Classification of Delphi outputs through robust ranking and fuzzy clustering for Delphi-based Future Scenarios

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1. Introduction

In the context of Futures Studies the Delphi method is widely used, and one of its most popular benefit concerns the construction of future scenarios. In most cases, the passage from the Delphi outputs to the scenarios is qualitative/subjective (von der Gracht and Darkow, 2010). In other studies, quantitative methods are exploited, and the key drivers identified with the Delphi are grouped by using cluster analysis (Tapio, 2002). Some authors propose fuzzy clustering approaches, which allow the inclusion of items that are in common between two or more scenario (Roßmann et al., 2018). Here we propose an advancement by using a robust ranking method, to combine the evaluations of the Delphi's panelists, before the application of the fuzzy clustering. The method is very flexible and with an application we also show as the ranking of the items does not depend on the expertise of the participants.

2. Delphi-based scenarios

In the context of Futures Studies, the Delphi can be used in various ways, but one of the most popular concerns the combination with the scenario development. A future scenario is a description of a possible future situation together with the paths of development leading to that future (Kosow and Gaßner, 2008). By using quantitative methods to classify the Delphi projections (e.g. cluster analysis; Tapio, 2002), some critical issues remain, because if a proper distance for ordinal data is not used, the results are distorted. Furthermore, the cluster analysis does not allow the detection of potential intersections of projections across scenarios. Therefore, here we suggest the fuzzy clustering approach (Roßmann et al., 2018).

3. Disadvantages of current methods

Any expert's judgement is measured on ordinal scales, therefore it is not recommended to use the Euclidean distance to compare evaluations. It is only possible to say that one judgement is greater, equal or less than the other. Other drawbacks of the current methods regard the selection of the experts and the measurement of their expertise. The validity of the self-rating is questioned, because problems on the psychological and cognitive sphere are involved (e.g. overoptimism and overconfidence biases). To overcome the above-mentioned issues we propose a method for generating robust ranks of Delphi's projections independent of the level of expertise of the panelists and in which the distance between projections is not relevant.

4. Robust ranking of experts' opinions

Let $\boldsymbol{X}$ be the matrix of scores: X_{ei} denotes the score given by expert $e = 1, \dots, E$ to item $i = 1, \dots, I$. Common approach for a summary is the arithmetic mean: $M_i = \frac{1}{E}\sum_{e=1}^{E} X_{ei}$ but it has several shortcomings (e.g. all experts have the same weight). Given a vector of weights $\boldsymbol{W} = (W_1, W_2, \dots, W_E)$ we have a weighted arithmetic mean: $M_i' = \frac{\sum_{e=1}^{E} X_{ei} W_e}{\sum_{e=1}^{E} W_e}$. But the vectors of expert's scores $X_{e1}, \dots, X_{eI}$ have different locations and variability and cannot be directly combined. Before combining, normalization is necessary: ${}_1Y_{ei} = \frac{X_{ei}}{max_i X_{ei}}$, ${}_2Y_{ei} = \frac{X_{ei} - M_e}{SD_e}$, ${}_3Y_{ei} = \sum_{h=1}^{I} \delta(X_{ei} \geq X_{eh})$, where *M* denotes the mean, *SD* the standard deviation and δ the indicator variable. We obtain the weighted means: ${}_1M_i' = \frac{\sum_{e=1}^{E} \frac{X_{ei}}{max_i X_{ei}} W_e}{\sum_{e=1}^{E} W_e}$, ${}_2M_i' = \frac{\sum_{e=1}^{E} \frac{X_{ei} - M_e}{SD_e} W_e}{\sum_{e=1}^{E} W_e}$, ${}_3M_i' = \frac{\sum_{e=1}^{E} (\sum_{h=1}^{I} (X_{ei} X_{eh})) W_e}{\sum_{e=1}^{E} W_e}$. By multiplicative rules, we have also: ${}_1G_i' = \left(\prod_{e=1}^{E} \left(\frac{X_{ei}}{max_i X_{ei}}\right)^{W_e}\right)^{\frac{1}{\sum_{e=1}^{E} W_e}}$, ${}_3G_i' = \left(\prod_{e=1}^{E} \left(\sum_{h=1}^{I} (X_{ei} X_{eh})\right)^{W_e}\right)^{\frac{1}{\sum_{e=1}^{E} W_e}}$. Every M' and G' has its pros and cons so we consider simultaneously all by applying the uncertainty analysis through a Monte Carlo procedure, so that the result does not depend on the formula used to combine experts' scores. With m Monte Carlo iterations we obtain a $m \times I$ matrix $\boldsymbol{S} = [s_{di}]$ whose d-th row $s_{d1}, \dots, s_{dI}$ contains the summary scores according to the formula selected in the d-th step. Follows the rank matrix $\boldsymbol{R} = [r_{di}]$, whose d-th row $r_{d1}, \dots, r_{dI}$ has the I item ranks corresponding to the d-th formula of the summary score. The i-th column of $\boldsymbol{R}$ $(r_{1i}, \dots, r_{mi})$ is the vector of ranks for item i considering m different summary formulas. The median of the rank vector is almost independent on the formula and the variability of the ranks can be assessed computing the 5th–95th percentile interval of the rank vector.

