerned operation (consult all tasks and all possible teams described below).

The questionnaire considered 52 tasks described in Table 1.

Also, the questionnaire included eleven teams as displayed in Table 2.

A total of 572 questions were classified on a Likert scale of 1 to 6. Each expert should answer to questions, indicating the degree of confidence of the given answer and how much experience had with each team previously.

In the first round of questionnaires, 12 experts were considered, all males with at least 5 years on board, all aged between 35 and 54 years, with positions of Captain-lieutenant, Captain-of-sea-and-war and Captain-of-frigate (the most common). Between all experts only 25% have real past experience of disaster response. The remaining 75% experts are training experienced.

To identify the tasks that reached consensus is necessary to determine the Inter-Quartile Range (IQR), that is, the difference between the 1st Quartile and the 3rd Quartile. IQR represents 50% of the observations closest to the median. When IQR is less

Table 1. Collected tasks. Source [14].

Identify incidents	Repair electrical power system
Screen survivors / homeless and injured	Repair communications system
Provide 1st aid	Repair of lighting system [point of interest]
Census individuals	Repair mechanical energy production system
Identify location for [point of interest]	Repair power distribution system
Transport equipment to install [point of interest]	Recover basic sanitation
Mount [point of interest]	Create safety perimeter
Carrying severe injuries	Ensuring perimeter safety
Stabilize serious injury	Impose order and safety
Carry minor injured	Carry out order and safeguard of goodies and property
Rescue imprisoned victim	Carry out flight operations to transport material
Rescue victim from altitude	Perform flight operations for medical evacuations
Rescue victim in collapsed structure	Transport material [type] from [local] to [local]
Rescue isolated victim by land	Shift escort
Rescue single victim by air	Convey distribute food for the wounded
Rescue an isolated victim via water	Convey and Distribute food
Stabilize structures	Dead transport to morgue
Clear paths	Support the funeral ceremony
Build support structures for rescue	Status report
Fire fighting	Evacuate equipment to [point of interest]
Fighting floods	Evacuating population to [point of interest]
Carrying out shoring	Diving for minor repairs
Diving drinking water	Diving for rescue
Restoration of water supply	Evacuation of animals
Control of water leaks	Distribution of animal feed
Repair electric pumping system	Burying dead animal

than 1 it means that more than 50% of the responses obtained are within 1 point of the Likert scale [5].

To process the questionnaires data and classify each one as consensual/no consensual, was necessary to compute a weighted mean (WM), where the weights are based on the experience of each expert responded to with each team. These weights evaluate the individual time of service. Notice that the opinion of a more experienced expert has a more significant weight in the weighted mean of the importance of a certain team and vice-verse. See Table 3.

For the tasks with an IQR greater than 1, was assumed that the experts have not reached a consensus on how important a certain team is to perform a specif task. In this way it will be considered in the next round of questionnaires.

When a task has an IQR less or equal than one, is necessary to analyze its distribution of frequencies. Can be seen that the answer distribution per task is, come times, non consensual. In this case, it was proposed a new criterion: there is no consensus on all questions when there are 2 or more non-adjacent levels of importance that account for at least 20% of the sum of weighted levels of experience.

By the proposed rule, the first round of questionnaires, between the 572 questions, there was no consensus on 290 questions (50.7%), from which 282 have an IQR higher than 1; between the tasks with IQR less or equal to one, only 8 did not meet the requirements of the proposed methodology. These total of 290 questions are included in next round of questionnaires.

Table 2. Available teams. Source [14].

Reconnaissance	Water and Sanitation Technique Brigade
Search and Rescue - SAR	Mechanical Engineering Brigade
Search and Rescue Urban - SAR URB	Technical Brigade of Electricity
Search and Rescue Structures - SAR EST	Supply
Brigade Firefighting Technique	Food
Medical	

Table 3. Weights as function of level of experience of each expert.

Level of experience	Weight
1	0.1
2	0.5
3	0.9
4	1.1
5	1.5
6	1.9

4 Proposal

Here, we present the motivation of improving the table of weights Table 3 in the first round to get the WM. The initial weights depend on the individual time of service (see the Table 3). Notice that the opinion of a more experienced expert has a more significant weight in the weighted mean of the importance of a certain team and vice-versa. But

