Vector and triangular representations of project estimation uncertainty: effect of gender on usability

Dorota Kuchta[1[0000-0002-9747-0759]], Jerzy Grobelny[1[0000-0001-9791-9395]], Rafał Michalski[*1[0000-0002-0807-1925]], and Jan Schneider[1[0000-0001-6738-1790]]

[1] Faculty of Computer Science and Management,
Wroclaw University of Science and Technology,
27 Wybrzeże Wyspiańskiego st., 50-370 Wrocław, Poland
[*] Corresponding author
{dorota.kuchta, jerzy.grobelny,
rafal.michalski, jan.schneider}@pwr.edu.pl

Abstract. The paper proposes a new visualisation in the form of vectors of not-fully-known quantitative features. The proposal is put in the context of project defining and planning and the importance of visualisation for decision making. The new approach is empirically compared with the already known visualisation utilizing membership functions of triangular fuzzy numbers. The designed and conducted experiment was aimed at evaluating the usability of the new approach according to ISO 9241-11. Overall 76 subjects performed 72 experimental conditions designed to assess the effectiveness of uncertainty conveyance. Efficiency and satisfaction were examined by participants subjective assessment of appropriate statements. The experiment results show that the proposed visualisation may constitute a significant alternative to the known, triangle-based visualisation. The paper emphasizes potential advantages for the proposed representation for project management and in other areas.

Keywords: Fuzzy number visualisation, Fuzzy number vector representation, Visual processing, Project uncertainty, Usability.

1 Introduction

Project estimating is a crucial element of project planning [1]. It involves providing quantitative estimates of various parameters of the project: e.g. cost and duration of individual activities or the necessary amount of resources needed. The problem is that in the stage of project planning those parameters are often not completely known. This is natural, as project is per definition a unique endeavour [2] and at least some of its elements are performed for the first time in the given circumstances. The uniqueness is especially acute for innovative or R&D projects.

The reason for the incomplete knowledge in the stage of project planning is either the lack of information (e.g. it will be known only in the future how many persons will be necessary to perform a task) or ambiguity of available information (in numerous cases the customer is unable to communicate clearly what they expect [3]). The "not

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

knowing for sure, due to lack of information or ambiguous information" [4] is one of possible definitions of uncertainty. This means that dealing with the problem of not being able to provide exact estimations in the stage of project planning is part of project uncertainty management [5].

Project plan plays a crucial role in project-related decision making [2]. It is on the basis of project plan that resources are assigned, or even such critical decisions taken as acceptance or rejection of projects. Uncertain information complicates the decision-making process. That is why it is important to search for ways of supporting decision makers in this uneasy but extremely important process.

One possibility of providing such support is visualisation [6]. It is used in various areas and supports decision makers in analysing the current situation and drawing conclusions. As one possible representation of uncertainty are fuzzy numbers (according to [7], fuzziness is a consequence of uncertainty), their graphical representation (the graphs representing their membership function) is a visualisation of uncertainty and should support decision makers in analysing projects in their planning stage.

It is true that fuzzy numbers [8], together with the graphical representations of their membership functions, are widely used in the literature to represent uncertainty in the planning stage of projects (e.g. [9]). However, we hypothesize that graphs representing the membership functions of fuzzy numbers may not always be the optimal way of visualising uncertainty and that the same information can be conveyed in an alternative way, more attractive and useful from the point of view of at least some decision makers.

The objective of this paper is thus to propose a new, vector-based method of visualizing uncertainty linked to project estimation, a method which would convey the same information as triangular fuzzy numbers but possibly in a more attractive and appealing form, and to compare the two uncertainty visualisations from the point of view of their potential users.

To achieve the assumed goal, empirical research was designed and carried out. It was focused on identifying the basic features of the new uncertainty representation proposition in comparison with the traditional form of triangular fuzzy numbers. The experimental study was conducted in the perspective of the usability definition proposed in the ISO 9241-11 standard [10]. According to this norm, the key usability assessment dimensions of any information conveying system (e.g. computer program interface) include effectiveness (to what extent the system meets user's needs), efficiency (what resources are necessary to meet those needs), and user satisfaction (related to using the system). In this paper, the effectiveness of conveying information about uncertainty was tested be means of an objective indicator. We measured the accuracy of identifying information presented by means of vectors and triangles in relation to their textual description. Efficiency and user satisfaction for both representation methods were identified subjectively by means of appropriate survey scales measuring participants' preferences. The questions about interpretation easiness of both graphical representations allowed for their assessment in terms of the efficiency dimension. Participants' subjective opinions on the attractiveness of vector and triangular visualisations refer to the satisfaction component of the uncertainty conveyance usability. The last

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

aspect of the usability has been explored in recent decades in the area of human-computer interaction. As it was shown many years ago, an attractive message significantly influences the objective results in other usability dimensions (e.g., [11–13]).

