Relevant Points of Interest: a Visualization Issue

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Resumo
Na maior parte das vezes, um observador não é capaz de processar instantaneamente tudo aquilo que estimula os seus sentidos. Estímulos adequados e bem escolhidos podem produzir melhores resultados e podem ser processados mais rapidamente.
Tendo isto em conta, o objetivo do nosso estudo é identificar os símbolos gráficos que transmitem adequadamente ao utilizador o nível de relevância dos pontos de interesse desenhados sobre um mapa, quando se usam computadores de secretária ou portáteis.
Efectuámos testes com utilizadores para tirar conclusões sobre a eficácia de um conjunto de símbolos gráficos com adaptações específicas. Uma função de grau de interesse é utilizada para determinar o nível de relevância de cada ponto de interesse e cada nível de relevância está associado a um símbolo gráfico específico.

Palavras-chave: Pontos de Interesse, Relevância, Ícones, Variáveis Visuais

Abstract

Most of the time, an observer is not able of processing instantaneously everything that stimulates his senses. Adequate and well chosen stimuli can produce better results and be processed more quickly.

Taking this into account, the aim of our study is to identify graphic symbols that adequately transmit to the user the relevance of the points of interest on a map, when using desktops or laptops.

We performed a user study to test the effectiveness of a set of adapted graphic symbols. A degree of interest function is used to determine the level of relevance for each point of interest; each level of relevance is associated with a specific graphic symbol.

Keywords: Points of Interest, Relevance, Icons, Visual Variables.

1   Introduction

Maps on the Internet, such as weather maps and traffic information maps, are increasingly used by the public in general. Most frequently they are animated, interactive and they highlight information on top of a geographical map.

Our goal is to highlight the relevance of points of interest displayed over a map, when desktops or laptops are being used.

Each graphic symbol depicted over the map shows the geographical location of a point of interest, informs about its kind of item (for example, if it is a monument or if it is a hotel) and, besides, exhibits its relevance level. This relevance level is calculated by a mathematical function, based on information provided by the user.

Most of the time, an observer is not able of processing instantaneously everything that stimulates his senses. Adequate and well chosen stimuli can produce better results and be processed more quickly. Taking this into account, the aim of our study is to identify graphic symbols that adequately transmit to the user the relevance of the points of interest. The interpretation of graphical information is preceded by a decoding graphic symbols task. This task must be minimized, in order to avoid misleading interpretations.

In each graphic symbol two characteristics can be identified: the appearance (size, shape, colour, among others) and the content which refers to the semantics that we associate to the symbol (for instance: we assume that a particular symbol represents a hotel, a church, or a castle). Both characteristics have to be addressed in a systematic and careful way.

In section 2 we briefly describe a set of works that focus on the visual attributes that arouse our attention. Section 3 is devoted to the proposed adaptations and to the implemented prototype. In

section 4 we present the user study. Finally, in section 5 we draw some conclusions and point to future lines of work.

2   Visual Attributes that Attract User's Attention

The French cartographer Jacques Bertin was the first investigator to propose a systematic approach to communication of graphical information in the particular context of the maps in his work "Sémiologie Graphique" edited in 1967 and translated into English in 1983 [Bertin 1983]. Besides the two variables, x and y, which provide a position on the map, Bertin identified six characteristics of graphic symbols or marks which he called "retinal variables": size, texture, orientation, shape, and two more on colour, hue and value.
Bertin classifies these visual variables or visual attributes according to their perceptual characteristics such as selective, associative, and quantity ordered.

A visual variable is:
- selective, if it helps to isolate all represented symbols and form groups of identical symbols (the dominant colour is a selective variable);
- associative, if it allows to group all the categories of symbols used (the shape is an associative variable);
- ordered, if it makes possible to define an order (the brightness is an ordered variable, allows the use of symbols lighter vs. darker symbols);
- quantitative, if it supports the quantification of the variation degree of a quantity (the size is a quantitative variable).

Bertin ordered visual variables accordingly to the number of these perceptual characteristics that each one contains. In his opinion, the size is at the top of the list, since it is a quantitative, ordered and associative variable, while orientation is at the bottom of the list, having only the associative characteristic.