5. Application

To apply the method we used the results of a Delphi study on the development of future projections of the key variables (41 projections) that will led the future of the families in the north-east of Italy.

Figure 1. Medians of the ranks for Relevance and Evolution

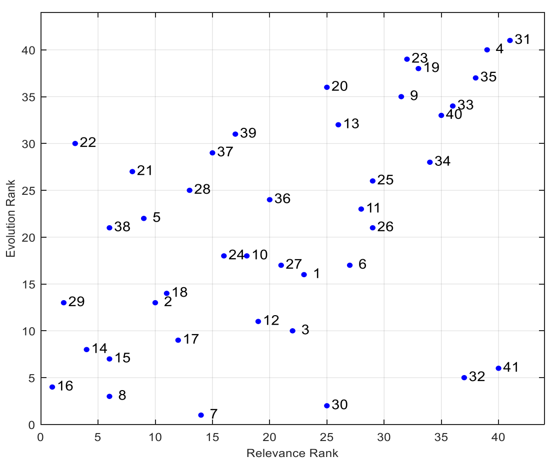


Figure 2. Robust ranking of projections for Relevance. 5th–95th percentile variab. interval as a vertical segment.

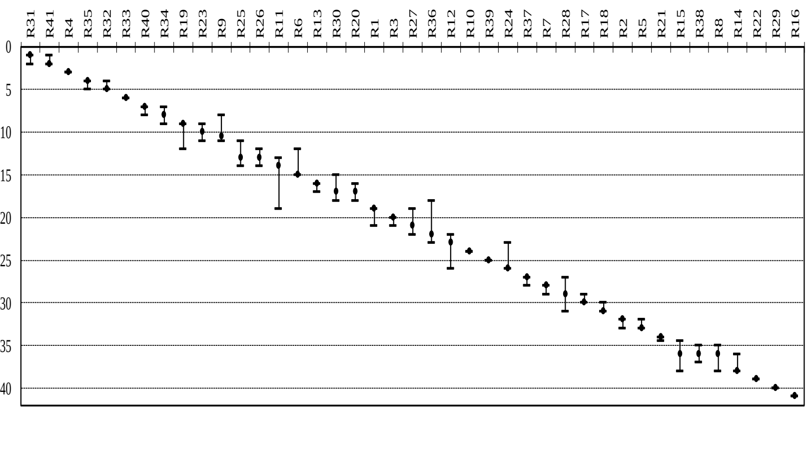
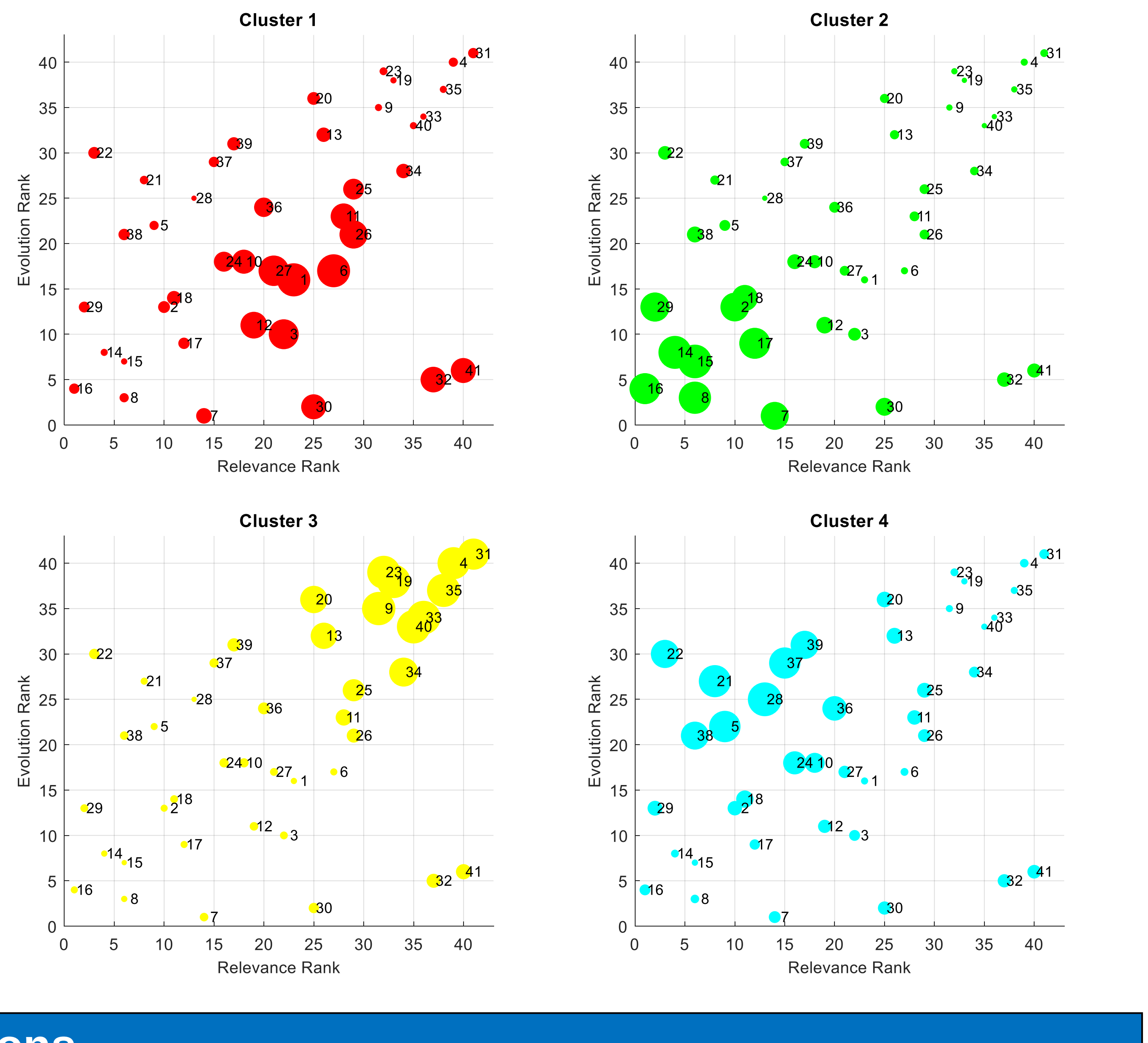


Figure 3. Plots of the clusters with highlighted the degree of memberships (large points = major degree)



6. Results

Medians of the ranks for Relevance and Evolution are shown in Fig. 1. By fuzzy clustering ("fclust" R package) the ranks on Relevance (Fig. 2) and Evolution of the projections, we obtained four groups of projections, which are the bases for the development of the future scenarios (Fig. 3). Accordingly, a substantive analysis produced the following scenarios: 1. The family: parents and children; 2. The family and the private sphere; 3. Family: relationships and vulnerabilities; 4. The family and the public sphere.

6. Conclusions

We proposed a method for generating robust ranks of Delphi projections, suitable as input for fuzzy clustering. Then, the resulting clusters can be used as a base for the construction of Delphi-based scenarios. The method is very flexible and, regardless of the Delphi and the scenarios, can be adapted to classify any kind of variables derived from subjective judgments.

References

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