INFORMATION SYSTEMS IN MANAGEMENT

Information Systems in Management (2013) Vol. 2 (4) 300–312

PROBLEMS OF VISUALIZATION OF DIGITAL IMAGES FOR THE BLIND PERSONS WITH SPECIAL ATTENTION PAID TO BUSINESS GRAPHICS

MARCIN OLEJNICZAK, TOMASZ ŚMIAŁOWSKI, LESZEK J. CHMIELEWSKI, ARKADIUSZ ORŁOWSKI

Warsaw University of Life Sciences (SGGW)

Sight is the most important sense of a human. For the most of the society, the perception performed by the sight organ is perceived as something very natural. Reflection on life without the sight is not common, which slows down the technological development aiming at reducing the social exclusion of persons with sight disabilities. The dynamical development of advanced technologies does not provide solutions for all the cases of illness. However, many tools exist which allow people with visual disabilities to interact with the outside world. In most cases these tools allow only for the exchange of very basic information. We present some problems associated with the visualization of images for the blind, with the attention concentrated upon business graphics. We also give some propositions to enhance the level of non-visual perception of images with the use of specialized tactile equipment.

Keywords: non-visual presentation of images, blind and visually impaired, tactile interface, business graphics

1. Introduction

The contemporary concepts of sustainability and knowledge-driven economy are proper paradigms of the development of individual persons and societies. However, there are domains in which these paradigms seem to stagger. Some of the reasons for such a state is the natural and inevitable existence of numerous human disabilities. The ageing of the European society makes this phenomenon even more apparent. On of the valuable ways of overcoming the social and technological exclusion of the disabled persons is the development of supporting technologies tailored for specific types of disabilities. In humans, sight is the sense which is responsible for the major part of incoming information (usually estimated as 85%). Therefore, sight impairment is one of the most acute disabilities on the one hand, and is exceptionally difficult to compensate with the use of technological devices on the other. In Poland the number of visually impaired persons is over 60 thousand, nearly 80% of them aged over 50 [9]. Unfortunately, due to the ageing of the society and the lack of effective methods of medical treatment and external compensation, the percentage of the population with this disability is constantly increasing. Together with the loss of sight, the visually impaired people face a lot of problems and barriers, sometimes insurmountable. Dressing up, preparing a meal, shopping, moving at home are some of the problems. The greatest difficulty is moving outside home. Unknown environment, problem with spatial orientation, the need to remember many details in a correct order and lack of proper signage makes the departure from home an extremely difficult task for the blind [12]. Of course, the properly marked, friendly places exist, like urban communication stops, railway stations, loud talking cash machines, and modern buildings. However, their number is so small that the world of sighted people is a hostile environment that evokes the feeling of otherness, the vast loneliness, and consequently, frequent social exclusion of people with visual disabilities.

Not only social, but also technological exclusion is an effect of the lack of healthy sight. There exist solutions to change the word written in the website to the spoken word. This requires that both the design of the web page and the browser are compliant to the Web Accessibility Initiative (WAI) which is the W3C recommendation [21]. It is not observed by many developers, however.

There are numerous methods to improve the visibility for persons with visual impairments, but not totally blind. It is useless to list the software for enlarging the selected fragments of the computer screen and to strengthen the contrast, due to that such applications or functionalities are usually included in the operating systems, under the name of accessibility enhancements or the similar. Interesting works have been published on using the mathematical models of sight diseases in the form of transfer functions included in the processing of the human visual system. By inverting these functions it is possible to transform the images so that they are better perceived by the persons with sight deficiencies [16].

Blind persons use other senses, mainly hearing and touch, to compensate for the lack of sight [10, 12, 13]. Touch information is fragmented and rather pointwise than general, and it can only initiate the complex cognitive process of analysis of the shape as a whole. This requires strong imagination from the subject [15]. It can be expected that spatial imagination can be seriously reduced in blind persons.