The study of Bertin [Bertin 1983] contains no references to previous works that support the ideas therein contained. However, this work constitutes a landmark that is widely quoted and what came to be proven in large measure, by studies subsequently carried out.

Among the most recent works on visual attributes in the particular context of geo-visualization we highlight the papers by [Swienty at al. 2008] and [Garlandini and Fabrikant 2009], both using, among others, results obtained by Wolfe and Horowitz.

The latter two authors, professors of ophthalmology at the Harvard Medical School, conducted a comprehensive study on the graphical attributes that arouse our attention, in any context of application [Wolfe and Horowitz 2004]. Based on a significant number of studies of several authors, mainly in the areas of neuroscience and psychology, Wolfe and Horowitz define five groups of visual attributes based on the likelihood that they must contribute to awaken the viewer's attention: undoubted attributes, probable attributes, possible attributes, doubtful attributes and probable non-attributes.

The attributes colour, motion, orientation and size are undoubted attributes, shape is a probable attribute, while 3D is a probable non-attribute, to mention just a few.

Swienty et al. present a table of visual attributes [Swienty et al. 2008] that aggregates the proposals of Bertin and other authors as MacEachren [MacEachren 1995]. Swienty et al. propose a methodology to produce geo-visualizations involving three methods: 1) relevance is calculated and represented based on the use context information (eg, query parameters), 2) the relevant objects are filtered based on this same context, 3) the hierarchy of relevance values is represented using visual attributes that arouse our attention.

From a broader point of view, the goal is to prevent a cognitive overloading, producing simple representations, organized in well defined visual layers and that are able to highlight the most important information using the visual attributes that attract users' attention.

The authors present examples of application of the methodology. In one of these examples, points of interest have an obvious semantic and the corresponding relevance level is represented and associated with levels of transparency; in another example, the points are small circles and relevance is expressed by varying the dominant colour. They concluded that yellow to red colours represent higher degrees of visual attention than lemon to green colours. As a pre-evaluation method they propose the analysis of the movements of user's eyes.

Studies performed by Garlandini and Fabrikant have also confirmed some of Bertins' ideas [Garlandini and Fabrikant 2009]. These authors tested four of the variables identified by Bertin: size, orientation, colour hue and value. Measuring the movement of user's eyes, they focused its evaluation on the task of detecting the information when a visual stimulus occurs. They concluded that the orientation variable produced the worst results and that size is the variable that supports more effective and efficient observations. For colour hue and colour value they obtained similar results, however, colour value seems to have a slight (but non significant) advantage.

3   The Performed Study

Our goal is to highlight the relevance of points of interest (POI) displayed over a map. Taking into account studies conducted by the authors mentioned above, we have explored the size, the colour, considering hue and saturation, movement and changes in the symbols' design to express different levels of relevance. Next, we describe how to quantify the relevance, the adaptations proposed and the prototype developed to perform the user study.

3.1   Relevance Level

Our purpose is to visualize geo-referenced POI organized in several categories with multiple attributes. Each POI is represented by a graphic symbol drawn over a map showing its

geographical location, informing about its category (for example, if it is a monument or if it is a hotel) and exhibiting its relevance level.

The relevance is a value between 0 and 1 and is computed by a degree of interest function [Carmo et al. 2008]. Based on information provided by the user about his interests on the available categories and attributes of the POI, the degree of interest (DOI) function calculates the value that expresses the relevance of each item. Only those items whose relevance is above a threshold, also defined by the user, are displayed over the map. This is, therefore, a filtering mechanism.

In our approach the relevance of each item that is calculated by the DOI function is transformed into a discrete value as follows: the interval between the threshold and the value 1 is divided into three equal sized subintervals. All DOI function values in the same subinterval correspond to the same relevance level. The quantitative magnitude "relevance" calculated by the mathematical function is thus transformed into a 3-qualitative magnitude; its value determines the choice of the graphical symbol that corresponds to the point of interest. We chose to use three sub-intervals, considering that this number is adequate, firstly, to give enough information to the user (we consider that two intervals are insufficient) and, secondly, to prevent overloading the user with an excessive cognitive stimulus. This was a weighted choice and we did not considered necessary to conduct tests with a larger number of sub-intervals. The same approach is used by Swienty et al. [Swienty et al., 2008].