The outline of the paper is as follows: In Section 2 a literature review on the present usage of visualisation in project uncertainty management is performed. In Section 3 the two representations of estimation uncertainty are shortly described: that using the graph of a triangular fuzzy number membership function and the new one, based on vectors. Section 4 includes all details about the experimental study, whose results are presented in Section 5. We finish the paper by discussing the results and summing up the findings.

2 Visualisation in project uncertainty management: state of art

In order to analyse the state of art with respect to the use of visualisation in project uncertainty management, we assumed first of all that project risk is a form of uncertainty [14]. The search string 'TITLE (project AND (visualisation OR visual))) AND (uncertainty OR risk)' was applied to scientific literature bases ScienceDirect and Scopus. The results can be summarised as follows:

The primordial role of uncertainty communication to project managers is underlined. At the same time it is stated that visualisation can play a significant role in conveying uncertainty information, and shown that appropriate visualisation methods can improve the communication process in project uncertainty management [15].

Visualisation is used to represent the following aspects of projects: probability distributions of estimated project parameters [15, 16], resource flexibility [17], interdependencies between projects [18], project initial data generally [19], project portfolio information [20], project constraints [21]. Other identified papers treat specific projects or problems related to project control, which is not the object of our considerations here.

Visualisation techniques used to represent project uncertainty are graphs, maps, tables, grids, boxplots, violin plots, strip charts, tree diagrams and stacked bar charts [15]. No vectors have been used in this context so far.

As mentioned above, fuzziness is widely used to model uncertainty of project estimates [9]. Here the only visualisation technique used are graphs representing the membership functions. This will be presented in the next section, along with a new visualisation proposal.

3 Membership functions versus vectors – two uncertainty visualisation approaches

Let us suppose that a project parameter P is not known exactly in the stage of project planning. The only information which is given is that the most possible value of the parameter is $\hat{p}$, that the value of the parameter will be included in the interval $\left[\underline{p}, \overline{p}\right]$, $\hat{p} \in$

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

$\left[\underline{p}, \overline{p}\right]$ and that the further a value lies from $\hat{p}$, the less its possibility degree is, and the changes are linear. Obviously, the possibility degree of numbers outside $\left[\underline{p}, \overline{p}\right]$ is 0. Let us mention in this place that possibility degree is not the same as probability. The discussion about the relationship of the two notions has been subject to a vast research [22], but here let us limit ourselves to the statement that possibility can be determined more subjectively and it expresses the subjective feeling of an (or a group of) expert(s) about the possibility of occurrence of the given crisp number in the role of the actual value of *P*.

Our knowledge about parameter *P* can be represented first of all as a graph of the membership function of the triangular fuzzy number determined by the parameters $\underline{p}, \hat{p}, \overline{p}$ [8]. This fuzzy number will be denoted as $\tilde{P} = \left(\underline{p}, \hat{p}, \overline{p}\right)$. Its membership function μ_P is defined on the set $\Re$ of real numbers and represents the possibility degrees of the respective real numbers. It is defined as follows:

$$\mu_P(x) = \begin{cases} 0 \text{ for } x \leqq \underline{p} \text{ or } x \geq \overline{p} \\ \frac{x - \underline{p}}{\hat{p} - \underline{p}} \text{ for } x \in \left(\underline{p}, \hat{p}\right) \\ \frac{\overline{p} - x}{\overline{p} - \hat{p}} \text{ for } x \in [\hat{p}, \overline{p}) \end{cases} \quad (1)$$

Its representation can be seen in Fig.1 (for *P* represented by numbers 2, 4, 5).

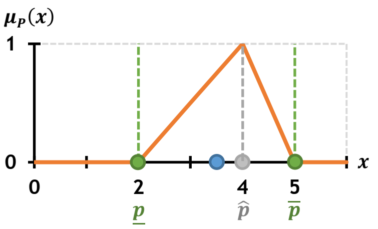

Fig. 1. Membership function-based visualisation of parameter *P* determined by numbers 2, 4, 5.

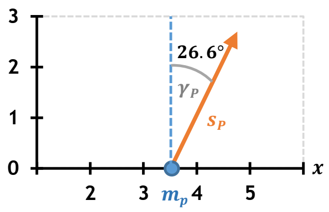

Fig. 2. Vector visualisation of parameter *P* determined by numbers 2, 4, 5.