Current technology has made considerable progress in the direction of presenting visual information by information channels other than vision thanks to the development of audiodescriptions and typhlography. In the first case, shape is transformed by a trained human into text description. Such text can be reproduced in the form of speech with many generally available devices. In the second case, the shape is transformed into a form for which the acquisition by way of senses other than sight is possible. In this range such technologies are applied as special embossed paper for 2D objects, three-dimensional printing for 3D objects, spatial presentation of images, maps, diagrams, etc., or representation of shape by sound (as described for example in [2]). All these techniques suffer from their specific restrictions. The use of special printers for visualization of images is time consuming and the resulting images are static. Getting to the next page in paper editions makes it impractical to present dynamic phenomena. Understanding the shape presented as sound requires gaining appropriate experience and will always be less informative in some aspects and excessively informative in the others. At present, solutions are available on the market which make it possible to dynamically create simple images or maps. However, in addition to high cost, the resolution offered by a tactile table is up to 300*200 points, each of which can be in one of two stares only: on (protruded) or off (retracted). Such technology makes it possible to display only simple two-level graphics, like black and white images or edge images. It goes without saying that such a form of display is far from high standards of a really tactile book (see for example, at [19], the information and tutorials on how to make a tactile book for blind children and how a good tactile book can be). None of the known solutions can enable the blind persons to read digital photographs or charts, with a possibility to capture the detailed and colourful representation of the image in full.

Some promising experimental data are already available. In [3] experiments are shown in which non-speech sound information combined with haptic experience make it easier to understand and use the information contained in graphs. The sound information was correlated with the place the experimenter was touching. In [8] it is proposed to use friction and texture to simulate colour. Other techniques are collected, compared and arranged in the review paper [14], where many haptic concepts and devices are described, not only in the context of supporting the visually impaired people, but also in the applications where multimodal experience can be useful to capture and learn information in many dimensions, to have some data reinforced to train skills etc.

If practical applications are the target, it would be necessary to meet the requirements with a relatively low price. Creating a good solution would be profitable in many areas, among others, in contact with art, in operating software systems and in acquiring business graphics. The latter issue is the one to which the most attention will be paid in this study.

2. Purpose and scope of study

As the basis for this paper the functionality of a tactile table will be used. First, some examples of the problems encountered in presenting the images of general kind with the use of such a simplified tool will be given. Then, some more examples will be shown in which a restricted domain of business graphics will be used. Such a restriction will reduce or even remove some of the problems, but not all. Finally, we shall attempt to give some propositions on how the experience with the tactile table could be improved if its technical possibilities are extended, and what good practices resulting from other domains should be applied.

3. Transforming images into the form presentable with a tactile table

As it was already said, the tactile table has up to 300*200 elements, each of which can be either in an *on* or *off* state (protruded or retracted). By examining such a table with fingers the person can experience a two-level image, usually called a *binary* image. The problem arises of how to transform an arbitrary image into a low-resolution, binary one, and how to do this with the least information loss possible.

The solution of such stated problem is not known in general. However, it seems that there are two ways of solving it. One is to *binarize* an image, and the other is to display only the *edges* of the imaged objects, which is based on a common observation that edges are a good candidate for the element which constitute the most significant part of the information contained in an image. In both approaches it is important that the resulting image will be presented with a low resolution medium (however, it can be expected that the available resolutions will rather increase than decrease in the future).

In our case, binarization of an image can be reduced to finding a suitable threshold. The threshold can be global for the whole image, or local, that is, variable across the image. A set of methods is presented in [1, 11, 18]. Binarization of an image can be preceded by improving its histogram. Histogram corrections are not necessary for properly exposed images, which are neither too dark nor too bright. This operation generally does not introduce new information and is used mainly for visualisation purposes. However, local histogram equalisation [6] can make it possible to use a global threshold instead of a local one. Nevertheless, an excessively strong local histogram equalisation can amplify the noise while enhancing the visibility of details. Global histogram equalisation (described, among others, in [6, 11]) and its results are shown in Figs. 1- 4.

Figure 1. Before using the histogram equalization (photo view)

Figure 3. After applying the method of histogram adjustment (photo view)

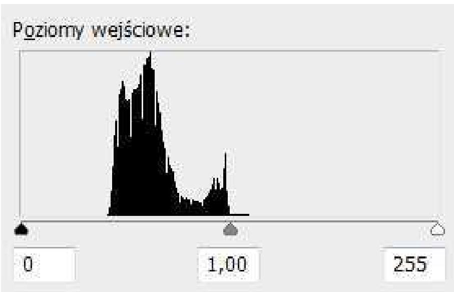

Figure 2. Before using the histogram equalization (histogram view)

Figure 4. After applying the method of histogram adjustment (histogram view)

At the present stage only grey level images can be considered. Therefore, colour images should be transformed into grey ones. The simplest method yet close to the colour sensitivity characteristics of the human eye is to calculate the grey level in each pixel as $I = 0.3R + 0.5G + 0.2B$, where I is the grey image intensity in a pixel, and R, G and B are the red, green and blue components, respectively, in this pixel.