3.2   The proposed adaptations

As mentioned before, to represent different relevance levels we have explored adaptations in size and in colour, considering hue and saturation, and also tried to apply movement and changes in the symbols' design. For this purpose, we have considered five sets of symbols each one with three symbols representing three different relevance levels.
To represent each category we used symbols with obvious semantics and symbols with non-obvious semantics. Figure 1 shows the symbols with obvious semantics for the three available categories of POI.

Figure 1- Symbols with an obvious semantic meaning.

To test the relevance level representation with size variation we used the symbols illustrated in Figure 1 drawn with three different sizes shown in Figure 2 (a). The size is directly proportional to the relevance level of the POI.

To test colour variations in saturation and hue we used three levels of saturation and three colours, respectively. A more saturated colour corresponds to a higher relevance level (Figure 2 (b)). A more intense colour (orange) corresponds to a higher relevance level, a neutral colour (grey) corresponds to the lower relevance level and an intermediate colour (lilac) corresponds to the medium relevance level (Figure 2 (c)).

To test movement adaptation, we have applied a blinking variation. Symbols in Figure 1 are displayed with three different blinking rates, directly proportional to the relevance level of the POI.

To test changes in symbols' design, symbols with non-obvious semantic were used. The chosen symbols support adaptations to convey different levels of relevance. We tested only two symbols for two categories of POI: a star and a target with concentric rings, a sort of bull's eye. The target with more concentric rings corresponds to the highest level of relevance. The targets corresponding to the minor and intermediate relevance levels have the same number of rings, but the thickness of the outer ring is lower in the first (Figure 3 (a)). In the star, a thicker edge corresponds to a greater relevance (Figure 3 (b)). These symbols were carefully chosen among a set of proposals during a pre-evaluation phase.
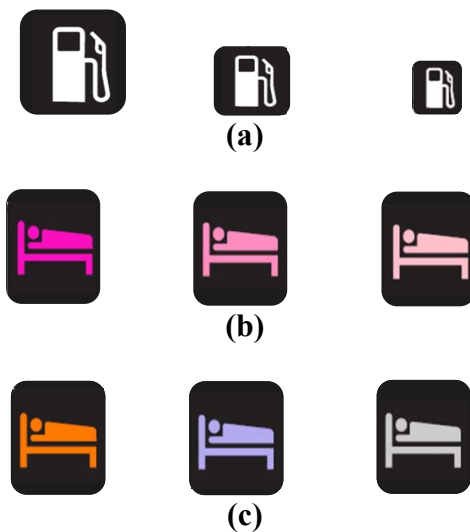

Figure 2- Symbols used to test: (a) size variation; (b) saturation variation; (c) hue variation.
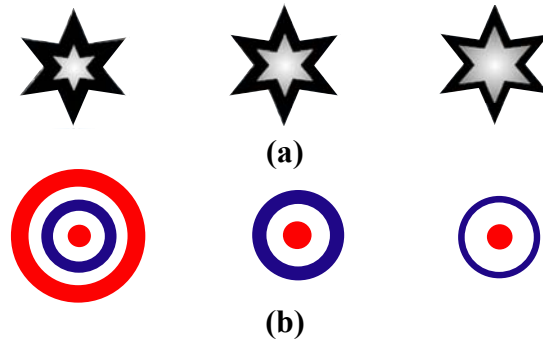
Figure 3 (a) and (b)- Symbols used to test design variations.

3.3 The prototype VisWide

To perform this study we implemented a prototype, named VisWide. This prototype was based on a previous version whose main concern was the application of representation techniques that adequately address cluttering [Paiva et al. 2009]. VisWide uses JavaScript, PHP, Java, SQL, HTML and SVG.

To depict the map and the points of interest, the SVG (Scalable Vector Graphics) format was chosen mainly because it is an open W3C standard for graphics on the web, it allows three types of graphic objects (vector shapes, images and text) that fulfill our needs and it supports both interactivity and animation.

The VisWide prototype interface has two windows. The first contains two areas: a map (Figure 4 on the left) and a dialog area (Figure 4 on the right) where the user gives the information that feeds the DOI function. In the dialog area the user selects the categories and corresponding attributes which he considers the most important for his search. He has to specify the weight of each chosen attribute and the relevance threshold. As explained before, the items whose relevance is bellow this threshold will not be displayed.

