Addressing the limitations related to thresholds in scoring-based decision support tools through graphical visualisation

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Abstract

The purpose of this paper is to analyse the challenges, identify the limits of traditional scoring systems, and propose solutions for selected ones to overcome them. Health and finance are generally considered the most critical areas of application of scoring systems, as scores can directly affect a person's life or quality of life. Other areas, for example, education, performance evaluation, human resources, justice, public safety, customer relationship management, marketing, and sports, are also important, but with less immediate effect. The domain of medical diagnostics was selected as the primary area for implementation, testing, and validation of the proposed solutions.

Keywords: decision-making, scoring systems, scoring limitations, cirrhotic portal hypertension, graphical visualisation.

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1 Introduction

A scoring system is a structured approach that assigns numerical values to various criteria/parameters in order to evaluate and compare different options objectively. This method, often used in multi-criteria decision analysis, helps in prioritizing options based on their overall score, facilitating a more informed and transparent decision-making

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process. Consequently, this leads to more data-based and evidence-based decisions. Traditional scoring systems play a significant role as effective decision-making tools.

Traditional scoring systems have shown great potential in supporting decision-making from the very beginning. This is primarily due to their high degree of objectivity and consistency by reducing human bias, applying the same approach and rules to all cases/precedents, and leading to fairer and more explainable decisions. The requirement for clearly defined scoring criteria ensures that the outcomes are traceable and justifiable. Additionally, quantifying qualitative factors – often subjective or complex – into measurable values facilitates the comparison between different options or precedents. Most importantly, scoring systems can be integrated into digital tools and algorithms, enabling quick, data-driven decisions, which are particularly useful when managing large volumes of data, facilitating the automation of the decision-making process. These factors have led to the rapid and widespread adoption of this important decision-making tool.

However, its practical application has revealed several significant limitations. These include the excessive simplification of complex issues; subjectivity in weighting criteria; lack of flexibility in dynamic environments; and excessive dependence on source reliability and data accuracy. These limitations may lead to hesitation in the use of scoring systems.

2 General and domain-specific limitations of scoring systems

Although traditional scoring systems offer objectivity, a structured environment, and visualisation in decision-making processes, it is essential to recognize their limitations. The most well-known issue is the excessive simplification of complex situations. This problem can arise even in the initial stages of score creation – the selection of insufficiently justified parameters in the basic set of the scoring criteria, or a data source with a low degree of reliability. Additionally, concerns regarding subjectivity, bias, and flexibility pose significant challenges for traditional scoring systems.

To identify and systematise the most important limitations and challenges of traditional scoring systems, we reviewed the relevant literature in the domains of decision-making, traditional scoring systems, decision intelligence, dynamic environments, and related areas.

As a result, the following limitations were identified:

- Reducing complex situations to the analysis of a set of criteria and ultimately to a single score may overlook context, nuances, or important qualitative factors.
- Small differences in scores that are close to the thresholds can lead to significantly different conclusions, sometimes resulting in dramatic differences. End-users perceive this issue as score rigidity.
- Lack of regular updates or adaptability to changing environments or user behaviour/preferences; also, perceived as score rigidity.
- The final result is heavily dependent on the quality, completeness, and impartiality of the data, as well as trust in its source.
- Creation of a false sense of confidence and accuracy, neglecting additional context that should influence the final decision.

Subsequently, to identify any specific limitations of the scoring systems used in the selected primary area of study, as well as any specific nuances related to previously identified limitations in this domain, we conducted an analysis of information systems in the field of medical diagnostics.

Scoring systems are deeply embedded in almost every formal approach to medical decision-making. They may be used explicitly, such as in risk calculators and cut-off values, or implicitly, as seen in the embedded weights within models or AI. Scoring systems are universal connectors across approaches: in rule-based systems, they formalize knowledge; in statistical models, they simplify complex mathematics; in ML/AI, they make outputs interpretable; in knowledge-based systems, they operationalize alerts; in shared decision-making, they communicate risk; in intuition-based practice, they check human biases.