Assume the image in Fig. 5 after transformation into a grey image in Fig. 6 has a bimodal histogram which can be displayed as a sum of normal distributions of grey levels, as in Fig. 9. For such a histogram a good method for finding the best threshold is the old method of Illingworth and Kittler from 1986 (described among others in [11]). Its results for Fig. 7 are shown in Fig. 8. In this figure the original style and mood of Fig. 5 can still be seen, however it is doubtful to which degree it is still possible to capture by a person with sight disabilities.

Figure 5. Photo scaled to the size of the supported by the tyflographics device (saturation of colors is optimal)

Figure 6. Image 5 in grayscale mode

Figure 7. Histogram equalization

Figure 8. Photo converted to binary form

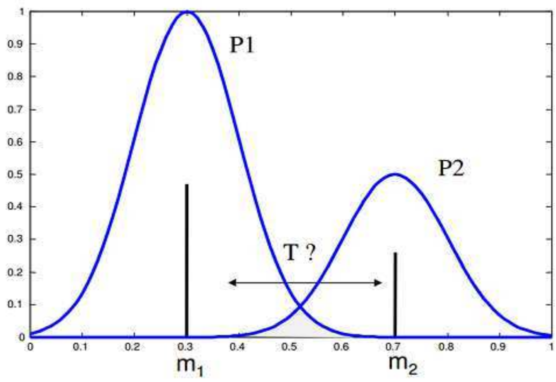

Figure 9. Selection of the threshold on the basis of the analysis of brightness histogram. The optimal threshold value (T) minimizes the total image segmentation error which is the sum of the numbers of points belonging to the object but classified to the background (false negative) and those belonging to the background but classified to the object (false negative)

Many examples of images can be found for which the contents is so difficult to interpret and the details vary so much by their meaning that no attempts can succeed in transforming them into binary ones in a useful way, like in Figs. 10-12.

Figure 10. Blurred image

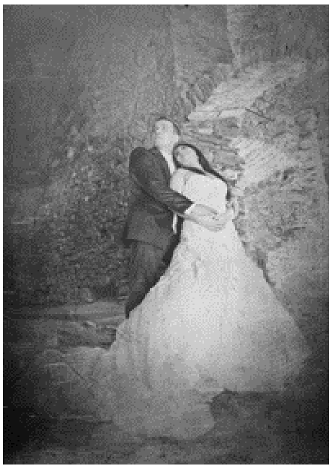

Figure 11. Image in grayscale

Figure 12. Binary image

As said before, the second idea to transform the image into a binary one is to display only its edges. In the case of images in general it is doubtful whether the outcome is equally satisfying as the original in terms of artistic effects. Compare the images in Figs. 13 and 14. The two thresholds of the Canny edge detector [4] have been chosen so that all the details which seem relevant for a typical observer are still visible in the edge image. The results are doubtful. What makes our task easier is that we have not the artistic images, but business graphics in mind.

Figure 13. The image before processing

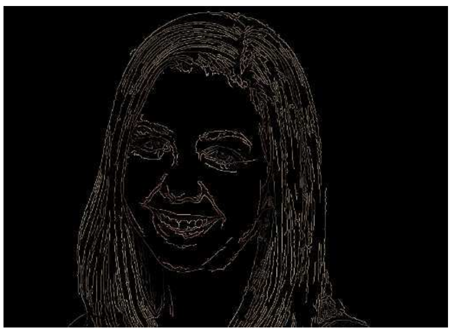

Figure 14. The image after processing using Canny algorithm

The purpose of presenting the examples shown until this point was only to recall the basic techniques. They were all not more than classical. However, even the most recent ones would give the results for which the quality is not significantly better when used in the application of our interest.

4. Presentation of business graphics for the blind persons

The basic assumption is that the graphics to be considered should rather be simple than very dense, due to the rational awareness of the limitations due to the observer and the displaying device. However, we will not adhere strictly to any specific resolution, as it will change according the current technological possibilities. Another assumption is that the text in the image will either be transformed in to Braille or it can be read out in another way.

Let us consider the graphics of quantity and sales for several categories of goods in Fig. 15. Let us criticise on it having in mind the recommendations for good data presentation according to [20].