The interpretation of Fig. 1 is as follows: value 4 is the most possible value of the unknown parameter *P* and the width of interval [2, 5], thus 3, represents the indeterminacy degree linked to the estimation of *P*. The wider the support of the triangle, the less is known about the actual value of the parameter being estimated.

Here we propose an alternative representation of the same information about parameter P. The information will be represented as vector whose end will point to the most possible value and whose length will indicate the indeterminacy degree. The vector $\vec{P}\left(\underline{p}, \hat{p}, \overline{p}\right) = \left\{m_p, s_P, \gamma_P\right\}$ will be defined by:

- its beginning: point with coordinates $\left(m_p, 0\right)$, where $m_p = \left(\overline{p} + \underline{p}\right) / 2$

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

- its length $s_P = \overline{p} - \underline{p}$
- the angle γ_P between the line $x = m_p$ defined as $\gamma_P = arc\,tan(\hat{p} - m_p)$, where positive values of γ_P stand for the inclination to the right and negative – to the left.

The vector representation for the considered example of parameter P is given in Fig. 2. The interpretation of Fig. 2 is as follows: the inclination of the vector to the right from the line $x = m_p = 3{,}5$ indicates the distance of the most possible value (here 4) from the mean value 3.5: the inclination is to the right because here the most possible value is higher than the middle value. Inclinations to the left correspond to most possible values lower than the middle values. The length of the vector (here 3) shows the indeterminacy degree linked to the estimated parameter.

We hypothesize that vectors may act as clock hands and be more appealing to some recipients of the information about the estimated parameter than triangles. The inclinations show changes of the most possible values with respect to the centre points of the possible range of the parameter: both the magnitude and the direction of those changes. The lengthening of the clock hand indicates that our knowledge about the parameter decreases, the shortening shows the opposite direction.

The two representations were compared in an experiment described in next sections.

4 Method

4.1 Subjects

Overall, 76 volunteer students of Wroclaw University of Science and Technology (Poland) took part in the experiments. There were 37 (48.7%) female and 39 (51.3%) male participants. Their age ranged from 21 to 29 years, with the mean of 22.5 and standard deviation equal 1.1 years.

4.2 Experimental task and measures

Factors and their levels were chosen so that it would be possible to verify the effectiveness of both triangular and vector representations. We included both clear-cut conditions where it was easy to check the correctness of answers, and a number of variants that served as noise. That is, an unambiguous answer was not available. The subjects were to assess whether the textual information about two features of the examined visualisations (the indeterminacy and the most possible value) match fuzzy number-based and vector-based graphical representations of unknown parameters being estimated.

Independent variables. We examined two representations, that is, the vector and triangular ones that were described in detail in Section 3. The knowledge about the investigated not-fully-known parameters differed in two aspects: (1) the indeterminacy, which was examined on two levels (low and high), and (2) the most possible value (MPV) which varied on three levels (small, medium, big). The factors and their levels are graphically shown in Fig. 3.

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

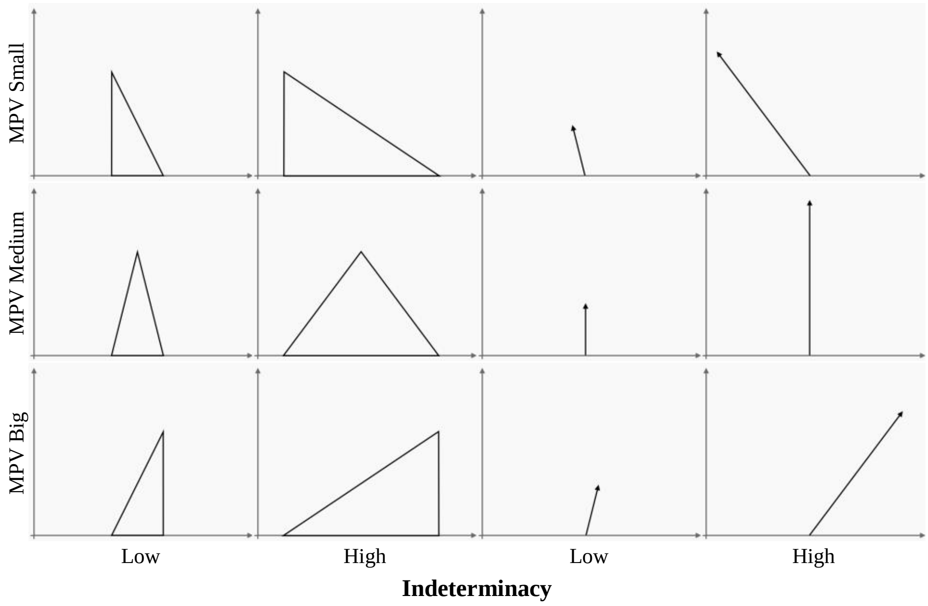

Fig. 3. Factors and their levels examined in the current study: visual representation (vectors, triangles), indeterminacy (low, high), the most possible value (MPV: small, medium, big).