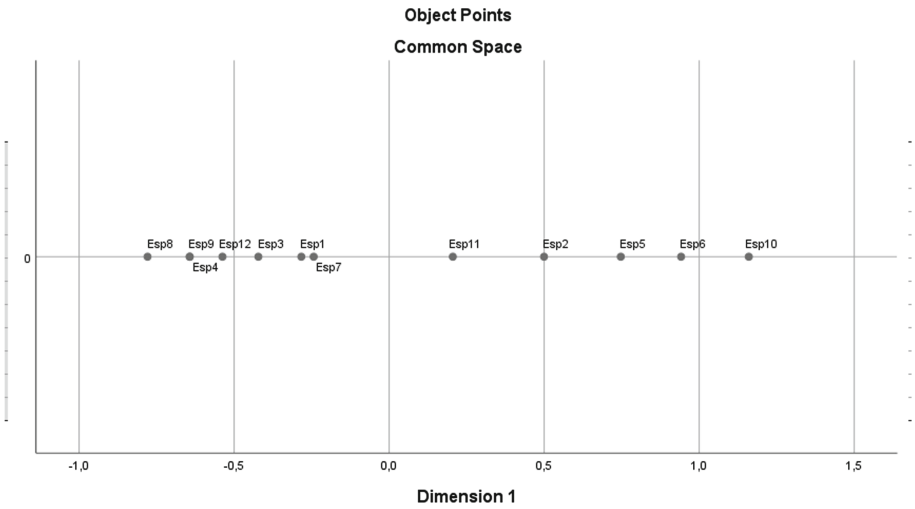

Fig. 1. Global position, dimension 1. The different experts appears in a different order for dimension 1. SAR-REC.team.

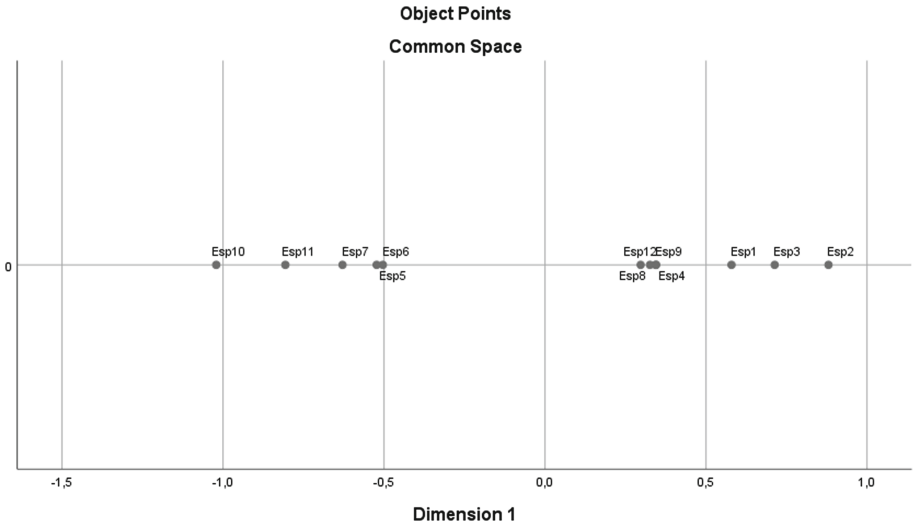

Fig. 2. Global position, dimension 1. The different experts appears in a different order for dimension 1. SAR-URB team.

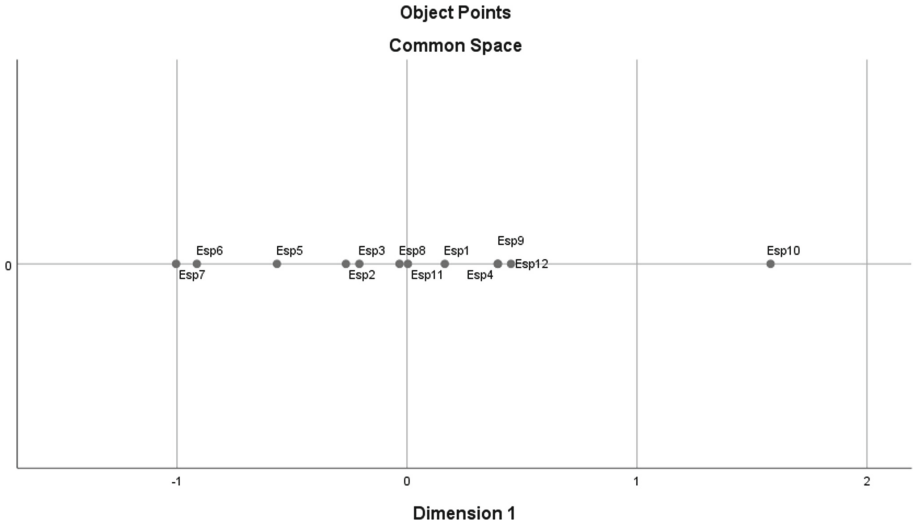

Fig. 3. Global position, dimension 1. The different experts appears in a different order for dimension 1. SAR-ST team.