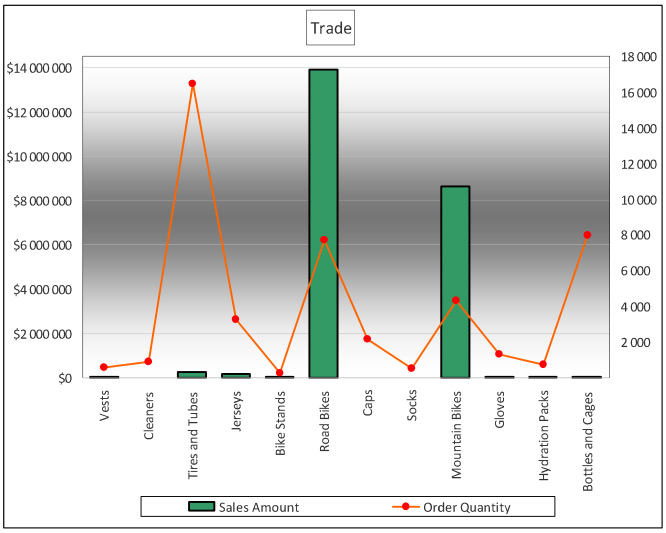

Figure 15. An example of bad practices in data presentation (see text)

These recommendations, formulated for visual presentation, are as follows:

- Above all else show the data
- Maximize the data-ink ratio
- Erase non-data-ink

- Erase redundant data-ink
- Revise and edit

The graphics has an unnecessary background. The frames around the title, labels and the whole graph are meaningless. The data are not sorted according to any reasonable criterion. There is nothing real which can be represented by the line which connects the point of the graph of “Order Quantity”: what does it mean that the quantity changes linearly between the categories of “Caps” and “Socks”? It is puzzling which scale refers to which graph; the only cue is that the sales amount is probably displayed in dollars. The title is not informative. There is no zero value in the right-hand side scale.

If the data are of interest, we should ask the question what is important to show. A probable answer is that these are the differing order quantities for large sales versus small sales categories. If also the obvious drawbacks of the graphs are removed, the image could be like that in Fig. 16.

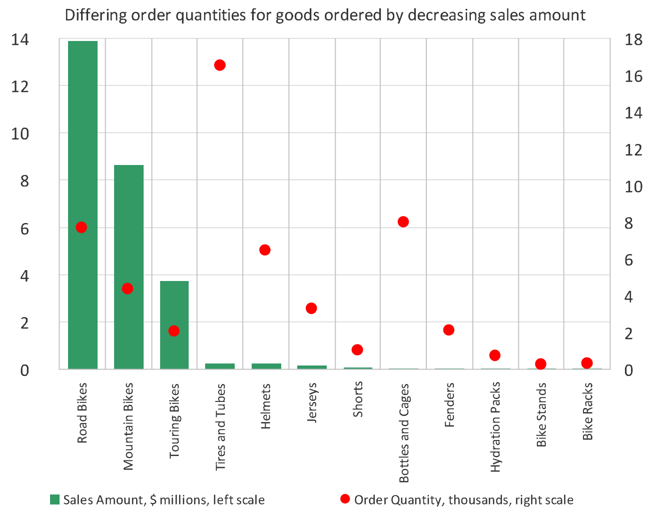

Figure 16. Example from Fig. 15 enhanced for visual observation (see text)

Title is more informative. Scales are simplified and explained with appropriate text. Vertical lines are added to clarify the relation of round points to categories.

Let us now come back to the display for the blind. In this case, the relation of quantities to the categories are important, but the observation that the quantities do not have the same trend as the sales amount is even more important. Hence, coming back to the connection of points with the line can be considered, to make it easier to follow the points along the line with touch. Vertical lines are moved to the centres of the categories and they end at the points, for better showing the membership of each point to the category. The pixels of the display should be in one of the two states, *on* or *off*, so colours and shades of grey are removed. In Fig. 15 *on* is shown with black, for clarity in print.

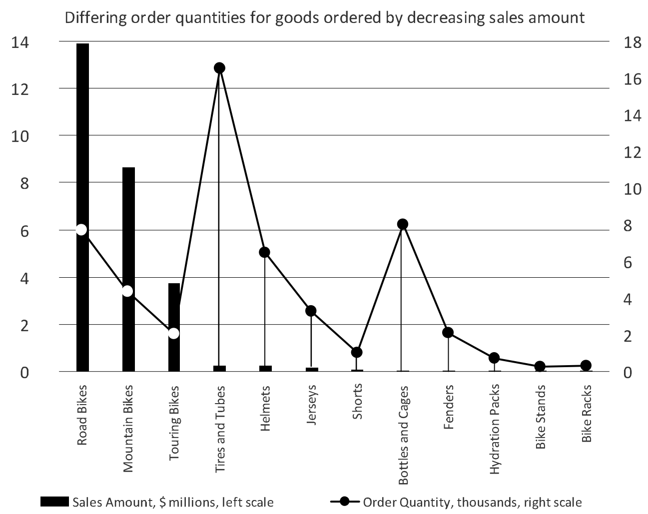

Figure 17. Example from Fig. 15 enhanced for tactile observation (see text)