Dependent measures. Two types of dependent variables were employed. For determining the effectiveness of both visualisation types, we examined the number of perfectly correct responses and the quantity of entirely false selections. Subjects were presented with a following statement: "The description fully corresponds to the graphics". They were to assess on a five-point Likert scale (1 – "I do not agree", 2 – "I rather disagree", 3 – "Hard to tell", 4 – "I rather agree", 5 – "I agree") to what extent the description of uncertainty and the most possible value match the visual representation. A sample experimental task is demonstrated in Fig. 4.

The participants' preferences towards the investigated stimuli were examined by asking them questions regarding both representations, once all effectiveness tasks were completed. Subjects were presented with four statements and instructed to specify their degree of agreement or disagreement on a seven-point Likert scale (1 – "I strongly disagree", 2 – "I disagree", 3 – "I rather disagree", 4 – "I do not have an opinion", 5 – "I rather agree", 6 – "I agree", 7 – "I strongly agree"). The questions were as follows: "Triangular/Vector representation was easy to interpret", and "Triangular/Vector representation was more attractive to me". One of the four questions is illustrated in Fig. 5.

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

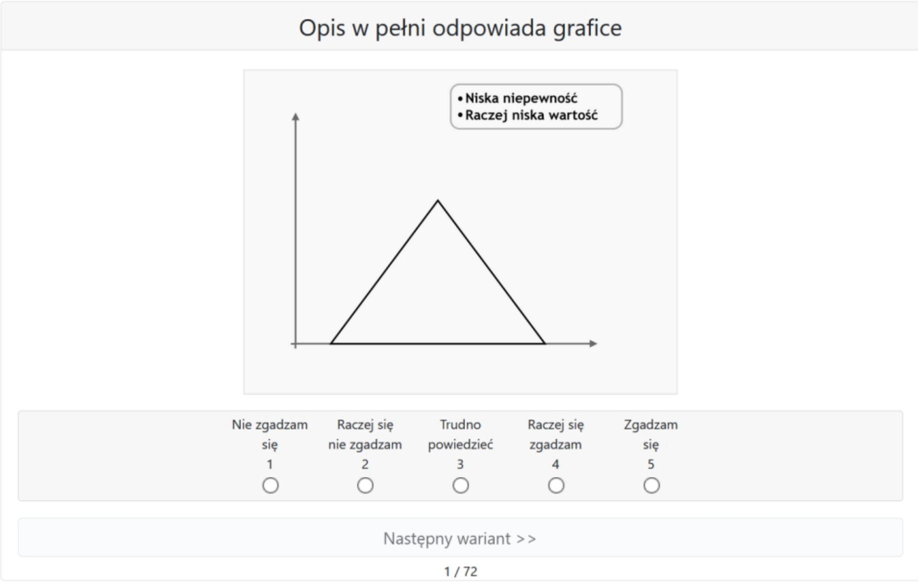

Fig. 4. Sample screen shot of an experimental task. Subjects assessed on a 5-point Likert scale to what degree the description of indeterminacy and the most possible value match the visual representation.

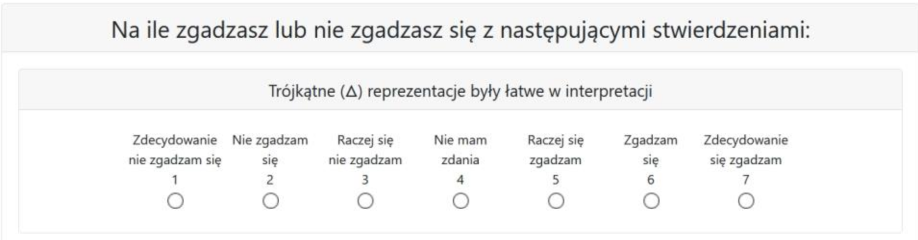

Fig. 5. Sample screen shot of one of the questions related to the subjects' preferences. Participants assessed on a 7-point Likert scale to what extent they agree or disagree with one of the statements on the easiness of interpretation and attractiveness of representations.