the experts details, in what specific area shall have a bigger weight or a lower weight is not contemplated in the initial phase. As a first glance, we have performed a hierarchical classification of the experts per task/team. The associated dendograms presented different profiles for distinct tasks. The clusters of individuals were distinct from task to task. The discriminant analysis corroborated with that: the profile of the experts were

distinct per task/team. We propose to analyze the proximity of experts per specific team. We have tested some teams and studied the measures of proximity between the experts using multidimensional scaling, algorithm PROXSCAL that minimizes the normalized raw stress. We can give as example, the proximity of the twelve experts has a distinct tip when we consider the SAR-URB, SAR-REC or SAR-EST as we can see in Figs. 1, 2, 3, where the different experts appears in a different order for dimension 1 (we have considered a 2D space, but, for simplicity we represent the 1D space). Also, the measure of distance between experts about the same teams has distinct patterns (see Figs. 4, 5, 6). These facts suggest that the Table 3 can be reformulated taking into account the similarity of the experts per each team. The details about the analysis of results per round using this proposal will be available in an extended version of the this article.

Distances

Dimensionality: 1

	Esp1	Esp2	Esp3	Esp4	Esp5	Esp6	Esp7	Esp8	Esp9	Esp10	Esp11	Esp12
Esp1	.000											
Esp2	1.164	.000										
Esp3	1.810	.646	.000									
Esp4	.411	.753	1.399	.000								
Esp5	1.357	.193	.453	.946	.000							
Esp6	.129	1.035	1.681	.282	1.228	.000						
Esp7	.867	.296	.943	.456	.490	.738	.000					
Esp8	.687	.477	1.123	.276	.670	.558	.180	.000				
Esp9	.411	.753	1.399	.000	.946	.282	.456	.276	.000			
Esp10	1.033	.131	.777	.622	.324	.904	.166	.346	.622	.000		
Esp11	1.523	.359	.287	1.112	.166	1.394	.656	.836	1.112	.490	.000	
Esp12	1.674	.510	.136	1.263	.317	1.545	.807	.987	1.263	.641	.151	.000

Fig. 4. Distance between experts. The different experts appears distinct distances with each other when we consider different teams. SAR-REC team.

Distances

Dimensionality: 1

	Esp1	Esp2	Esp3	Esp4	Esp5	Esp6	Esp7	Esp8	Esp9	Esp10	Esp11	Esp12
Esp1	.000											
Esp2	.301	.000										
Esp3	.134	.167	.000									
Esp4	.235	.536	.369	.000								
Esp5	1.102	1.403	1.236	.867	.000							
Esp6	1.083	1.384	1.217	.848	.019	.000						
Esp7	1.208	1.509	1.342	.973	.106	.126	.000					
Esp8	.253	.555	.387	.019	.849	.829	.955	.000				
Esp9	.235	.536	.369	.000	.867	.848	.973	.019	.000			
Esp10	1.600	1.901	1.734	1.366	.498	.518	.392	1.347	1.366	.000		
Esp11	1.385	1.687	1.520	1.151	.284	.303	.177	1.132	1.151	.215	.000	
Esp12	.282	.583	.416	.047	.820	.800	.926	.029	.047	1.318	1.103	.000

Fig. 5. Distance between experts. The different experts appears distinct distances with each other when we consider different teams. SAR-URB team.

Distances

Dimensionality: 1

	Esp1	Esp2	Esp3	Esp4	Esp5	Esp6	Esp7	Esp8	Esp9	Esp10	Esp11	Esp12
Esp1	.000											
Esp2	1.164	.000										
Esp3	1.810	.646	.000									
Esp4	.411	.753	1.399	.000								
Esp5	1.357	.193	.453	.946	.000							
Esp6	.129	1.035	1.681	.282	1.228	.000						
Esp7	.867	.296	.943	.456	.490	.738	.000					
Esp8	.687	.477	1.123	.276	.670	.558	.180	.000				
Esp9	.411	.753	1.399	.000	.946	.282	.456	.276	.000			
Esp10	1.033	.131	.777	.622	.324	.904	.166	.346	.622	.000		
Esp11	1.523	.359	.287	1.112	.166	1.394	.656	.836	1.112	.490	.000	
Esp12	1.674	.510	.136	1.263	.317	1.545	.807	.987	1.263	.641	.151	.000

Fig. 6. Distance between experts. The different experts appears distinct distances with each other when we consider different teams. SAR-ST team.

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