

Linguistic-Summary–Based Feature Selection for Qualitative Decision Support

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ABSTRACT

Qualitative decision models such as DEX rely on a hierarchical aggregation of elementary criteria into interpretable decision rules. While this structure supports transparency and explainability, it also makes model construction sensitive to the number and interdependence of elementary criteria. This paper proposes a decision-aware feature selection approach that supports parsimonious DEX modelling by explicitly accounting for directional relevance and redundancy among candidate criteria. The method employs linguistic summaries to estimate asymmetric dependencies enabling features to be ranked by their directional influence on the decision concept and pruned when mutually redundant. Applied to internal migration modelling in Serbia, the approach reduces a highly interdependent socio-economic feature set to a smaller number of interpretable and policy-relevant criteria, despite weak correlations with the target variable. The results demonstrate that linguistic-summary–based directional analysis can uncover meaningful regularities not captured by symmetric measures and provide a bridge between numeric data analysis and qualitative decision support modelling.

Keywords: Decision Support Systems, Feature Selection, Fuzzy Logic, Internal Migration, DEX

INTRODUCTION

In DEX models, elementary criteria form the lowest level of the decision hierarchy and are subsequently aggregated into higher-level concepts using qualitative IF–THEN rules [1]. While this hierarchical structure is central to DEX interpretability, it also imposes a constraint. The number and interdependence of elementary criteria directly affect the size and complexity of the decision rules base [9]. Consequently, feature selection in DEX is of structural clarity and explainability. A challenge is that while dependencies among elementary criteria are often strongest at the lowest level of the hierarchy, retaining multiple highly dependent criteria increases redundancy and inflates the rule base

without adding substantively new information or skew existing one. Traditional correlation analysis, however, is insufficient for guiding principled reduction, as correlation is symmetric and provides no indication of which criterion should be preferred when simplifying the model.

To address this, we adopt a directional dependency perspective based on linguistic summaries (LSs). For each pair of variables, we estimate asymmetric influence of the form “*most of A implies B*” and “*most of B implies A*”. This approach allows us to distinguish in which direction the relationship is stronger. Importantly, LSs are computed directly on numeric data using overlapping fuzzy partitions, avoiding information loss introduced by (premature) discretization of data and mitigating smaller data imprecision [7].

We propose a DEX-oriented feature selection procedure that identifies a compact, non-redundant set of elementary criteria aligned with qualitative decision modelling. Candidate features are first evaluated and ranked using LS-based directional influence toward the decision concept, favouring strong and asymmetric feature–target relationships. Redundancy among retained features is resolved through pairwise dependency analysis returning a final set of features.

This work contributes to the decision support systems literature in three ways. First, it introduces a feature selection mechanism that is explicitly aligned with qualitative, rule-based decision models. Second, it operationalizes directional dependency using LSs. Third, it demonstrates the practical applicability of the approach on an internal migration decision problem in Serbia.

BACKGROUND

Qualitative hierarchical decision models are a core approach in decision support systems when decision problems are complex and require transparent reasoning rather than purely numerical optimization. In this family, DEX is widely recognized as a hierarchical, qualitative, rule-based decision modelling method that represents criteria using symbolic value scales (e.g., *low/medium/high*) and aggregates them via IF–THEN rules organized in decision tables [1]. The method has been applied across diverse real-world domains, and prior work [2] emphasizes DEX’s strength in supporting explanation and analysis (e.g., *what-if* analysis).

Despite its interpretability advantages, DEX places a practical burden on model construction. As the number of elementary criteria increases, rule bases grow rapidly, and validation becomes harder. This creates a fundamental tension familiar in DSS [11]. In qualitative hierarchical models, selecting and pruning elementary criteria is not merely a data-preprocessing step, it is a model design choice that affects transparency, completeness, and the feasibility of rule elicitation. A body of literature has explored feature selection through multi-criteria lenses, including approaches that explicitly cast feature selection as an MCDM problem [5]. However, these methods generally target predictive modelling pipelines and rarely confront the qualitative rule-base complexity that is specific to DEX-style models. This gap motivates decision-aware feature selection methods that prioritize structural parsimony and explainable simplification, not only accuracy.

A common baseline for redundancy detection is correlation, but correlation is a symmetric measure. It can indicate that two criteria co-vary but cannot support an argument about directionality. This is a critical limitation because modelers need a clear rationale for preferring one criterion over another when both are related. Contrary, LSs reveals patterns like “*high values of A are almost always associated with high values of B, while the opposite direction is weaker*”, that are often interpretable. LS provides a mature framework for expressing dependencies using natural-language terms formalized by fuzzy sets and logic [6].