The second window exhibits the points of interest over the map (Figure 5). Using the fade in option on the upper right corner, the points of interest may become transparent whenever the user wishes to observe the background map in detail and with "no noise" over it. The fade out option restores the representation of the points of interest.

In this study, we have not considered techniques to treat excessive graphic information; our concern was to test the effectiveness of a set of carefully chosen graphic symbols to represent points of interest.
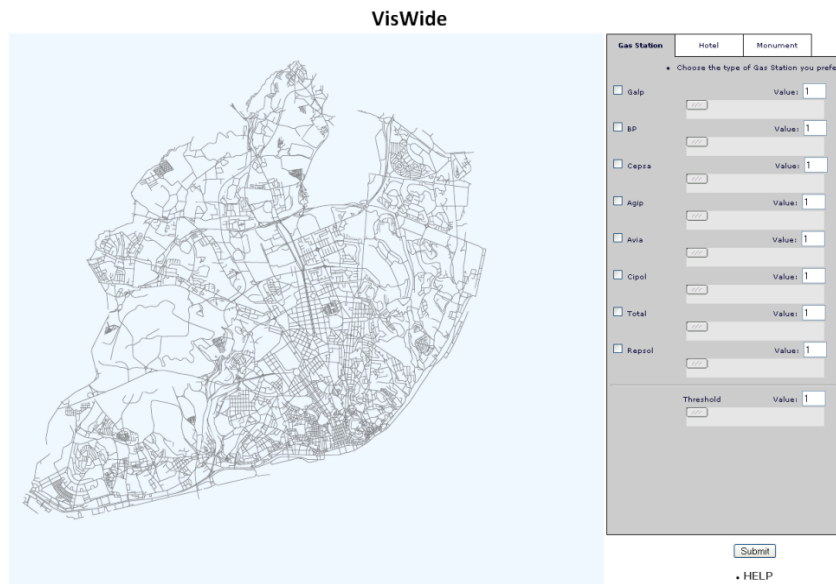
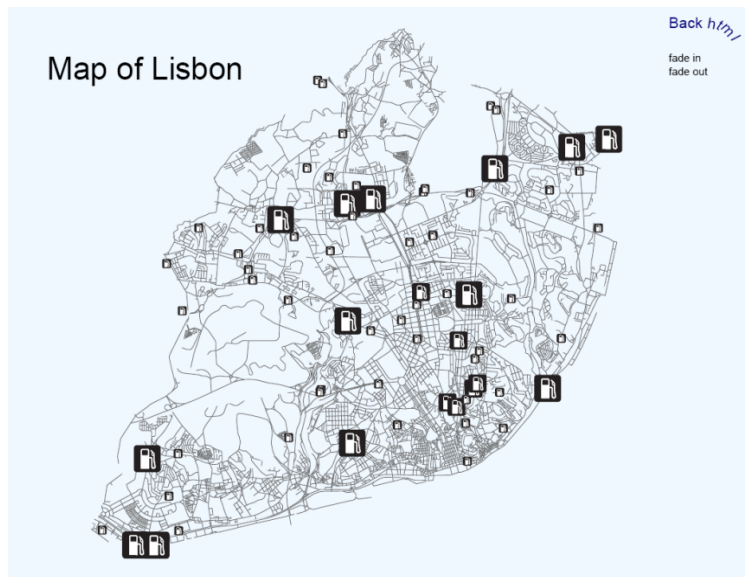**Figure 4- Main window of the VisWide prototype.**

Figure 5- Points of interest over the Map of Lisbon.

4   User Study

We have conducted a user study to evaluate the proposed adaptations to express relevance.

Considering the adaptations we wanted to study, our hypotheses are the following.
     The user will perceive that**:**
     H1) the size of a symbol is directly proportional to its relevance level;
     H2) a more saturated colour corresponds to a higher relevance level;
     H3) a more intense colour expresses a higher relevance level;
     H4) a change in a symbol design expresses variation in the relevance level;
     H5) the blinking rate of a symbol is directly proportional to its relevance level.