It can be argued if black points should be made white while on black background, or rather the bars should be made thinner, and points larger. If bars are too thin they would be difficult to discern from auxiliary lines. This suggests that simple transformation of one image into another is not always possible and that special cases can arise and should be considered separately.

It should be noted that the graphics in Fig. 17 can be at the border or even outside the scope of possibilities of a low resolution tactile display. Overloading the image with any unnecessary details is unfavourable. Any complicated constructs are excluded. According to [5, 19, 20], to interesting tutorials to be found in [17], and to common sense, 3D graphs and any 3D elements in 2D graphs should be strictly avoided.

5. Need for tactile feedback

A great advantage of a good data display is the possibility of browsing through it with a pointing device. Simple operations which could be made in this way are pointing to the data and reading the detailed values. One of the most valuable operations that can be made is *coordinated highlighting in context*, as described in [7]. This notion pertains to cases where a complex set of multidimensional data is displayed simultaneously in a small number of graphs, with a subset of dimensions shown in each graph so that all the graphs are in two dimensions. It can be briefly described as a possibility to select the interesting parts of data in one graph and seeing how the view changes in the others, according to the same or corresponding selection. Due to natural limitations, for blind persons such possibility would probably not be useful if many graphs are shown. However, it could be used in a simplified version, in a single graph.

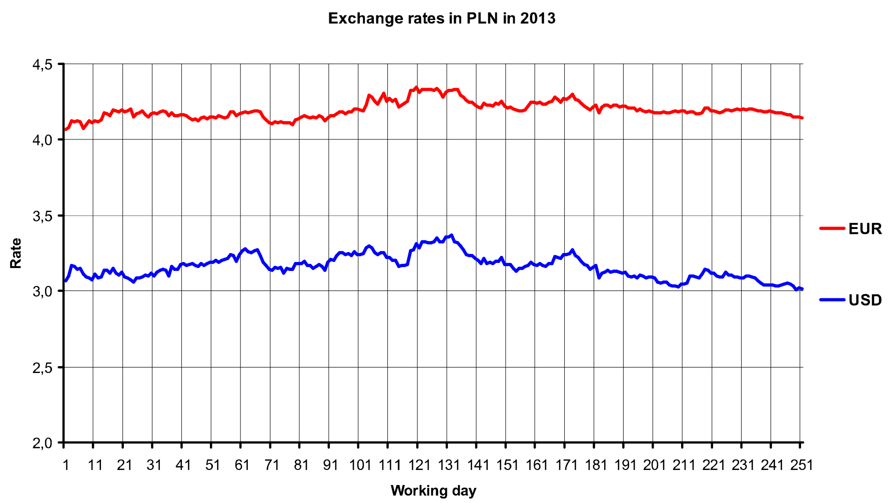

Figure 18. Example of Fig. 15 enhanced for tactile observation (see text)

Let us look at the simple, self-explaining graph in Fig. 18. Colour information can be replaced by showing one graph by a line and the other one by points. However, if the information to which graph the user is touching is available, new possibilities arise. The system could read aloud the relevant graph name, or the data for the day under the finger. If the user touches one of the two graph labels, at the right, the system could display only the graph related to the touched label.

The most interesting feature which could emerge if the information on which pixel (or pixels, that is, a region) is touched could be the possibility of representing the features of this pixel (or region) by sound. Such an approach has already been proposed in [3], but without relation to the tactile *on* and *off* information as provided by a tactile table. The practical possibilities of such a precise, local sonification seem to be many. The features of the pixel which come to mind first could be the grey intensity, colour, or local texture. Colour can be represented in coordinates of a colour space such as HSI, in which the distance is close to natural perception of colour difference. The features of the sound could be frequency, loudness, and all the possible variations of tone, like violin, piano etc. An interesting experiment with tactile feedback in a tablet with the application for the blind are described, for example, in [22]; however, the tablet is not the tactile table, due to that the tactile information in the form of *on* and *off* signal, can not be transferred to single pixels. Nevertheless, the development of touchscreens is likely to be close to breaking the barriers in communicating the precise, multimodal information including the sense of touch.