We argue that LSs are a natural fit for DEX-oriented feature selection. LSs offer a dependency explanation that is (i) computable on numeric data via fuzzy sets and (ii) expressible in the same linguistic style used in DEX decision rules. Moreover, LSs can support the specific need of calculating a directional dependency (e.g., “*most of A implies B, while about half of B implies A*”).

METHODOLOGY

The goal of the proposed feature selection procedure is to construct a compact, non-redundant set of elementary criteria, while preserving interpretability and directional relevance to the decision concept. While conventional feature selection methods optimize predictive accuracy alone, our approach is aligned with the structural requirements of qualitative decision models. The procedure consists of three sequential steps:

- Each candidate feature is evaluated with respect to the target variable using fuzzy LSs to quantify directional influence (feature \rightarrow target).
- Features are ranked by their net directional contribution to the target, rewarding strong influence toward the target while penalizing reverse influence.
- Pairwise dependencies among retained features are analysed to identify redundant predictors.

To explain the procedure in more detail, we introduce $X = \{X_1, X_2, \dots, X_p\}$ as the set of candidate numeric features, and Y as the target decision variable. All computations are performed on numeric data using fuzzy partitions shown in Figure 1.

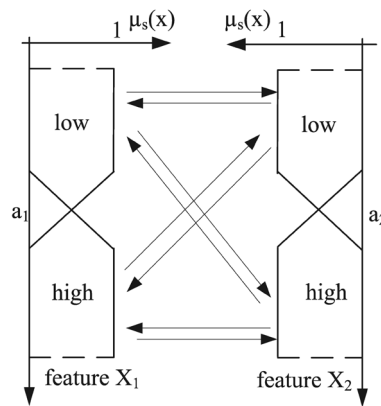


Figure 1: Fuzzy partitions of two features and dependencies between their respective subdomains

Positive correlation indicates that we should compute validities of linguistic summaries [6], see Figure 1:

- ls_1 : most of low values of criterion X_1 has low values of criterion X_2
- ls_2 : most of low values of criterion X_2 has low values of criterion X_1
- ls_3 : most of high values of criterion X_1 has high values of criterion X_2
- ls_4 : most of high values of criterion X_2 has high values of criterion X_1 .

Analogously, the negative correlation indicates that we should explore the following summaries:

- ls_5 : most of low values of criterion X_1 has high values of criterion X_2
- ls_6 : most of high values of criterion X_2 has low values of criterion X_1
- ls_7 : most of high values of criterion X_1 has low values of criterion X_2
- ls_8 : most of low values of criterion X_2 has high values of criterion X_1 .

To avoid the influence of outliers, parameter a (Figure 1) is calculated as a median of feature values.

Next, we compute arithmetic mean (latter used as influence I) of ls_1 and ls_3 - how criterion X_1 influences criterion X_2 ; then I of ls_2 and ls_4 - how criterion X_2 influences criterion X_1 for positive correlation. For negative correlation arithmetic means I of ls_5 and ls_7 - how criterion X_1 influences criterion X_2 ; as well as I of ls_6 and ls_8 - how criterion X_2 influences criterion X_1 .

For all linguistic summaries we have the same function for quantifier *most of*:

$$\mu_{most\ of}(p) = \min \left[1, \max \left(0, \frac{p - m}{n - m} \right) \right] \quad (1)$$

where p denotes the proportion (or degree) to which a linguistic statement holds.

To address the first step of the proposed procedure, for each feature $X_i \in X$, we estimate its directional influence on the target Y using above explained linguistic summaries where X_i is replaced by Y . Analogously, we compute the reverse influence $I_i(Y \rightarrow X_i)$.

In the second step, we evaluate the net contribution of each feature to the decision concept, we define a directional score:

$$S(X_i) = I(X_i \rightarrow Y) - I(Y \rightarrow X_i) \quad (2)$$

This score rewards features that predominantly influence the target while penalizing features whose association is primarily reactive or bidirectional. Features are retained if they satisfy:

$$I(X_i \rightarrow Y) \geq \tau_{inf}, \quad S(X_i) \geq \tau_{asym} \quad (3)$$

where τ_{inf} is a minimum influence threshold and τ_{asym} enforces directional dominance. Finally, to prevent the inclusion of multiple elementary criteria that encode largely overlapping information, we detect redundancy by analysing all pairs (X_i, X_j) . For each pair, we compute bidirectional influences:

$$I(X_i \rightarrow X_j), \quad I(X_j \rightarrow X_i) \quad (4)$$

and define a symmetric dependency measure:

$$R(X_i, X_j) = \frac{1}{2} \left(I(X_i \rightarrow X_j) + I(X_j \rightarrow X_i) \right) \quad (5)$$

We complement this with the absolute Pearson correlation $|\rho(X_i, X_j)|$. Two features are considered redundant if:

$$R(X_i, X_j) \geq \tau_{red}, \quad |\rho(X_i, X_j)| \geq \tau_{\rho} \quad (6)$$

Redundancy is resolved greedily by retaining the higher-ranked feature (according to $S(\cdot)$, Eg. (2)) and discarding the other. The final output of the procedure is a compact set of elementary criteria that exhibit strong directional relevance to the decision concept and are minimally redundant with respect to each other.