For the most part, the limitations remain the same across various fields; however, the weighting and nuances change when applied to specific areas like health, finance, engineering, law, etc. Let us look at this fact using the example of health (see Table 1).

Additionally, we collected information from decision-makers, experts in the selected domain, and stakeholders regarding their experiences, challenges, and preferences in the decision-making process. The information collected included qualitative data on decision-making practices and perceived limitations of traditional scoring systems.

As a result, the following disadvantages of scoring systems, as observed in the field of medical diagnosis, were identified:

- A strict reliance on scores may overlook unique patient factors or comorbidities that are not included in the scoring model. This issue is particularly significant, given the shift towards personalized medicine.
- Patients who fall slightly above or below a certain threshold may receive significantly different care (e.g., different drug dosages), despite a similar overall risk. It corresponds to a general limitation previously identified, but with a nuance specific to the selected domain.
- Extreme dependence on the quality, completeness, and source of the data used. It aligns entirely with a general limitation.
- Inflexibility in a dynamic environment. Scoring systems do not adapt well to rapid advancements in medical technology or changes in treatment protocols.
- Physicians may place excessive trust in the objectivity of the score, relying on a false sense of certainty. Fully reaffirms a general limitation.
- Bias in the scoring model development. Refers to cases where the development of scoring systems may be biased, not taking into account some segments of the population (e.g., based on age, gender, race, income, etc.). Thus, the scoring system may perform poorly in different ethnic, age, or socioeconomic groups. While this is a general issue, it is particularly emphasized within the selected domain.

Table 1. Domain-specific limitations depending on different approaches to formalizing the decision-making process using scoring systems (health domain)

Approaches	Role of scoring systems	Domain-specific limitations
Heuristic / Intuition-assisted	Scores act as prompts to reduce bias from intuition.	Risk of anchoring, oversimplifying complex cases, variability between clinicians, and limited reproducibility.
Rule-based / Knowledge-based	May use scoring thresholds as rule triggers (e.g., if score $\geq X$, then recommend imaging).	Brittleness when new evidence emerges; poor handling of exceptions/rare cases; alert fatigue from rigid thresholds.
Scoring / Threshold models	Scoring is the central mechanism – variables converted into additive points with thresholds guiding action.	Miscalibration across populations; thresholds often arbitrary or not re-validated; information loss from categorization; limited nuance in borderline cases.
Statistical models	Scoring systems are often derived from regression coefficients; thresholds are set for clinical use.	Assumes linearity/independence; sensitive to prevalence shifts; requires regular recalibration; may be poorly understood by clinicians.
Machine Learning / Data-driven	Scores may be hidden as probability outputs; sometimes, post-hoc simplified scores are built for interpretability.	Often seen as a 'black box', vulnerable to dataset shift, risk of bias amplification, explainability gaps limit trust, and require ongoing drift monitoring.
Hybrid	Integrates scoring models with alerts, order sets, or recommendations.	High risk of alert fatigue, automation bias, dependency, workflow disruption; requires strong governance and versioning.

3 The limitations highlighted by the revision of the existing information assets and exploratory study

Having long-term experience in developing clinical decision support systems and knowledge-based applications, we analysed previously developed information systems (data/knowledge assets) to investigate how the identified limitations manifested in practical contexts.

In the development of decision support tools for clinical diagnostics, scoring systems were utilized in two distinct ways. Primarily, they serve as an effective method for formalizing professional knowledge, thereby enabling the structured representation of clinical diagnostic reasoning. Alternatively, scoring systems can be used explicitly, where the scoring framework itself constitutes the formalized diagnostic reasoning and forms the core component of the knowledge base.

The revision revealed several major problems: the rigidity of thresholds; the perception among practitioners that these are insufficiently justified, particularly when minor differences in scores may lead to substantially different conclusions; and the need to adjust thresholds to reflect new realities in medical diagnostics as conditions, interpretations, and understandings evolve [1].

In addition, we conducted a survey to explore the experiences of medical practitioners regarding maintaining the relevance over time of data/knowledge assets (scoring systems, data and knowledge warehouses, and AI models) [2].