To test these hypotheses, we have performed the same tests for each one of the five sets of the symbols presented before. Each set is called a Version and Table 1 summarizes the corresponding adaptations.

Version no.	Type of Symbols	Relevance
1	Symbols with obvious semantic	Size
2	Symbols with obvious semantic	Saturation
3	Symbols with obvious semantic	Hue
4	Symbols with non obvious semantic (star and bull's eye)	Star: edge thickness Bull's eye: no. of concentric rings and outer ring thickness
5	Symbols with obvious semantic	Movement

Table 1: Adaptations used to represent relevance.

4.1   Participants

We consider that the typical user of the application is an adult, belonging to the general public and that uses, even casually, the Internet. Having that in mind, we have interviewed 30 users, 15 men and 15 women. Their age ranged from 18 to 71, averaging at 38, evenly divided in three age groups: less than 30 (<30), between 30 and 45 (30-45) and over 45 (>45). Their academic background was quite diverse: college students of Informatics, Biology, Architecture and Design, lawyers and teachers from different grades and areas. The users were asked if they are used to

consult maps in the Internet (we gave the example of *Google Maps*). They all answered affirmatively and half of them use Internet maps on a regular daily basis.

4.2   Procedure

Each user performed the tests alone with the interviewer in a quiet room. The test was previously explained and the interviewer emphasized the fact that we wanted to test the graphical symbols used to represent points of interest and if they are effective to transmit the relevance level.
The map used was from the city of Lisbon, where all participants live and/or work or study. The categories of points of interest include hotels, gas station and monuments, and all categories have several attributes. Therefore, it is quite easy for the user to provide a credible input to the DOI function in the main window of the prototype.

We have not made time measurements; therefore we have not tested the efficiency of the representations, only its effectiveness.

4.3   Tasks

For each Version the user performed two tasks:

Task 1 - Controlled searches:

> a) The user observed the layouts resulting from a set of pre-defined searches and ordered the symbols according to the perceived level of relevance. In this task it was assured that symbols corresponding to the three relevance levels are displayed.

> b) The user answered to a set of questions, for each layout.

The questions posed to users during this task were:

> 1. How many different symbols can be distinguished over the map?

> 2. How do you associate each symbol with the corresponding level of relevance?

> 3. What was the icon that caught your attention in the first place?

Task 2 - Autonomous searches: the user examined the layouts of searches carried out autonomously by him. He could confirm or adjust responses given in the previous task.

After performing tasks 1 and 2 for the five Versions, the user ranked the three Versions that he considered the most appropriate. He could also give suggestions for improvements and personal

opinions on more general aspects of the observed representations. In this stage the following questions were asked

4. Taking into account that we want to evaluate the quality of the icons used to express the relevance level of each POI, how would you classify each Version (3-Very Good, 2-Medium, 1-Weak)?

5. What is the best icon among all you have observed?

6. What are, in order, the three Versions that you consider the most appropriate?

4.4   Results

In a previous paper, we have presented a preliminary and rough analysis of the tests [Gil at al. 2010]. This paper presents a more complete and accurate statistical analysis of the same results.

The answers to the previously described questions were statistically analysed using non-parametric tests (qui-square and Friedman) in the SPSS software (IBM SPSS). Non-parametric tests let us conclude if the differences observed in answers given by elements of distinct groups are significant, that is, not due to chance.

The results obtained from these statistical tests, with a significance level of 5%, identified the situations in which the given answers depend on the users' group. For significant cases we produced bar charts that are presented throughout this section.

Following the order of the questions mentioned in the previous section, we can draw the following conclusions.

1. In this question we wanted to verify if the differences of the symbols in each set were perceived by users. As a matter of fact, all users could distinguish three different symbols on the map in all Versions, except on Version 5. Six users among the thirty were not able to distinguish the existence of three symbols in this Version: the icon with the intermediate relevance level was the more confusing one.

2. This question access if the users were able to match the relevance level with the correct symbol. Version 1 was unique in that all users have agreed on the level of relevance of the three graphic symbols presented. The worst observed results correspond to Version 5 with only fifteen correct answers. The other three Versions had similar results; only one or two users were confused or hesitated before giving the answer because they were not sure about the order of the colours.

