Proceedings of the 2014 Industrial and Systems Engineering Research Conference
Y. Guan and H. Liao, eds.

A Comparative Evaluation on Multi-perspective Representations of Business Controls: An Experimental Case Study

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Abstract

The internal controls embedded in an organization's business processes are designed to help an organization achieve specific control objectives. These controls are generated from different perspectives, i.e. governance, security, and certification. Currently, experts in an organization typically act on internal controls from one perspective at a time, which creates inefficiencies and duplication from a corporate standpoint. This research proposes a multiperspective model for representing internal controls, in order to provide a comprehensive view of the organization's internal controls. In previous work [1], we suggested that the radial and linear representations were the most suitable models for this purpose, and so we developed an experimental case study to compare their usability. The results of this case study show that the linear representation enables users to browse the internal control structure faster than the radial representation. However, the radial representation can be understood more quickly by users. The study also reveals that a linear representation seems to be more familiar to users than a radial one. Using the Analytical Hierarchical Process (AHP) technique to assess their suitability, we conclude that the radial layout representation is the most appropriate model for viewing the internal controls of an organization from multiple perspectives.

Keyword

Internal controls, tree layouts, control framework, multiperspective representation, business process

1. Introduction

The global economic environment continues to change and to impose obligations and constraints on firms, especially those listed on the stock exchange. World events (wars, large-scale tax evasion, agreements between countries, etc.) can affect the constraints to which businesses are subjected. Whatever the source of these constraints, companies need a control system to apply them and to ensure compliance.

Control system implementation is a process that involves a number of company stakeholders, each with different expertise (CEO, accountant, information technology (IT) experts, etc.). These stakeholders each have their own vision and perspective from which to set up internal controls of their business processes. This could create duplication and inconsistencies in the control system. To ensure a comprehensive overview of business processes and the required controls, a multiperspective approach to setting up the control system is required, so that the system will represent the business processes faithfully.

In this paper, we propose to define a graphical interface for the multiperspective representation of internal controls. Our aim is threefold: first, to present the various alternatives for visualizing internal controls; then, to propose an experiment which can be used to select the most appropriate alternative; and, finally suggest future directions and prospects for improvement.

2. Hierarchical information representation approaches

Information visualization is a research domain that has been growing in popularity in recent years. It is defined as the study of interactive visual representations of abstract data to reinforce human cognition. The visualization of hierarchical information constitutes a specific research area, in which data are represented using tree structures. In this section, we present a synthesis of proposals from the literature in an attempt to answer the following question: Which hierarchical framework is best suited for visualizing a multiperspective representation of internal controls?

2.1 Tree layout comparison

In the literature, we find a number of tree layouts, which can be summarized as follows [1, 2]: 1) the linear tree (e.g. organizational charts); 2) the horizontal tree (orientation from right to left, or left to right); 3) the icicle; 4) the radial tree; 5) the concentric circles; 6) the nested circles 7) the treemap; and 8) the indented tree.

Several publications [1-8] compare tree layouts and attempt to determine which layout is the most suitable for representing structured data. In doing so, these publications focus primarily on two criteria: 1) space management, and 2) usability. McGuffin and Jean-Marc [2] compare the various representations of two-dimensional trees mathematically, using what they term the "space management" criterion. Their assumption is that the size of the node labels tends towards 0 when the tree size tends towards infinity, and their study compares tree performance by studying the speed of the tendency of its labels to move towards 0. Their findings reveal that the Treemap is the layout that can ensure the most efficient management of the representation space. This is because the Treemap uses the whole display area to represent its contents. However, the continual division of the triangles on the Treemap can result in the creation of thin and elongated triangles that become difficult for the user to select or compare. In order to solve this problem, the authors of [9] propose an algorithm to approximate the ratio of the Treemap rectangles to 1. The resulting rectangles are "squarified", making it easier for users to select and compare them.