The survey covered various aspects, such as: use of information tools in medical practice, their relevance over time, validation and update procedures, interpretation and explanation issues, and cut-off points in scoring systems.

Here are the main findings related to scoring systems:

- All respondents indicated that they seek additional information to fully understand the parameters/values of a scoring system.
- Most (62.5%) of respondents reported encountering cases in their medical practice where small differences between cut-off points implied different conclusions.

- The vast majority (87.5%) emphasized the need for an additional grounding/explanation in scoring systems, especially in cases when there are small differences between cut-off points.

If we consider the issues identified during the revision of our information assets and the exploratory survey as limitations, they can be found in the general list (application-dependent limitations), but presented in a more nuanced manner (see Table 2).

To conclude, the main disadvantages of scoring systems in the general decision-making process include their tendency to oversimplify complex realities, reliance on potentially biased or incomplete data, and creation of rigid threshold effects. These issues are particularly pronounced in the health domain, where they can lead to misjudgments of patient health risks, inappropriate treatment decisions, reduced personalized care, and excessive reliance on scores at the expense of clinical expertise, imposed by the multiple existing protocols. In its turn, any information tool used in the decision-making process 'inherits' the limitations of the first three types and generates additional limitations, which depend significantly on the approach used in its development, namely at the formalization stage.

Thus, an important limitation of scoring-based informational tools is their rigid thresholds and the perception among practitioners that these thresholds lack sufficient justification. This issue is particularly concerning when minor differences in scores lead to disproportionately different conclusions. It highlights the need for stronger explanatory grounding in scoring systems, especially in situations where small variations around threshold values have a significant impact on outcomes.

4 Limitations related to thresholds in scoring-based decision support tools

Addressing the limitations related to thresholds in scoring-based medical decision support tools can substantially enhance the quality of the decision-making process. Implementing more flexible and transparently justified thresholds would allow these systems to reflect the complexities of clinical practice better. This can also minimize the risk

Table 2. Types of scoring limitations

	Type of limitation / When detected	Limitation
1	General limitation	Small differences in scores that are close to the thresholds can lead to significantly different conclusions, sometimes resulting in dramatic differences. End-users perceive this issue as score rigidity.
2	Limitation of Scoring / Threshold models	Miscalibration across populations; thresholds often arbitrary or not re-validated; information loss from categorization; **limited nuance in borderline cases.**
3	Limitation as seen in medical diagnostics	Patients who fall slightly above or below a certain threshold may receive significantly different care (e.g., different drug dosages), despite a similar overall risk.
4	Limitation highlighted by revisioning the existing information assets	The rigidity of thresholds and the perception among practitioners that these are insufficiently justified, particularly when minor differences in scores may lead to substantially different conclusions.
5	Limitations highlighted by our exploratory study	Need for an additional grounding/explanation in scoring systems, especially in cases when there are small differences between cut-off points (encountering cases in their medical practice where small differences between cut-off points implied different conclusions).

of small score variations leading to disproportionately different conclusions. In turn, this would strengthen clinicians' confidence in the recommendations generated by such tools and encourage their broader adoption in practice. These improvements not only support more accurate and individualized diagnostic reasoning but also contribute to reducing diagnostic errors and improving patient outcomes.

We attempted to develop an approach that could represent a potential solution to minimize the negative effect of threshold limitations on scoring systems [3]. Our proposed approach involves using an additional graphical representation to better interpret the scoring system. We chose the Doppler ultrasound score in cirrhotic portal hypertension as the domain for implementing and validating this approach [4]. This score enables the assessment through duplex ultrasound of the severity of portal hemodynamics disorders in patients with liver cirrhosis.

In what follows, we will describe it in more detail.

As a graphical representation of the score interpretation, we selected the spider chart.

A spider chart is a method of visualizing multidimensional data. It allows for comparing several objects across multiple parameters simultaneously. These charts are often employed in comparisons and evaluations, but they can become less effective when dealing with a large number of variables due to potential visual overload. This method is particularly useful for compactly presenting 3-10 parameters for quick comparisons [5, 6].

Traditionally, liver function assessments using scoring systems are presented in tables and numerical indicators. However, there is potential for visualizing this data using spider charts, even though this approach is not standard in clinical practice [7, 8].

