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A NEW METHOD FOR ANALYSING EYE-TRACKING MEASUREMENT DATA

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Abstract: *When it comes to the function of photography in graphic communication, we should be aware of many different aspects of the medium. The standard criterion for a correct and successful photograph should always be its technical and artistic aspect. If something is not right, for example, if the exposure or composition are not correct, a photo should not be used for professional purposes. The third aspect is the content or meaning, where final decisions are usually made. With this in mind, editors are usually presented with photos from which they must select those to be used in a final publication.*

Since most editorial decisions are made on the basis of content or meaning, which is usually described as communication value, some decisions also involve technical aspects, such as whether it is better to use a slightly underexposed or slightly out-of-focus photo. In these cases, the standard criteria changes because the shooting conditions did not allow the photographer to take a technically correct photo, but the content or meaning is too important not to be published.

The research focuses on measuring how the way people see different photos changes when they are not technically perfect. Using eye-tracking technology, where we can measure where a person is looking and for how long, we can get an accurate idea of what that person is seeing and the way their eyes move. This type of measurement is actually not a problem and has been successfully used in many research studies. The main question to be answered in this study was how the nature of image perception changes when the image is distorted in some way. Therefore, a new method for analysing eye-tracking data was developed. The results show that eye-tracking can be used to determine how technical aspects of photography affect the way we look at it. The final judgement that the method works was made by comparing the data with data gathered with subjective tests in which observers had to choose between different distorted images and decide which is more acceptable. The correlation between the results of new method and a subjective testing is very strong.

Key words: *eye-tracking, photography, communication value, data analysis*

1 INTRODUCTION

Photography is one of the most important communication media today (*Giannakopoulos, 2017*). It is available almost everywhere and in both conventional (printed) and modern (electronic) media. When we try to describe how good a photograph is, we often use terms like beautiful, nice, blurry, dark, and so on. All these descriptions play an important role in the communication value of a photograph and its ability to convey a message correctly or as intended. The main topic of this research is to determine the parameters that are crucial for communication success and to analyse which of these parameters has the greatest influence on the process.

The parameters that influence the quality of photography are mostly technical in nature. Researchers (*Ponomarenko et al., 2009*) have divided and described them into the following groups: Sharpness, contrast, lightness, saturation, noise, compression and resize. In research (*Mohammadi, Ebrahimi-Moghadam & Shirani, 2014; Wang & Li, 2010*) focusing on image quality assessment, researchers use various algorithms to simulate all the parameters described. Which algorithms to use and how to decide between them is mostly a decision of the researcher, but using similar algorithms used by others gives us a better way to compare results. For this reason, there are many image databases (*Winkler, 2012*) that focus on research to evaluate image quality, and this approach can also be used to analyse the communication value of photographs.

The communication value of a photograph can be described as the ability to transmit information or communicate in the intended way. These are extremely important qualities when it comes to advertising, teaching, informing, etc. The way the viewer looks at the photograph and how much time he/she spends on some elements of the photograph is the reason for the main interest of this research. The quality parameters of the photo can influence some of the crucial communication elements, and the poorer the quality of the image, the lower the communication value. Different quality parameters have different

influence on it, and measuring which ones have the most influence is the main goal of our research, for example: is it better to use desaturated or blurred photos?
Using eye-tracking technology to measure how people look at different photos was an obvious choice. This approach has been widely used to measure legibility or attention, but to determine which quality parameters influence the way we look at a photo, it has not yet been used. The most important goal of our research was therefore to develop a method for analysing the gathered data that would give us accurate information about how different distortions affect the way we look at a photo.

2 MATERIALS AND METHODS

2.1 Materials

The research was conducted using the novel image database, which was first introduced in 2017 (*Ahtik & Starešinič, 2017*). The database consists of 30 different motifs (Figure 1), which differ mainly in their complexity and variety of colours. These two aspects were decisive for developing a new database for our research rather than using one of the existing databases. The analysis of the most used database TID2008 (*Ponomarenko et al., 2009*) showed that the included photos are simply not diverse enough to conduct a study where the communication value is something we are interested in. Our database is therefore 57% more complex than TID2008 and also offers higher resolution originals (*Ahtik, Muck & Starešinič, 2017*).