Another limitation of the Treemap presented in the literature [2, 9] is that the structure of the tree cannot be clearly visualized, especially in the case of large or balanced trees (i.e. each parent has the same number of descendants, and all the descendants are the same size). In the case of balanced trees, Treemaps are similar to regular grids, in which case it will be difficult to determine their structure (i.e. to differentiate the parents from the descendants). The limitations of the Treemap are related more to the usability criterion than to the space management criterion. In effect, allow a clear perception of the tree structure and facilitate the selection of the rectangles are considered to be the usability criteria that will ensure better use of the Treemap.

Usability is defined in ISO 9241-11 [10] as "*the degree to which a product can be used by specified users to achieve specified goals effectively, efficiently, and ensuring a certain level of user satisfaction.*" So, in addition to the effectiveness and efficiency of an interface, user preferences (or user satisfaction) constitute an important criterion for determining the degree of usability of an interface. Applying this definition to the context of trees, Barlow and Neville [4] attempt to decompose the usability criterion into three sub criteria: 1) ease of interpretation; 2) node magnitude; and 3) user preferences.

In the literature, usability is measured mainly by conducting experiments in which the users are asked to perform specific tasks (such as, "Select the deepest leaf on the tree" or "Select the immediate ancestor of two nodes," etc.) and their performance is measured (time taken, accuracy, eye-tracking, etc.) [4, 5, 8]. Other approaches are based on mathematical models that measure the usability of tree layouts, such as the Hickman model (used to estimate the user's reaction time), and the Fitts model (used to estimate the user's movement time). In fact, experimental approaches are considered the most effective way to measure the usability of tree layouts [2]. However, the findings of these studies reveal that these approaches do not coincide with those for determining which tree layout is the most suitable for visualizing structured information. This is because the tasks on which user performance is measured differ from one approach to another, and depend mainly on the application domain (e.g. data mining, business, IT, etc.) and on what researchers expect from these layouts. For example, in [7], the horizontal tree layout is recommended, with the nodes displayed in multiple columns. According to [8], the horizontal tree, even when it is oriented from left to right (the reading direction in Latin languages), is not as efficient as, for example, the linear layout (with the root at the top and the leaves at the bottom). This is because, in the case of the horizontal tree, the distance between the nodes is greater than it is for the linear tree, as the nodes travel horizontally, and would be much greater still if the nodes with the same parent were displayed in multiple columns, one after the other, as they are in [7]. By contrast, the nodes travel vertically in the case of a linear tree, and so the travel distance will be shorter in this case. Some researchers [8] are aware of this difference in findings, and claim that their results and conclusions are valid only for the tasks and the domain under study. This makes it difficult to determine which tree layout is better in terms of usability. Nevertheless, it is possible to determine which layout is better for a set of tasks, or for a particular domain (bounded by these tasks).

Developing an exhaustive task list is not the only difficulty encountered in measuring the usability criterion. In the approach proposed by Barlow and Neville [4], for example, despite the fact that they have compiled an extensive task list to evaluate several types of trees (i.e. organizational charts, nested circles, the Icicle, and the Treemap), the authors could not definitively identify the most usable one. This could be because there are better interface layouts for some tasks, but not for all of them.

After conducting this literature review, we can say that the Treemap is the preferred option in terms of space management, and that there is no clear consensus on usability. In fact, usability is difficult to measure, and is mainly achieved by conducting experiments with the help of users. In the next section, we present the experiment we propose for determining the most appropriate tree layout for the multiperspective representation of internal controls.

3. Experimental design

This work constitutes a continuation of our work performed in [1], in which we came to the conclusion that the radial layout and the linear layout are the best suited to provide a multiperspective representation of internal controls. Based on the literature [2], the radial layout is better than linear one in terms of space management. In term of usability, however, we need to conduct an experiment to determine the best layout.

In the experiment we ask the participants to use the two layouts discussed above (linear and radial) and give us their opinion on the usability of the layouts.