3. We wanted to find out if the most relevant symbol was the more attractive one. Version 1 obtained the best results. That is, twenty eight users identified the symbol that represents the most

relevant POI as the one that caught their attention in the first place. Once again Version 5 had the worst results: the attention of twelve users was not attracted by the most relevant symbol. For the remaining three Versions, only four to six users did not choose the most relevant symbol.

4. We wanted to evaluate the quality of the icons used to express the relevance level of each POI. All Versions were given at least once the Very Good (3) and the Weak (1) classifications. Version 1 obtained the best classification as the mode and the median value of the classifications is 3. Version 4 was the one that raised more hesitation on the users. Version 5 received the highest number of bad classifications (mode = 1). Figure 6 shows the classifications of the five Versions.
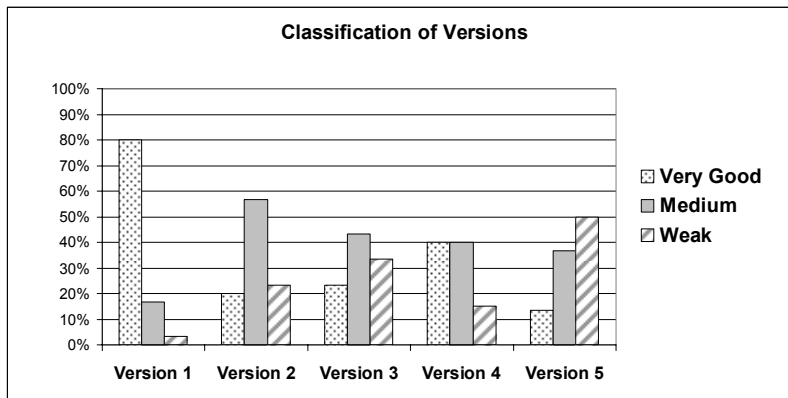

Figure 6- Classification of Versions.

The non-parametric tests identified a significant difference in the classification of Version 5 in two groups of users: over or less than 35 years old (Figure 7). Version 5 received some Very Good classifications from users over 35, while younger users clearly dislike it.
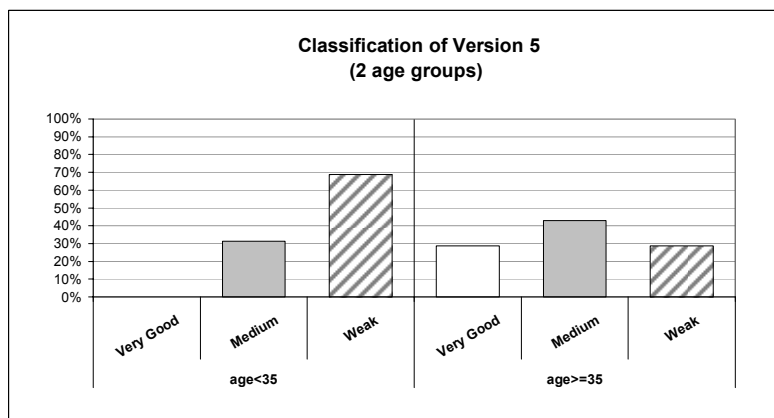

Figure 7 – Classification of Versions 5 in two age groups (less than 35 years old and over 35).

Men and women also have given significant distinct classifications. Figures 8 and 9 illustrate the differences.

Some facts can be observed: women clearly prefer Version 1, most of them classify Version 2 and 4 as medium, there is not a clear tendency about Version 3 and dislike Version 5; men also prefer version 1 but not so pronouncedly, they give similar classifications to Versions 2 and 3, most of them dislike Version 4 and they do not classify Version 5 so badly as women.
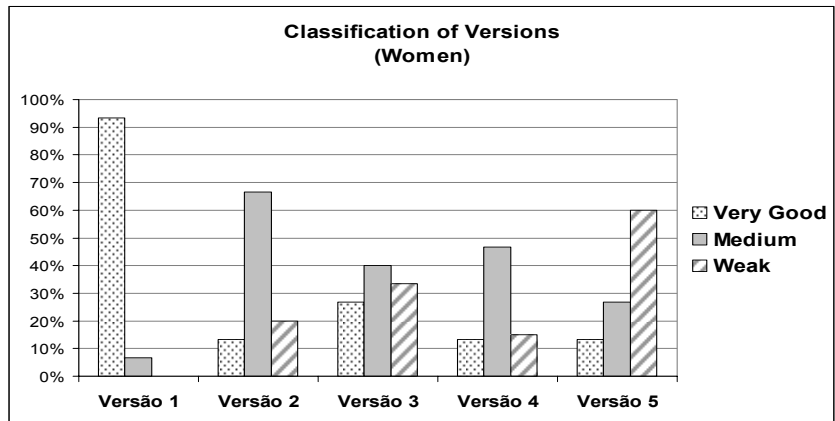