4.3 Experimental design

A combination of independent variables' levels resulted in 72 experimental conditions. There were 6 not-fully-known parameters differing in the indeterminacy degree (2 levels) and the most possible value (3 levels). The information about all these parameters was prepared in two graphical versions, that is triangular and vector. Each of the 12 graphical variants could be displayed with corresponding 6 different descriptions varying in the same way as the investigated 6 parameters. A within-subject design was applied, which means that every participant examined all 72 experimental conditions.

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

4.4 Procedure

The experiments were conducted entirely online. Students received information about the possibility of participating in the study. They were provided with the hyperlink to a slideshow including voice recorded explanation of the experiment in the context of project estimation uncertainty. On the last slide, the subjects were asked to click the button that opened the React.js-based supporting software in the default local web browser. The experimental software was freely available on the Internet. Due to the web page structure, participants were asked to use devices having the screen larger than 10 inches in diagonal. In the application, subjects had to read and accept the informed consent for taking part in the examination and provide their basic data such as gender and age. Next, the main part of the study took place, that is, they performed the evaluation of all 72 conditions presented in a random order, followed by assessing four questions about their subjective opinions on the unknown parameter information visualisations (see Fig. 4 and 5). In the final thank-you page, they had an opportunity to input free-text comments before sending the data to the server.

5 Results

Generally, the obtained results prove that both graphical representations were to a large extent effective, despite a significant number of experimental conditions that could not be unambiguously assessed (3332 out of all registered 5482 cases = 76 subjects × 72 conditions). From among 2150 records that could be clearly identified as either correct or incorrect, as many as 2069 (96%) were perfectly answered, and only 81 (4%) were obvious mistakes. The difference is significantly better than random answers (χ^2 = 1838, p < 0.0001). These are illustrated in Fig. 6.

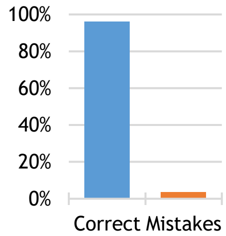

Fig. 6. Fully correct answers and clear-cut mistakes as percentages of unambiguous cases.

5.1 Effectiveness

Detailed results regarding the 2150 unambiguous records, in relation to the two types of unknown parameter representations, are presented in Fig. 7. They show that the number of the correct responses and errors were comparable both in the triangular and vector variants, with a tiny advantage in favour of the vector representation. To formally

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

verify the differences, in this section we use typical Chi-Square (χ^2) test based in frequencies. Such an analysis showed that the influence of the graphical representation on the number of correct answers was not statistically meaningful ($\chi^2 = 0.22$, $p = 0.64$).

Since the sample was almost perfectly balanced in terms of gender, we examined if there were any discrepancies in this regard. In Fig. 8, one may notice that females more often provided correct answers than men. This effect was statistically significant ($\chi^2 = 13.2$, $p = 0.0003$). Correspondingly, there were fewer clear-cut mistakes registered for women than for male participants however, the difference was not statistically meaningful ($\chi^2 = 1.49$, $p = 0.22$). This interactive factor could be the reason of almost identical general effectiveness.

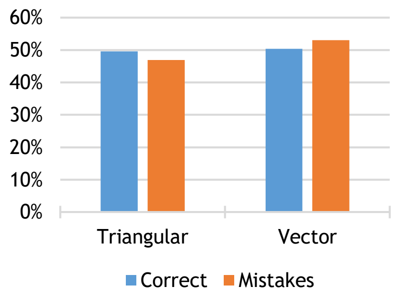

Fig. 7. Triangular and vector percentages of correct answers and mistakes.

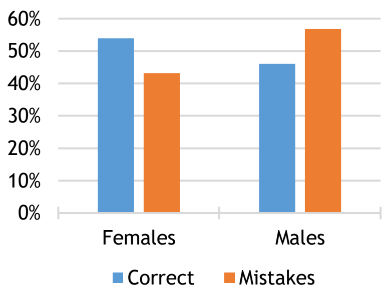

Fig. 8. Females and males as percentages of correct answers and mistakes.

Due to the significant gender impact on the number of correct and incorrect responses, we checked whether this effect influenced the results of visualisation effectiveness. The results of this analysis are illustrated in Fig. 9. The data show that there were decidedly more correct responses among women than men both for triangular ($\chi^2 = 6.55$, $p = 0.0105$) and vector representations ($\chi^2 = 6.60$, $p = 0.0102$), which is consistent with the results from Fig. 8. There were no differences between triangular and vector variants – both sexes performed equally (for females: $\chi^2 = 0.72$, $p = 0.79$, and males: $\chi^2 = 0.67$, $p = 0.8$).