In this section, we present the prototype we have developed for each layout, the participants in the experiment, the tasks we asked the participants to perform using the prototypes, the measures to be collected, our hypotheses, and the procedure we use to analyze the data.

3.1 Proposed prototypes

For tree layout selection, we developed a prototype for each (linear and radial) and conducted an experiment with a group of participants. This experiment was designed to: 1) determine the performance of the participants (response time, accuracy, etc.) with each layout; and 2) record the participants' opinions of the layouts. The proposed prototypes represent internal controls according to the following structure:

- Level 1: Internal control.
- Level 2: Business level (strategic, organizational, and operational).
- Level 3: Control perspectives.
- Level 4: Control practices proposed by each perspective.
- Level 5: Business processes to which these practices are applied.

3.1.1 Radial prototype

Figure 1 illustrates the proposed radial prototype for representing internal controls. In this figure:

- The business level is characterized by the labels "strategic", "organizational", and "operational".

- The perspectives level is characterized by the labels “COBIT”[1][11], “CMMI”[2][12], and “COSO”[3][13].
- The internal controls level is characterized by cubes labeled with unique identifiers. Note that the label orientation remains the same (left to right), regardless of the location of the internal control node in the circle (right or left semicircle). The circle colors change from green to yellow to red, according to the degree of conformity of the internal control (green = conforming, yellow = partially conforming, red = non-conforming). The control color has been determined as in [14], and will be explained in another publication.
- The business processes level is characterized by gray cubes, each with an identifier, as is the case for the internal controls.