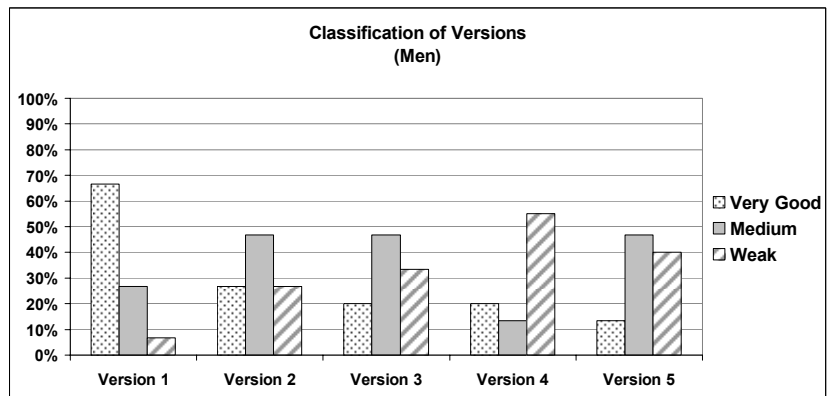**Figure 8 – Classification of versions by women.**

Figure 9 – Classification of versions by men.

5. This question tries to identify the set of symbols that receives the most favourable impression. Twenty one users chose Version 1 (size variation), followed by bull's eye symbols in Version 4 (design variation), with 11 answers, Version 3 (hue variation) with 6 answers, Version 5 (blinking variation) with 4 answers and Version 2 (saturation variation) with 3 answers. Some users have chosen more than one symbol as their favourite.

6. We tried to identify how the users rank the different Versions. The graph in Figure 10 shows the ranking of the five Versions. Clearly, the Version 1 obtained the highest ranking receiving the majority of first places, while version 5 received the worst ranking classification, preceded by

version 2. Comparing Version 3 and 4, we observe that although they received the same percentage for the first choice, Version 4 had more second choices.
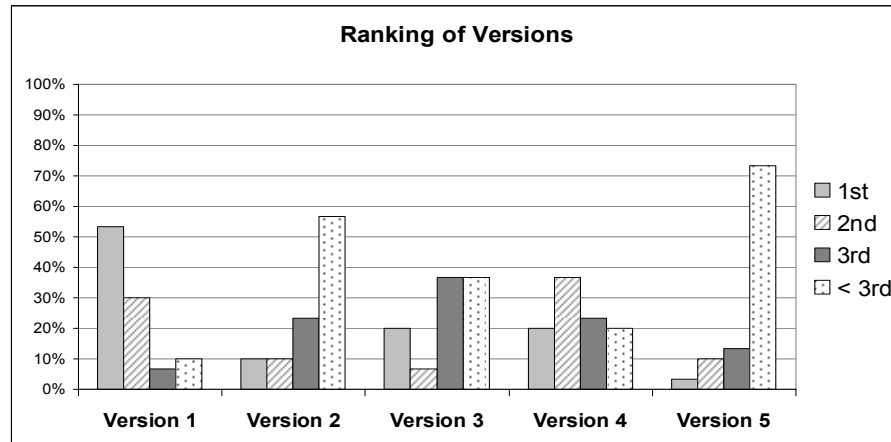

Figure 10 – Ranking of Versions.

5   CONCLUSIONS AND FUTURE WORK

The described results allow us to identify a set of principles to take in consideration when it is necessary to choose graphic symbols to represent relevant points of interest on a map, when using desktops or laptops.