When selecting spider charts as a graphical representation, the following advantages were considered:

1. They allow for the display of individual parameter values along with the overall value (represented by the area of the resulting figure) as a combination of all parameters. In medical diagnostics, it is essential to assess each parameter separately while also considering its impact in combination on the patient's condition.

2. Spider charts provide a clear visualisation of each parameter's

scores alongside their specific values, highlighting which parameter most significantly affects the severity of the patient's condition, particularly in relation to specific values.

3. By overlaying several spider charts (for example, representing the patient's condition before and after treatment), changes in the patient's condition can be easily tracked. Variations in the shape and area of the figure indicate which indicators have been modified and to what extent.

Structurally, the Doppler ultrasound score in cirrhotic portal hypertension corresponds to the well-known score systems. It involves: i) a system of parameters that describe the problem area, ii) determining the weight of the parameter in part of the final score, and iii) an interpretation of the final score. Both the score itself and its interpretation are presented in numerical tabular form (see Tables 3-4).

Table 3. Doppler ultrasound score in cirrhotic portal hypertension

Parameter	1 point	2 points	3 points	4 points	5 points	6 points
Congestion index		$x < 0.07$	$0.07 \leq x < 0.11$		$0.11 \leq x < 0.18$	$0.18 \leq x$
Splenoportal index, %	$x < 29$		$29 \leq x < 60$		$60 \leq x < 67$	$67 < x$
Portal venous index			$9 \leq x$		$7 \leq x < 9$	$x < 7$
PHT index	$x < 1.5$	$1.5 \leq x < 1.6$		$1.6 \leq x < 2.7$		$2.7 \leq x$
Spleen aria		$x < 57$	$57 \leq x < 113$		$113 \leq x < 206$	$206 \leq x$

At the initial stage, we used a spider chart to visualize the scoring interpretation of specific individual cases (including primary ones), as well as the dynamics of the patient's condition (if there are repeated

Table 4. Interpretation of Doppler ultrasound score in cirrhotic portal hypertension

Total points	Severity of portal hemodynamic disorders
9-10	Low
11-12	Low (to moderate)
13-16	Moderate
17-24	Moderate (to high)
25-30	High

scoring results).

5 Graphical representation of Doppler ultrasound score

Let's consider specific cases of assessing the portal hemodynamics disorders severity in liver cirrhosis through the Doppler ultrasound score in cirrhotic portal hypertension (see Table 5).

In Figure 1, we can see a graphical representation of the score using spider charts for case 1 from Table 5: based on the scoring points for each scoring parameter (left) and based on normalised parameter values (right).

The spider chart on the right is based on normalised values. When constructing a spider chart, normalisation is necessary in order to bring all indicators to a single scale and avoid distortions that arise due to differences in units of measurement and ranges of values. Thanks to normalisation, the visualisation reflects the actual ratio of indicators, allowing them to be correctly compared with each other.

The normalisation formula for the numerical values of the four parameters – congestion index, splenoportal index, PHT index, spleen area – is as follows:

$$X_{norm} = 100 * X/X_{max},$$

where X_{max} is the maximum numerical value of the parameter in the sample/selection taken:

Table 5. Selected cases from the whole dataset of 116 cases

	Congestion index	Splenoportal index	Portal venous index	PHT index	Spleen area	Scoring points (interpretation)
Case №1	0.088	56	10	2	68	16 (moderate)
Case №5	0.112	65	9	2.6	67	20 (moderate)
Case №13	0.17	75	8	2.5	229	26 (high)
Case №16.1	0.13	29	9	1.7	47	17 (moderate)
Case №16.2	0.12	44	10	1.8	53	17 (moderate)
Case №20	0.06	41	12	1.3	53	11 (low)
Reference low	0.08	33	11	1.3	48	12 (low)
Reference moderate	0.10	45	9	1.8	63	15 (moderate)
Reference high	0.15	75	6	2.7	120	28 (high)

congestion index $_{max}$ = 0.32;
splenoportal index $_{max}$ = 86%;
portal venous index $_{max}$ = 16;
PHT index $_{max}$ = 3.9;
spleen aria $_{max}$ = 236.
For the fifth parameter – portal venous index – the scale was inverted:

$$X_{norm} = 100 - 100 * X/X_{max}.$$

The use of these visualisation methods can increase the informative value of the analysis. Scoring is convenient for quick clinical assessments, while the numerical normalized values of the same parameters offer experts additional insights into the ratio of individual score parameters in the whole dataset.