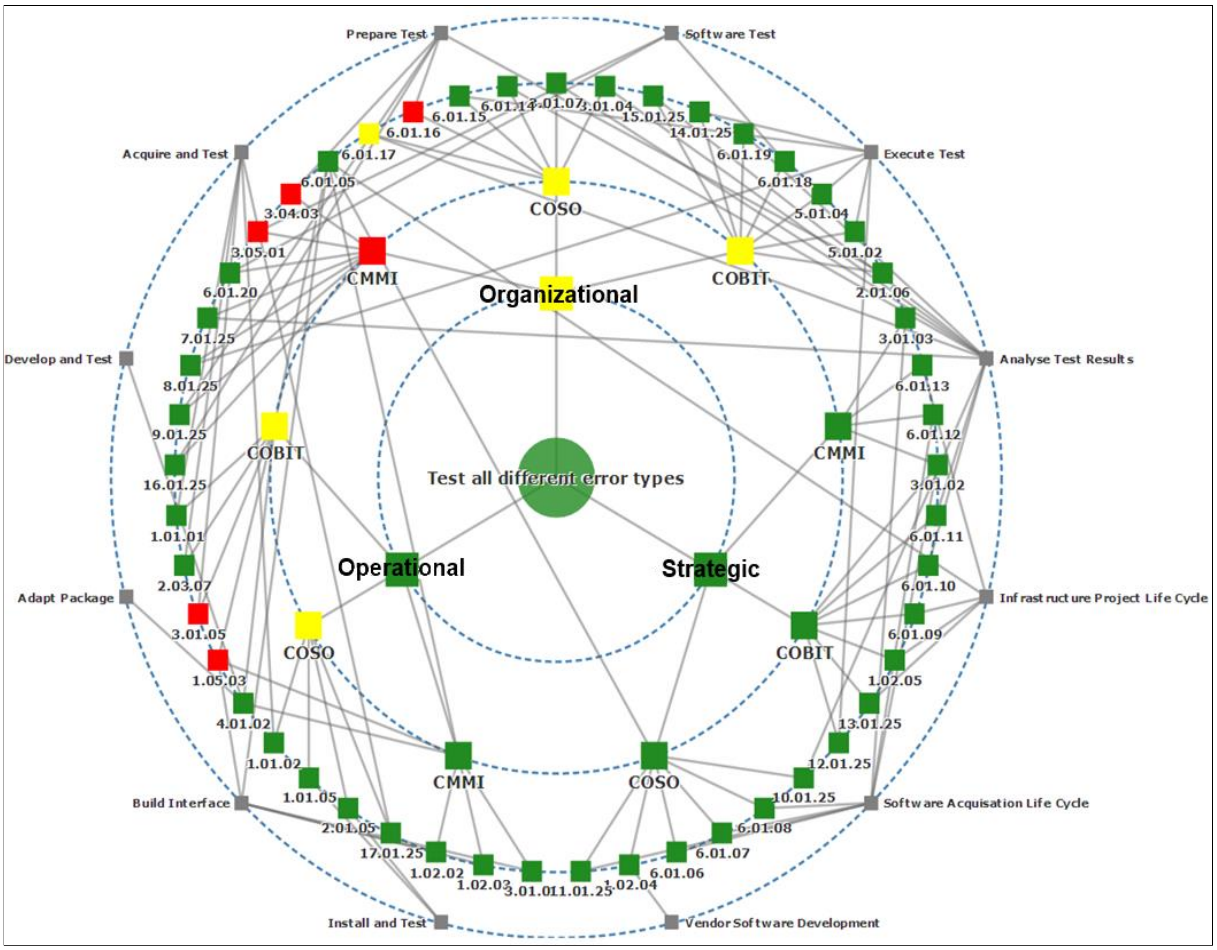

Figure 1: Radial prototype for the multiperspective representation of internal controls.

In a radial representation, the user can choose to focus on just one of the displayed nodes, in this case by selecting it and clicking on it. The selected node is then displayed on the whole screen, along with the details of the branches for which it is a parent. For example, when a user selects one of the business level nodes (i.e. strategic, organizational, or operational), the interface will interactively adapt to the desired view, and the selected level will appear in the center of the screen with all the control perspectives. The user can also select one of the perspectives, for example

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[1] COBIT is an IT governance framework that supports toolset allowing managers to bridge the gap between control requirements, technical issues and business risks.

[2] Capability Maturity Model Integration (CMMI) is a process improvement training and appraisal program and service administered and marketed by Carnegie Mellon University and required by many government contracts, especially software development.

[3] The Committee of Sponsoring Organizations of the Treadway Commission (COSO) is a joint initiative of five private sector organizations and is dedicated to provide frameworks and guidance on enterprise risk management, internal control and fraud deterrence

COBIT, to see which COBIT controls have been implemented, in which of the organization's business processes, and their level of conformity, etc.

3.1.2 Linear prototype

The linear prototype is similar to the radial one in terms of icons. However, the arrangement of the nodes is not the same. In this prototype, the multiperspective business controls are placed at the top level, the business level is the second level, and the control perspectives are placed at the third level. For each perspective, we have practices, which are placed at the fourth level. At the last and lowest level are the business processes to which the control practices are applied.

3.2 Participants and tasks

This controlled experiment was carried out among 50 participants, who were invited to perform tasks similar to those performed by auditing experts, which is to say that we translated the tasks performed by these experts into similar tasks to be performed by the participants and requiring the same effort. These tasks are the following:

- **Task 1:** Specify the number of level 4 nodes that are red.
- **Task 2:** Specify the number of leaves on the tree.
- **Task 3:** Specify the number of level 3 nodes that are red.
- **Task 4:** Specify the number of nodes named "COBIT".
- **Task 5:** Specify the number of nodes with a parent named "COBIT".

These tasks are equivalent to those performed by the experts:

- Specify the control practices that do not conform (Task 1).
- Specify the processes for which control practices are in place (Task 2).
- Specify the perspective from which the control does not conform (Task 3).
- Specify the perspective from which we consider a node to be named "COBIT" (Task 4).
- Specify the COBIT control practices (Task 5).

3.3 Measures

As mentioned earlier, this experiment is designed to measure the usability of each of the proposed prototypes. According to ISO 9241-11 [10], usability can be described based on three criteria:

- **Effectiveness:** This criterion is measured based on the completion time of the proposed task.
- **Efficiency:** This criterion is measured based on the accuracy of each participant in performing the tasks listed above.
- **User preferences:** This criterion is measured based on a questionnaire distributed to the participants at the end of the experiment, in which we asked for their opinion on each of the proposed prototypes.