As far as errors are concerned, women made more mistakes while assessing triangular than vector representations. Men, in turn, committed more errors for vector than triangular visualisations. However, since the general number of incorrect answers was small, none of these differences were statistically significant on the level of 0.1. Similarly, males made more obvious mistakes than females both for triangular and vector representations, but in both cases the differences were statistically irrelevant (for triangular: $\chi^2 = 0.42$, $p = 0.52$, and vector: $\chi^2 = 1.14$, $p = 0.29$).

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

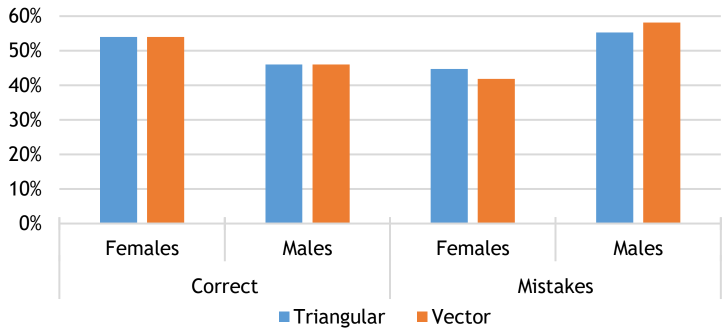

Fig. 9. Triangular and vector interaction with gender. Correct answers and errors.

5.2 Preferences

The outcomes of the analysis of the subjects' preferences expressed after performing the 72 experimental tasks are illustrated in Fig. 10. Participants rated the easiness of interpretation and attractiveness of triangular and vector visualisations of the examined parameters. If the gender is taken into consideration, a similar pattern of preferences emerges in responses to both types of statements. To formally verify if proportions of positive answers differ significantly, we employed classic ratio statistics. It occurred that male participants regarded triangles as easier to interpret (77% vs 65%, $p = 0.0509$) and more attractive (74% vs 57%, $p = 0.014$) than vectors. Women, in turn, tended to rate significantly better vector representations than their triangular counterparts in terms of easiness of interpretation (73% vs 57%, $p = 0.019$). However, they rated vectors and triangles equally from the perspective of attractiveness (65% vs 65%). It can also be observed that females were more decisive as the number of neutral responses from men was twice as big (6 vs 12).

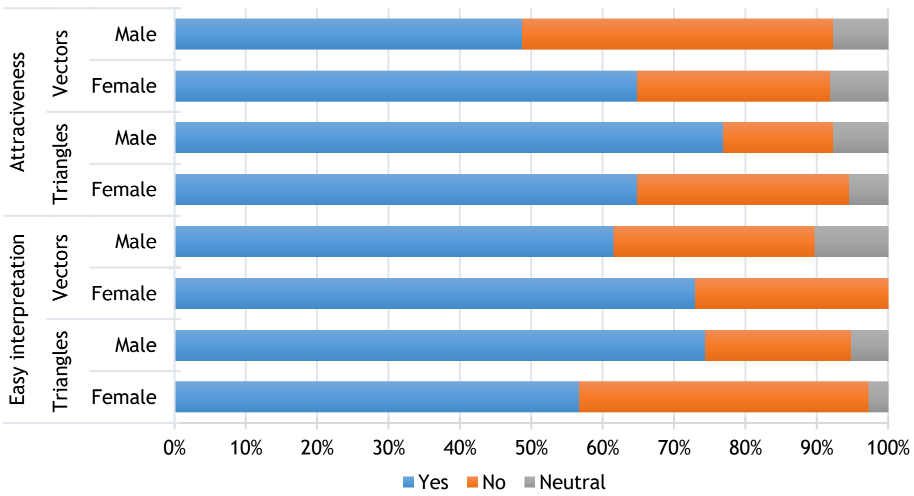

Fig. 10. Participants' subjective preferences towards vector and triangular representations.

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

6 Discussion and conclusion

The paper presents a new concept of applying a vector representation to project parameters' uncertainty. The performed experimental studies allowed to assess this idea in confrontation with the classical approach based on triangular fuzzy numbers. The research was designed and conducted in view of the usability concept specified in three dimensions: effectiveness, efficiency, and satisfaction (ISO 9241-11). The level of the number of correct identifications of the examined graphic messages was adopted as the measure of effectiveness. Efficiency and satisfaction were estimated by examining the appropriately subjective participants' preferences towards the easiness of interpretation, and attractiveness of the investigated stimuli. As there was a comparable number of men and women in the sample, we analysed the differences between both genders.