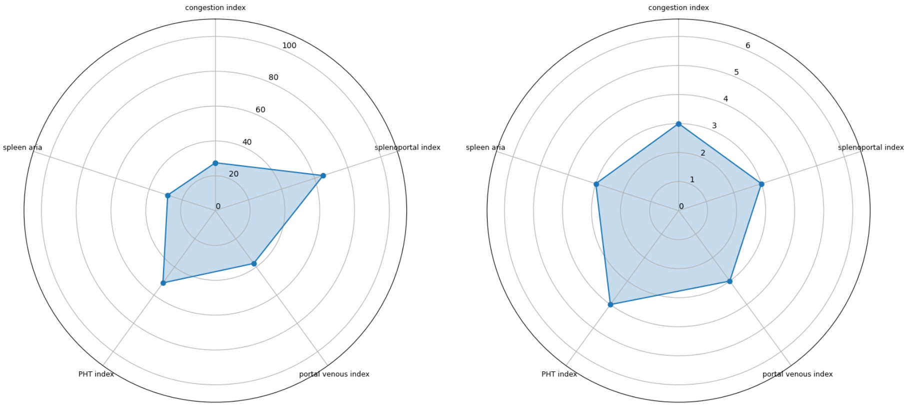

Figure 1. Graphical representation of score using spider charts (Case №1)

In Figure 2, the advantages of the proposed approach are clearer when comparing the scores of patients with different degrees of portal hemodynamics disorders severity in liver cirrhosis, for example, from left to right, low (11 points), moderate (20 points), and high (26 points).

The area of the figure in the chart increases as the severity of the stage progresses: from 11.41 for low changes to 37.57 for moderate and 63.72 for high. This visualisation enables us to clearly evaluate not only the total number of points but also the differences between stages through the increased area of the polygon.

Using spider charts to visualize the points from the Doppler ultrasound score provides hepatologists with additional opportunities to assess the severity of a patient's condition. These charts facilitate faster and more accurate evaluations of both the overall severity of cirrhotic portal hypertension and its manifestations, ultimately helping to optimize tactics of patient management.

The advantages of the proposed approach become evident when comparing scores over time. In Figure 3, we see the normalised numer-

Figure 2. Graphical representation of score using spider charts (Case №20, Case №5, Case №13)

ical values of Doppler parameters for the same patient over a three-month period. The initial values are indicated by a solid line, while the repeat examination is indicated by a dashed line.

Although the integral score in both cases is 17 points, the chart shows noticeable differences in the distribution of individual parameters. The area corresponding to the latter data surpasses that of the initial data, indicating an increase in the cumulative severity of the changes. Additionally, the chart's profile suggests a redistribution in the contribution of individual parameters: there is a relative increase in the values of the splenoportal index and spleen area, while other parameters remain stable or show minimal fluctuations. For a hepatologist, such visualisation offers valuable insights into the progression of cirrhotic portal hypertension, enhancing the accuracy of disease assessment over time.

In this way, by providing the possibility to use additional graphical representation to visualize: 1) scores for specific individual cases (including primary ones), and 2) the dynamics of the patient's condition (in the presence of repeated scoring results), we have completed the initial stage of developing our approach.