3.4 Hypotheses

The participants will perform poorly when browsing the traditional linear tree layout, since the child nodes are widely distributed on the linear tree interface, and users might need to do a great deal of scrolling to check them. However, since the linear tree interface is the most common way of displaying trees, most people are used to working with it, and we were not sure how this habituation would affect the experimental results, especially in terms of task completion time and accuracy.

The participants will find that the radial tree prototype can be browsed faster and more accurately, and with less scrolling, than the linear tree prototype, because all the child nodes are displayed in a small space. We speculate that it will be difficult for users to follow the path from the root to a specific node because of the clutter created by all the edges present on the image. We expect that the radial prototype will outperform the linear tree prototype in terms of task completion time and accuracy for all five tasks.

3.5 Results analysis

In this experiment, we analyze three parameters: 1) the time taken to complete a task (effectiveness); 2) the accuracy of the user (efficiency); and 3) the user preferences for each of the proposed prototypes. We also perform a statistical analysis on the questionnaire results.

3.5.1 Task completion time

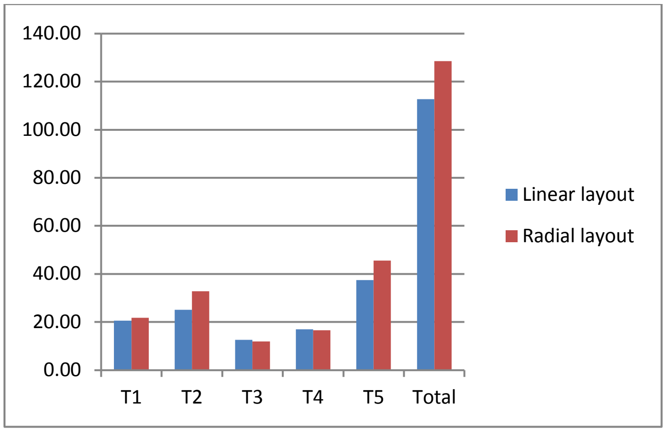

Figure 2: Time taken to complete a task (in seconds).

In terms of completion time (effectiveness), the linear prototype has a slight lead over the radial prototype. In most of the tasks, the participants took less time to perform the tasks using the linear prototype than using the radial one. As Figure 2 shows, it took almost 128 seconds to perform the 5 tasks using the radial layout compared to 112 seconds using the linear layout. We also note that performing tasks 2 and 5 involved the biggest time difference. These tasks are related to the same tree representation level (Level 3: control practices).

3.5.2 Accuracy

In terms of the number of mistakes made by the participants, the radial layout outperformed the linear one by 8% (the percentage accuracy for the linear layout is 74%, and that for the radial layout is 82%). We note that the performance of tasks 1, 3, and 4 involved the biggest time difference. These tasks correspond to the tree structure and node color analysis. For tasks 2 and 5 (where the linear layout outperformed the radial layout in terms of completion time), the two prototypes perform equally well (Figure 3).

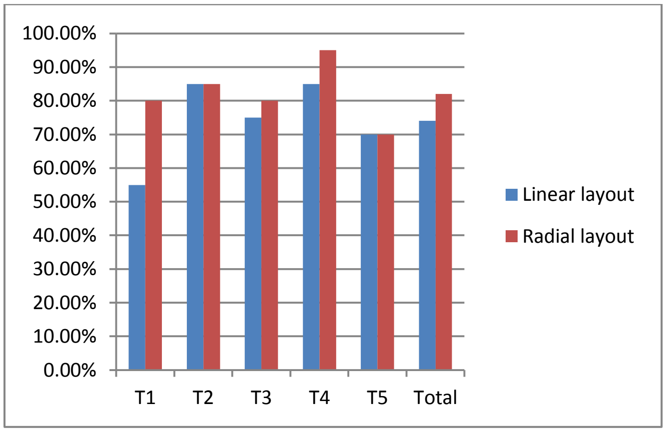

Figure 3: Accuracy (in %).