However, the approach entails several limitations. First, directional influence derived from LSs captures associational rather than causal relationships. Second, the method depends on the choice of fuzzy partitions, quantifier parameters, and threshold values, which may influence the resulting feature set and require domain-sensitive tuning. Third, pairwise redundancy analysis does not account for higher-order interactions among features, which may lead to residual redundancy. Despite these limitations, the method is well suited to decision support contexts where transparency, justification, and structural parsimony are important.

RESULTS AND DISCUSSION

The proposed feature selection procedure is evaluated on a problem of internal migration dynamics in Serbia at the level of cities and municipalities. The decision variable Y represents the ratio of immigrations interpreted as the decision concept in the DEX model. The candidate feature set $X = \{X_1, X_2, \dots, X_p\}$ comprises of indicators including population density, ageing structure, per-capita education and healthcare expenditures, municipal revenues and expenditures, development incentives, healthcare availability, employment and unemployment rates, income levels, housing construction, school capacity, transport infrastructure, and tourism intensity. All data is publicly available and retrieved from the open data repository of the Statistical office of the Republic of Serbia.

All variables are treated as numeric and analysed on their original measurement scales where two fuzzy set partition (Figure 1) is used, with smooth transitions between sets (parameter a as median and 20 % offset). Dependencies are quantified using quantifier *most of*(1) with $m = 0.5$ and $n = 0.9$.

Candidate features were first screened for directional relevance to the decision variable using LSs, then ranked by their net directional contribution (with $\tau_{inf} = 0.2$ and $\tau_{asym} = 0.0$), and finally pruned for redundancy based on pairwise dependency analysis (with $\tau_{red} = 0.4$, and $\tau_p = 0.8$).

Result is a compact set of four elementary criteria for modelling the ratio of immigrations: *Ageing index*, *Per capita expenditure of the budget of cities and municipalities*, *Emigrants per 1,000 inhabitants*, and *Average annual net salaries and wages*. All selected features satisfied the minimum directional influence threshold toward the target and were not eliminated by redundancy pruning. A notable result is that none of the selected features exhibits strong linear correlation with the target. Correlation values are weak to moderate and, in some cases, close to zero. Nevertheless, these features were retained due to their directional linguistic influence on the ratio of immigrations.

This divergence between correlation and directional influence is central to the motivation of the approach. Traditional correlation-based screening would likely discard several of these variables, particularly *Ageing index* and *Emigrants per 1,000 inhabitants*. However, the LSs reveal that these variables satisfy statements of the form “*most of low/high values of X_i are associated with corresponding levels of immigration*” to a degree that is both stable and asymmetric.

Prior DEX/DSS studies on internal migration in Serbia similarly emphasize transparency, parsimony, and decision usability over exhaustive indicator coverage. In comparison with [3], which highlight income, quality-of-life, and socio-economic conditions as central migration drivers, our results retain wages and demographic structure while additionally highlighting municipal fiscal capacity as a distinct, actionable lever for policy-oriented decision support. By contrast, recent work employing large language models to identify migration factors [10] emphasizes a broader set of infrastructure and service-access indicators, including transport, education, and healthcare availability. Interestingly, feature set aligns with findings from predictive migration studies outside Serbia, such as those reported by [8] for Germany and [4] for Poland. Taken together, these results show that LS-based directional feature selection can recover meaningful and policy-relevant drivers of internal migration while substantially reducing model complexity.

CONCLUSIONS

This paper proposed a DEX-oriented feature selection approach that explicitly accounts for the structural and cognitive requirements of qualitative decision models. By using linguistic summaries to estimate directional dependencies, the method moves beyond symmetric association measures and provides a principled basis for ranking, selecting, and pruning elementary criteria. Applied to internal migration modelling in Serbia, the approach reduced a highly interdependent feature set to a small number of interpretable and policy-relevant criteria while preserving substantive coherence with established migration research.

The results demonstrate that proposed approach can reveal meaningful regularities that are not

captured by correlation alone and can effectively control redundancy. Rather than aiming to maximize predictive accuracy, the proposed method supports transparent model construction and decision-oriented interpretation. As such, it offers a practical bridge between numeric data analysis and qualitative decision support, with potential applicability to a wide range of decision problems where explainability and parsimony are essential.

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