6. Conclusion

A number of simple yet practical methods have been proposed in the past to transform an image into a two-level form ready to display to the blind persons with the use of a tactile table. The domain of business graphics is a special case due to that the images are simplified to great extent with respect to the real world images, so some acceptable results can be obtained even with the classical techniques. Recommendations and methods known from the data presentation domain can be used to enhance these methods to some extent. However, a really large leap forward can be expected if the information on the location of the point or region being touched is available through a low-cost tactile table. One of the ways which will become possible to follow will be to represent the otherwise invisible image features, like colour and texture, with the features of a sound. This leap is likely to be made due to the development of tactile hardware in the nearest future. One of its effects will be that the business graphics becomes easier to read by the persons with severe sight deficiencies.

REFERENCES

[1] Acharya and Ray, Image Processing: Principles and Applications, Wiley-Interscience 2005.

[2] Berndt-Schreiber M., Lesiński W., Trzciałkowski Ł., Image data sonification in medicine, Journal of Medical Informatics Technologies, 12, 2008, 177-182.

[3] Brewster, S., Visualization tools for blind people using multiple modalities, Disability and Rehabilitation, 24(11-12), 2002, 613-621.

[4] Canny J., A computational approach to edge detection, IEEE Trans. PAMI, 8 (6), 1986, 679-698.

[5] Cleveland W.S., Visualizing data. ATT Bell Laboratories, Murray Hills, New Jersey 1993.

[6] Chmielewski L. J., Metody akumulacji danych w analizie obrazów cyfrowych, Akademicka Oficyna Wydawnicza EXIT, Warszawa 2006.

[7] Few S., Coordinated Highlighting in Context. Bringing Multidimensional Connections to Light. July, August, September 2010. In [17].

[8] Fritz, J.P., Barner, K.E., Design of a haptic data visualization system for people with visual impairments, IEEE Transactions on Rehabilitation Engineering, 7 (3), 1999, 372-384.

[9] Główny Urząd Statystyczny: Stan Zdrowia Ludności Polski w 2009 r., Warszawa 2011.

[10] Kwapiszowie J. i J., Orientacja przestrzenna i poruszanie się niewidomych oraz słabowidzących, WSiP, Warszawa 1990.

[11] Malina W., Smiatacz M., Cyfrowe przetwarzanie obrazów. Akademicka Oficyna Wydawnicza EXIT, Warszawa 2008.

[12] Majewski T., Dzieci z uszkodzonym wzrokiem i ich edukacja, w: Jakubowski S. (red.), Poradnik Dydaktyczny dla nauczycieli realizujących podstawę programową w zakresie szkoły podstawowej i gimnazjum z uczniami niewidomymi i słabo widzącymi, MEN, Warszawa 2001.

[13] Mizera L, Paplińska M., Walkiewicz–Krutak M., i inni, Pakiet edukacyjny projektu GALERIA PRZEZ DOTYK, Muzeum Regionalne w Stalowej Woli, Stalowa Wola 2007.

[14] Paneels, S., Roberts, J.C., Review of designs for haptic data visualization, IEEE Transactions on Haptics, 3(2), 2010, 119-137.

[15] Paplińska M., Rozwój percepcji i poznania dotykowego u niewidomych dzieci, w: Walczak G. (red.), Wspomaganie rozwoju małych dzieci z uszkodzonym wzrokiem, APS, Warszawa 2004, CD.

[16] Peli E, Goldstein R.B., Young G.M., Trempe C.L., Buzney S.M., Image enhancement for the visually impaired. Simulations and experimental results. Invest. Ophthalmol. Vis. Sci., 32(8), 1991, 2337-2350.

[17] Perceptual Edge Library, http://www.perceptualedge.com, Articles; access on March 22, 2014.

[18] Russ J.C., The Image Processing Handbook: Fourth Edition, CRC Press, 2002.

[19] Tactile Book Advancement Group (TBAG), http://www.tactilebooks.org, access on March 22, 2014.

[20] Tufte E., The Visual Display of Quantitative Information. Graphics Press, 2nd edition, 2001.

[21] Web Accessibility Initiative (WAI), http://www.w3.org/WAI, access on March 22, 2014.

[22] Zax D., A tablet for the blind? http://www.technologyreview.com/view/425732/a-tablet-for-the-blind/, Access on March 22, 2014.