3.5.3 User preferences

The user preferences were defined based on the questionnaire results. One of the questions we asked the participants to answer was, which tree layout do you prefer? Seventy-five percent of the participants responded that they prefer the linear prototype over the radial one. This may be attributed to the fact that people are more used to using the linear layout (in organizational charts, for example) than the radial one (Figure 4).

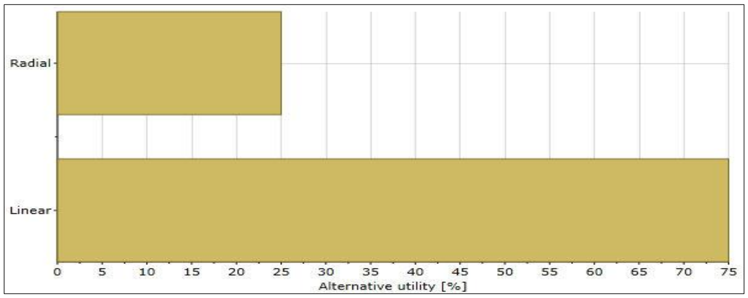

Figure 4: User preferences.

4. Multiperspective representation choice

At this level and given our experimental results, we can say that the linear layout outperforms the radial one in terms of completion time (effectiveness) and user preferences, while the radial layout performs well in terms of accuracy (efficiency) (Figure 5).

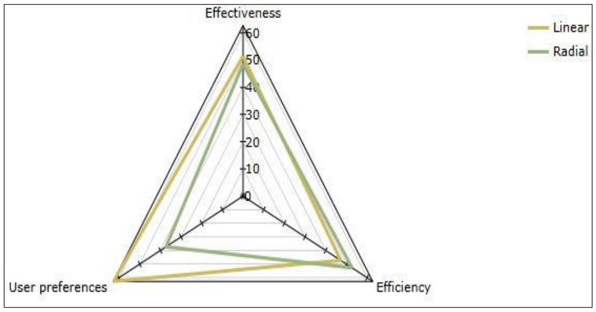

Figure 5: Usability comparison.

The results discussed so far are all related to the usability criterion. As we mentioned earlier in the literature review (2.1 Tree layout comparison), the choice of a multiperspective representation must be made based on two criteria: usability (usually through experimentation), and the efficient use of space. In terms of the latter, there is a consensus in the literature that the radial tree outperforms the linear tree. Figure 6 presents a comparison of the radial and linear layouts based on the results in [2].

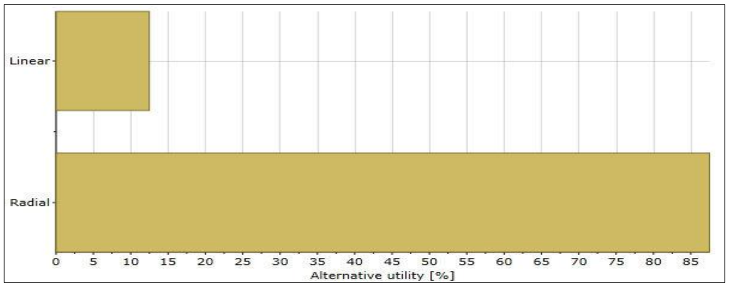

Figure 6: Spatial efficiency.

Looking at all these performance results, we can say that the radial prototype is more efficient in terms of accuracy and space management, while the linear prototype is more effective than the radial one, and that the participants in our experiments preferred using the linear prototype over the radial one. The question is, given all these criteria, which prototype performs the best overall?

To be able to answer this question, we propose to perform a multicriterion analysis using the AHP (*Analytical Hierarchical Process*) method, which is widely used on this type of problem.