The validation process (made by our expert group of physicians, developers of the Doppler ultrasound score in cirrhotic portal hypertension) shows that offering both forms of representation of a scoring system (numerical tabular form and graphic – as a spider chart) allows

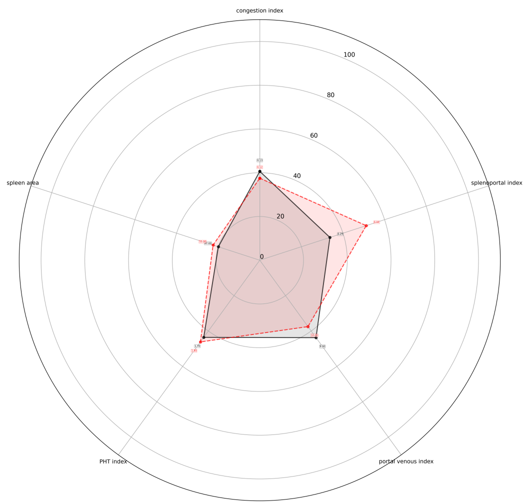

Figure 3. Graphical representation of score using spider charts (Case №16.1, Case №16.2)

for reducing misunderstanding and increasing the degree of trust in the conclusions generated by the score.

Experts assessed positively the additional possibilities for visualising multidimensional scoring data using spider charts, particularly when score parameters are normalised. The improved clarity in tracking the patient's conditions in dynamics was also noted.

However, it was noticed that graphical representation does not offer new opportunities and more informative solutions when visualising primary cases. This can be explained by the lack of another dataset with which to compare. Comparing, for example, with data from another similar patient does not seem informative and does not provide a basis for drawing any conclusions or prospects for the evaluated basic data.

As a possible solution, as part of the testing and validation process, it was agreed with the expert that there is a need to describe the reference values for the scoring parameters corresponding to the patient's main conditions. In our case, three reference sets were defined by an expert: for "low", "moderate", and "high" severity. These reference examples can be used to provide users with an opportunity to perform comparative analysis, even for the primary cases.

Figure 4 displays a spider chart illustrating the relationship between the patient's individual ultrasound parameters (Case №16.1, grey area with a solid black line, moderate severity) and reference values for adjacent stages of liver cirrhosis severity. Two reference profiles are used for comparison: values for the high severity stage (light grey area with densely dashed line on the chart, Reference high severity in Table 5) and for the low severity stage (dark grey area with dashed line, Reference low severity in Table 5). The figure shows that the patient's congestion index value for Case №16.1 is close to the reference value for this parameter for the high severity stage. At the same time, the values of the other parameters are closer to the reference values for the low severity stage.

Comparing the patient's individual profile with reference profiles helps reduce subjective perceptions and supports the standardization of ultrasound interpretation at the initial patient examination.

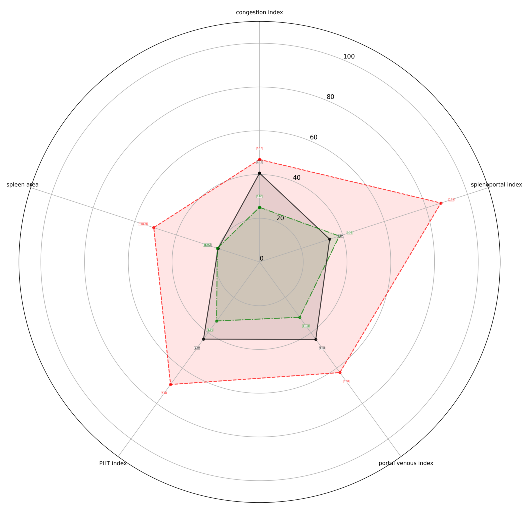

Figure 4. Graphical representation of score using spider charts (Case №16.1, Reference low, Reference high)

Thus, the proposed approach can be applied in the following ways:

1. When analysing primary cases, the user can visualise multidimensional patient data in a) numerical tabular form; b) a spider chart based on individual parameter scores; c) a spider chart based on normalised parameter values. Moreover, the user can visualise the analysed primary case in comparative mode. For example, if the analysed case is of "low" severity, then it is visualised in comparison with the reference template "moderate"; if the analysed case is of "moderate" severity – it is visualised in comparison with the reference template "low" and/or "high", separately or together; if the analysed case is of "high" severity – it is visualised in comparison with the reference template "moderate".