The obtained results allow us to evaluate the proposed vector representation of uncertainty as a promising alternative to the classic triangular approach. First of all, both forms of representation are generally equally effective. They correctly convey the designed messages. The vector representation is significantly better in relation to errors made by women, but worse as far as for men's mistakes are concerned. The effectiveness of both graphic solutions is differentiated by gender as well. For women, the information conveyed by vectors is significantly easier to interpret than in the triangular variants, while for men the opposite is true. The subjects' satisfaction measured by the subjective assessment of attractiveness is slightly higher for vectors (but not statistically significantly) in the case of women and considerably higher for triangles in the group of men.

The comparison of men and women overall performance showed a significantly greater number of correct answers and a lower number of errors among women than among men. This outcome is interesting, especially in light of relatively scarce empirical studies on the gender heterogeneity in various aspects. In a review of studies in this area, Vanston and Strother [23] presented the results showing significant differences in visual information processing systems by women and men, both at the level of eye physiology and neural mechanisms. The results of performing numerous visual tests discussed in [24] suggest generally higher efficiency of men (especially in the group under 30) in various types of visual message processing. However, some experimental studies indicate that women, though on the average slower in performing visually guided tasks, are superior to males when the accuracy is taken into account (e.g., [25–27]). It seems that our findings support this hypothesis, all the more that subjects had unlimited time to perform the experimental tasks.

The new uncertainty representation proposed here, along with the traditional, triangle based one, may find a wide application in defining and planning projects. In those processes a countless set of parameters and project quantitative features have to be given, even though most of them cannot possibly be known exactly yet. Thus, the two representations can be used alternatively, according to each user preferences, to represent incomplete knowledge about duration, cost, the available and the needed number of resource units, the risk occurrence probability and consequences etc.

It is important that our proposal makes it possible to adapt the visualisation method to the user: instead of just one, traditional visualisation it will be possible to offer to

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

project managers and project teams a choice. It is particularly important in the context of this study results, which show a significant gender influence on the graphical representations usability in conveying uncertainty.

The two visualisation methods can be of use in other than project management areas such as strategical and tactical management of organizations. Everywhere, where there is incomplete knowledge with respect to some important quantitative features, it might be useful to provide an appropriate form of visualisation to facilitate making decisions. Of course, both the vector and triangular forms can be used in any visual communication system that provides information of this type, e.g., multimedia presentations or printed materials.

While drawing conclusions from this article results, one should be aware that the research is preliminary in nature and exhibits a number of limitations. The sample size was moderate and included almost exclusively young students having similar characteristics. Thus, more experiments are needed to validate the two graphical representations and determine for which recipient groups which one should be selected. Conducting similar experiments in the environment of people professionally involved in project management seems particularly interesting. The two visualisations should be applied to real-world projects. In agilely managed projects, for instance, visualisation has already been being widely used [28]. Project teams are accustomed to analyse, discuss and make decisions on the basis of various types of graphics, therefore they might be open to testing new approaches in this regard. Triangles and vectors could visualize, e.g., task effort estimation for Scrum sprints. The application of triangle-based representation for this purpose has been already positively validated in practice [29]. A comparison with the vector-based representation should be the next step.

In this paper, we considered only static situations, which is acceptable in the context of project planning. During the project realization, however, the situation is dynamic and the most important goal is the identification of trends, in the project course. In our opinion, the visualisation akin to clock hands could be much more appealing in indicating the trends than triangles. But, of course, this is merely a hypothesis which need to be verified.

The results have shown that both representations of the incomplete knowledge about a parameter are generally accepted and understandable. Different groups of users may differ with respect to miscellaneous mistakes committed or personal preferences, but the results of the experiment show clearly that the new, vector-based representation is efficient in conveying the information and has a chance to be accepted and preferred by a large group of users.

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36

Acknowledgement

The work of Jerzy Grobelny and Rafał Michalski was partially financially supported by the Polish National Science Centre grant no. 2019/35/B/HS4/02892: *Intelligent approaches for facility layout problems in management, production, and logistics*. The work of Dorota Kuchta and Jan Schneider was partially financially supported by the Polish National Science Centre grant no. 2017/27/B/HS4/01881: *Selected methods supporting project management, taking into consideration various stakeholder groups and using type-2 fuzzy numbers.*