5. AHP analysis

The problem of selecting the most appropriate prototype for providing a multiperspective representation of internal control can be considered a multicriterion analysis problem. Such problems can be resolved using approaches like AHP, which is a structured technique for organizing and analyzing complex decisions, based on mathematical and psychological analysis. The decision to use the AHP technique is based on its ability to:

- decompose a complex problem into simpler modules,
- define a priority order for each criterion, and
- provide a means of checking the consistency of judgments made based on the criterion.

An AHP problem involves criteria and their alternatives. In our case, the alternatives are the two proposed prototypes, namely: 1) the linear tree, and 2) the radial tree.

Once the alternatives are defined, we need to define the criteria on which we will base our choice. The first-level criteria are as follows: 1) space management, and 2) usability.

As recommended by ISO 9241-11[10], we decompose the usability criterion into three sub criteria, namely: 1) effectiveness, 2) efficiency, and 3) user preferences.

Figure 7 illustrates the multicriteria problem modeled in AHP. This model consists of four levels: the objective (level 0), the first criterion level (level 1), the second criterion level (level 2), and the various possible alternatives (level 3).

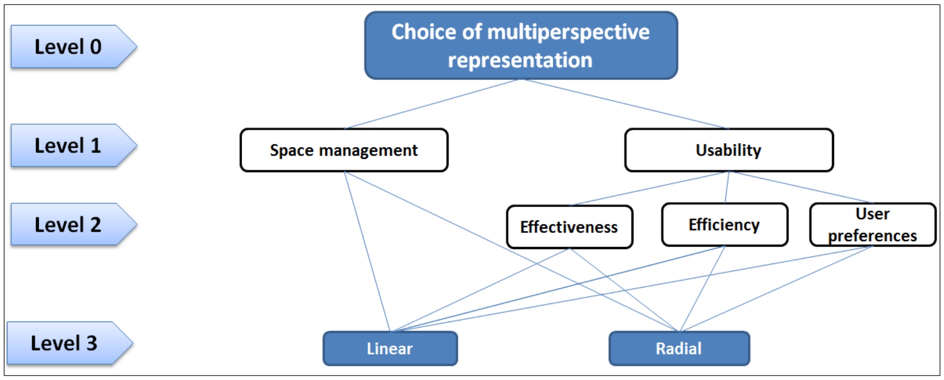

Figure 7: AHP problem formalization.

Once we've formalized the problem in AHP (as shown diagrammatically in Figure 7), we need to assign a weight to the criteria at each level (Step 1). Then, for each of these criteria, we define the order of the proposed prototypes, according to the participants' performance with respect to these criteria (Step 2).

In Step 1, the weight of each criterion is determined based on the opinions of the participants, who were asked to fill out a questionnaire in which they had to compare criteria at the same level in pairwise fashion, i.e. two by two.

In Step 2, the alternatives (radial and linear prototypes) are sorted according to the participants' performance with respect to each criterion. This is done based on the experimental results collected in the previous section and according to the results found by [2] with respect to the "Space management" criterion.

Figure 8 illustrates the results once the weights had been set. Based on these results (64.11% for the radial prototype and 35.89% for the linear prototype), we can conclude that the radial layout seems offer the best suited multiperspective representation of the internal controls.

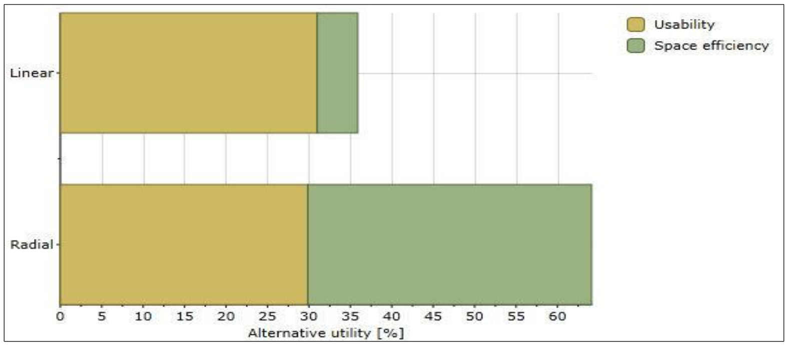

Figure 8: AHP analysis results.