2. With repeated scoring results (two or more), the user can visualise multidimensional data describing the patient's condition over time. Graphical representation based on both individual parameter scores and normalised parameter values allows for the visualisation of various combinations. For example, all available results, or specific selected results, with or without reference templates, can be displayed on a single chart. Dynamics can also be shown as an animation.

6 First evaluation of possible implementation of the proposed approach in other domain

As we mentioned above, scoring systems are used in many domains. Their use in professional practice plays a more important role in the fields of health and finance. In these fields, scores have a direct impact on life or quality of life.

The proposed method for visualizing and interpreting scores is not domain-specific. Health was chosen as the primary area for implementation, testing, and validation.

The initial assessment of the proposed approach in the financial domain found that the general limitations of scoring systems are similar, with domain-specific ones contributing to the same major negative effect – the rigidity of scores as a tool to support decision-making. Another conclusion is that in the financial domain, there is also a need to reduce this degree of rigidity, and graphical representation may be a solution. Unlike in medicine, graphical representation is already widely used and well-regarded in the financial domain.

Also at the evaluation stage, it was found that in finance, the problem of visualizing scores using spider charts, even for primary information, is minimal. That is, in medicine, comparing a primary patient's score with another patient's score (even if it represents a similar health condition) cannot be taken as a basis for any conclusions and treatments. In finance, this is not the case – in fact, it may be exactly the opposite. For example, comparing financial scores that describe the national economies of two countries over a certain period (fixed, not dynamic), i.e., comparing two cases of primary information.

The graphical representation of financial information in dynamics is standard practice.

It was interesting to identify that the problem of "...when minor differences in scores can produce disproportionately different conclusions" is not only present and well known in the domain of finance, but also has a name – the "cliff effect" near thresholds.

As a first sub-domain, within finance, where we can find extensive possible consequences of the "cliff effect," there is highlighted the budgeting based on human rights [9]. It is a sub-domain with multiple interdependent thresholds, which are often not analyzed as an interdependent multi-criteria environment, and the consequences can have serious negative effects on quality of life.

7 Conclusion and future work

Providing an additional tool for decision-making support, represented by the proposed new approach, may be a good solution for minimizing the negative effects of the general and domain-specific disadvantages and limitations associated with traditional scoring systems. The new approach provides a more informative representation of both primary observations and the dynamics of the status of the analyzed objects (depending on the selected domain). When viewing primary cases in comparison with reference templates, the user has the possibility to evaluate modification of the object's status.

Compared to the classic tabular representation, the graphical representation using a spider chart is more informative, especially when a dynamic representation is required. The proposed new approach allows for quickly assessing the severity of changes and identifying the structure of the contribution of individual parameters, which is especially valuable when monitoring the effectiveness of therapy or the development/progression of a disease.

Graphical representation, in the form of normalised score parameter values (particularly those illustrating dynamic changes) in cases of suspected accuracy, can indicate when it is necessary to initiate an "update procedure" for scoring threshold values. It can be seen as a possible solution to maintaining accuracy within diagnostic frameworks. Thresholds should be regularly adjusted to reflect evolving realities in medical diagnostics, as conditions, interpretation, and understanding advance. Regular updates are crucial because thresholds play a key role in ensuring the fairness, consistency, and effectiveness of scoring systems as a decision-making tool. Furthermore, the capacity to dynamically adjust thresholds ensures that scoring systems remain relevant and aligned with the latest knowledge. Such improvements not only support more accurate and personalized diagnostic reasoning but also contribute to reducing diagnostic errors.

The proposed approach provides practical recommendations. It guides the creation of new scoring systems with minimal limitations and helps enhance existing scoring systems. These recommendations also act as a foundation for developing practical tools and applications. They offer valuable prospects across diverse domains, making decision-making more robust, adaptable, and efficient.

The obtained and described results can be seen as important contributions to the domain of decision science, as they offer new insights and perspectives that can boost and broaden the scope of use of such an important decision-making tool as the scoring system.

Future work could explore several areas, including comparative analysis of alternative graphical visualisations such as parallel coordinates and heatmaps, integration of decision accuracy metrics, user performance, or time-to-decision impacts, and application of this approach within the finance domain.

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