References

1. Project Management Institute (2008) Project Management Body of Knowledge (PMBOK® Guide). A Guid to Proj Manag Body Knowl (PMBOK® Guid - Fourth Ed. https://doi.org/10.1007/s13398-014-0173-7.2
2. Kerzner H (2017) A systems approach to planning scheduling and controlling. New York. https://doi.org/10.1016/j.drudis.2010.11.015
3. Yen J, Lee J (1993) Fuzzy logic as a basis for specifying imprecise requirements. https://doi.org/10.1109/FUZZY.1993.327535
4. Grote G (2015) Promoting safety by increasing uncertainty—Implications for risk management. Saf Sci 71:71–79
5. Cleden D (2017) Managing project uncertainty. Manag Proj Uncertain. https://doi.org/10.4324/9781315249896
6. Burnay C, Dargam F, Zarate P (2019) Special issue: Data visualization for decision-making: an important issue. Oper Res 19:853–855
7. Hawer S, Schönmann A, Reinhart G (2018) Guideline for the Classification and Modelling of Uncertainty and Fuzziness. Procedia CIRP 67:52–57
8. Zimmermann HJ (2010) Fuzzy set theory. Wiley Interdiscip Rev Comput Stat. https://doi.org/10.1002/wics.82
9. Masmoudi M, Haït A (2013) Project scheduling under uncertainty using fuzzy modelling and solving techniques. Eng Appl Artif Intell 26:135–149
10. Bevan N, Carter J, Harker S (2015) Iso 9241-11 revised: What have we learnt about usability since 1998? In: Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics). Springer Verlag, pp 143–151
11. Tractinsky N, Katz A., Ikar D (2000) What is beautiful is usable. Interact Comput 13:127–145
12. Hassenzahl M (2004) The interplay of beauty, goodness, and usability in interactive products. Human-Computer Interact 19:319–349
13. Lavie T, Tractinsky N (2004) Assessing dimensions of perceived visual aesthetics of web sites. Int J Hum Comput Stud 60:269–298
14. Carvalho M (2017) Risk and uncertainty in projects management: literature review and conceptual framework RECEBIDO. GEPROS Gestão da Produção, Operações e Sist 12:93–120
15. Dikmen I, Hartmann T (2020) Seeing the risk picture: Visualization of project risk information. EG-ICE 2020 Work. Intell. Comput. Eng. Proc.

DOI: 10.1007/978-3-030-77980-1_36

16. Jaber K, Sharif B, Liu C (2016) An empirical study on the effect of 3D visualization for project tasks and resources. J Syst Softw 115:1–17
17. Lima R, Tereso A, Faria J (2019) Project management under uncertainty: resource flexibility visualization in the schedule. Procedia Comput Sci 164:381–388
18. Killen CP (2013) Visualizations of project interdependencies for portfolio decision making : evaluation through decision experiments . Decis. Sci. Institue Annu. Conf.
19. Kolychev VD, Rumyantsev VP (2014) Visual models' system of project management. Sci. Vis.
20. da Silva CG, Meidanis J, Moura A V, Souza MA, Viadanna P, de Oliveira MR, de Oliveira MR, Jardim LH, Costa Lima GA, de Barros RS V (2017) An improved visualization-based approach for project portfolio selection. Comput Human Behav 73:685–696
21. van der Hoorn B (2016) The Project-space Model: Visualising the enablers and constraints for a given project. Int J Proj Manag 34:173–186
22. Drakopoulos JA (1995) Probabilities, possibilities, and fuzzy sets. Fuzzy Sets Syst 75: 1–15
23. Vanston JE, Strother L (2017) Sex differences in the human visual system. J Neurosci Res 95:617–625
24. Shaqiri A, Roinishvili M, Grzeczkowski L, Chkonia E, Pilz K, Mohr C, Brand A, Kunchulia M, Herzog MH (2018) Sex-related differences in vision are heterogeneous. Sci Rep 8:1–10
25. Ives JC, Kroll WP, Bultman LL (1993) Rapid movement kinematic and electromyographic control characteristics in males and females. Res Q Exerc Sport 64:274–283
26. Rohr LE (2006) Gender-specific movement strategies using a computer-pointing task. J Mot Behav 38:431–137
27. Michalski R (2008) The Effects of Panel Location, Target Size, and Gender on Efficiency in Simple Direct Manipulation Tasks. Hum Comput Interact. https://doi.org/10.5772/6311
28. Wysocki RK, Kaikini S, Sneed R (2014) Effective project management : traditional, agile, extreme.
29. Rola PM, Kuchta D (2019) Application of fuzzy sets to the expert estimation of Scrum-based projects. Symmetry-Basel 11:1–22

ICCS Camera Ready Version 2021
To cite this paper please use the final published version:
DOI: 10.1007/978-3-030-77980-1_36