It is recommended that a sensitivity analysis be performed to validate the results of the AHP technique, by varying the weights of the various criteria and assessing the impact of this variation on the order of the alternatives (Figure 9).

The findings of the sensitivity analysis confirm that the results obtained are fairly robust and reliable. The radial prototype is considered the best alternative, with a variation of 38% for the usability criterion relative to the space management criterion. In other words, the order of the alternatives remains the same, on condition that the participants do not change their minds and favor the space management criterion over the usability criterion. Even if this variation occurs, it must not exceed the 38% margin of the current weighting. If it does, the linear prototype becomes the most appropriate framework for representing the internal controls, according to the participants.

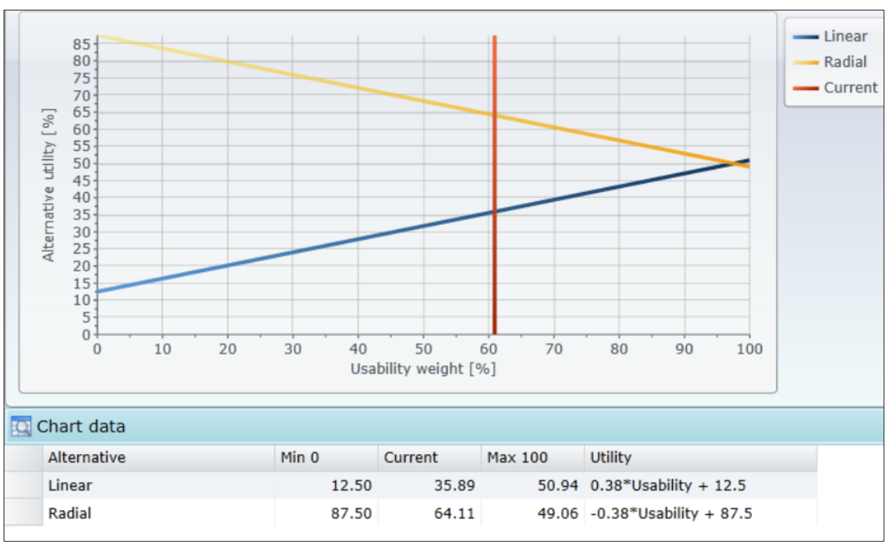

Figure 9: AHP sensitivity analysis.

6. Conclusion and perspectives

In this paper, our objectives were: 1) to present various alternatives for multiperspective representation of internal controls; and 2) to choose the one that best fitted our representation needs. This choice was based on an experiment conducted among 50 participants. The elements of our experiment and the results we reached have been described in detail throughout the paper.

In the proposed experiment, participants were invited to use two prototypes: linear and radial. Based on the results of the experiment, we were able to reach a preliminary conclusion, which was that the radial prototype is best suited to providing a multiperspective representation of internal controls.

Our continuing research will involve the further development of the prototype and more case studies, undertaken in industrial settings. Also, we are working on a complementary module, designed to provide a multiperspective measure of conformity of internal controls.

Conformity measurement is the phase that follows the definition and implementation of internal controls. Currently, each control perspective has its own scale of measurement. Consequently, it is possible for a company to measure its compliance vis-à-vis one particular perspective, but not vis-à-vis all the control perspectives simultaneously. In future work, we will attempt to answer to the following question: how we can have a "unified" conformity measure, which reflects the conformity of control vis-à-vis all the perspectives at the same time, especially since each perspective has its own scale of measurement? For example, ISO 9001 offers a binary measure (yes/no), CMMI provides a scale of four values (N: not achieved, P: partially achieved, L: largely achieved, F: fully achieved), etc.

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