Size is undoubtfully the best visual attribute to represent the level of relevance. This confirms hypothesis 1 and follows the basic ideas of [Bertin 1983] and [Wolfe and Horowitz 2004]. On the opposite side, stands the attribute movement. In this study, we simulated movement by blinking. This type of movement did not prove to be suitable to express relevance and therefore does not confirm hypothesis 5. This result contradicts to some point the idea presented by Wolfe and Horowitz that motion is an undoubted attribute. According to our tests, this attribute may be considered only if the application is intended for public above 35 years old or so (Figure 7).

After the variation size, the users preferred the variation in design. As a matter of fact, the design adaptations that were used also involved size variation. In Version 4, we have used stars and bulls' eyes symbols. The semantics of these symbols is not obvious (which one represents a hotel?), but these particular symbols are not completely strange to users because they are frequently applied in several contexts. The design adaptations, namely increasing the border thickness and the number of rings were correctly interpreted by users, although not being the preferred Version. This somehow confirms hypothesis 4.

In what concerns the use of saturation versus the use of hue, our tests show quite similar results in what concerns classification Very Good. However, saturation exhibits a slight advantage, because Version 2 (variation in saturation) obtained 23% of Weak scores while Version 3 (variation in hue) had 33% of Weak scores, because the users stated that they did not clearly understand the order of the chosen colours. Despite colour saturation had been chosen as a better symbol only by 3 participants, against the 6 choices for colour hue, in the individual appreciation it received less Weak scores. This means that hypothesis 2 and 3 are valid as users distinguished the relevance levels, but saturation may be a better adaptation compared to hue variation. Garlandini and Fabrikant obtained similar results about the use of colour, although they had compared colour hue versus colour value, the results of their user study also indicates that colour hue was slightly worse [Garlandini and Fabrikant 2009].

In the near future we will continue our study, namely testing simultaneous combinations of visual attributes. Considering that Versions using hue and saturation have obtained medium classifications, it can be valuable to compare the simultaneous use of size and hue versus the simultaneous use of size and saturation.
We will also consider various suggestions given by users during the test phase and we will also include forms of representations to be tested with colour-blind users.
In a next step we intend to incorporate these results with treatment of cluttering and think how we can apply the results to mobile devices and to different contexts of use.

ACKNOWLEDGE

REFERENCES

Bertin, J. (1983), Semiology of Graphics: Diagrams, Networks, Maps. University of Wisconsin Press, Madison (translation of the French edition of 1967).

Carmo, M.B., Afonso, A. P., Pombinho, P., Vaz, A. (2008) MoViSys - A Visualization System for Geo-Referenced Information on Mobile Devices", Proceedings VISUAL 2008, pp 167-178, Salerno, Sept

Garlandini, S. and Fabrikant, S. I. (2009), Evaluating the Effectiveness and Efficiency of Visual Variables for Geographic Information Visualization. In: Spatial Information Theory: 9th International Conference, COSIT 2009, Aber Wrac'h, France, Sep. 21-25, 2009, Proceedings, Lecture Notes in Computer Science. Stewart Hornsby, K., Claramunt, C., Denis, M. and Ligozat, G. (Eds.) Springer: Berlin, Germany.

Gil, F., Cláudio, A. P., Carmo, M.B. (2010), Pontos de Interesse Relevantes num Mapa: à Procura de Boas Práticas, Actas Interacção 2010, pp 159-162, Aveiro, Oct.

IBM SPSS, http://www.spss.com/software/statistics/

MacEachren, A.M. (1985), How Maps Work. Representation, Visualization, and Design. Guilford Press, New York.

Paiva, B., Cláudio, A. P., Carmo, M.B., Pombinho, P., Catita, C. (2009) Estratégias para a Representação de Pontos de Interesse sobre Mapas, Actas do 17º Encontro Português de Computação Gráfica, pp 305-306, Covilhã, 29-30 Oct

Swienty, O., Reichenbacher, T., Reppermund, S., Zihl, J. (2008), The role of relevance and cognition in attention-guiding geovisualisation. The Cartographic Journal, Vol.45, Nr.3, pp 227-238.

Wolf, J., Horowitz, T. (2004), Opinion: What attributes guide the deployment of visual attention and how do they do it? Nature Reviews. Neuroscience 5(6) pp:495-501.