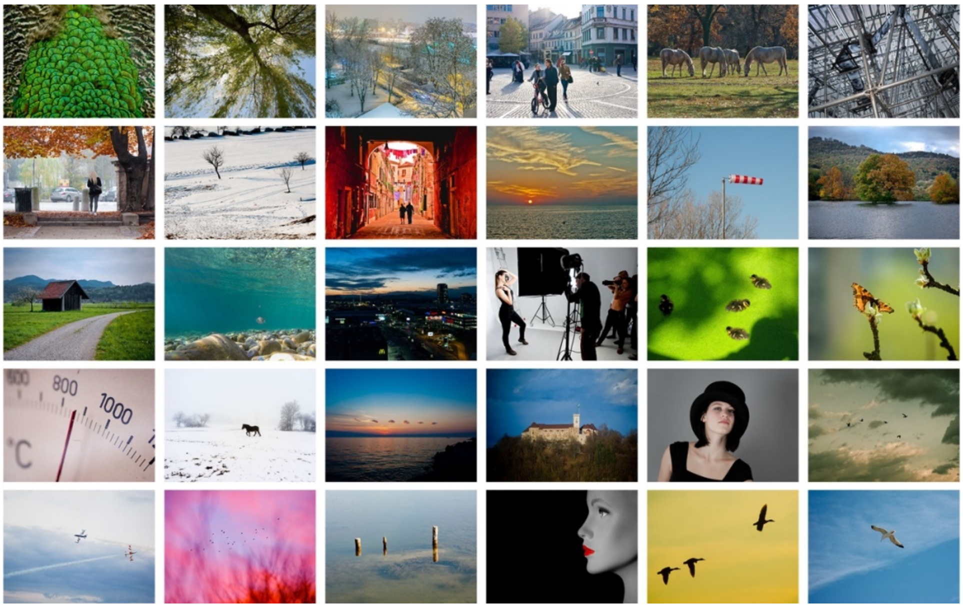
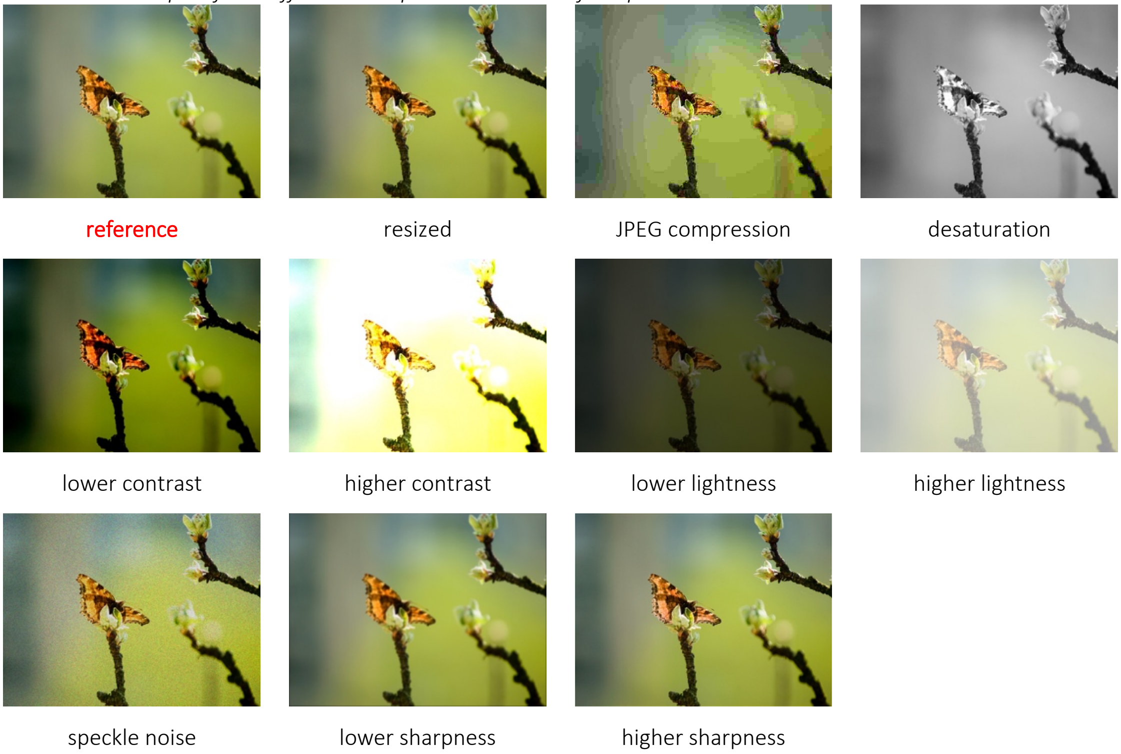


Figure 1: Reference images of novel image database used in the research

Various manipulations were then applied to the reference images, such as reducing/increasing contrast, reducing/increasing lightness, reducing/increasing sharpness, reducing saturation, compressing, adding noise and resizing. The parameters were applied in one to three steps using Mathworks Matlab R2014a. In total, we obtained 38 variations of each photo, so our database consists of 1140 photos. In this study, we used references (unmanipulated photos) and eleven manipulated photos where the manipulations are strongest (most seen). In total, 330 photos were used. Table 1 lists all the different manipulations of one of the photos used in the test - each observer saw only one of these variations.

Table 1: *An example of the different manipulations on one of the photos used in the test*



2.2 Apparatus

A TOBII X120 eye-tracker, a HP ZR24W LCD screen, a PC, a controlled darkroom environment and TOBII Studio 3.4.4 software were used to perform the measurements. The room was set up according to ISO3664:2009, ISO12646:2015, ISO,9241-305:2008 and ISO9241-305:2008 standards. The photos were displayed in the centre of a black screen at a fixed resolution of 840 × 630 px so that each observer had the same viewing angle of the photos (Figure 2). Each photo was displayed for 5 seconds, followed by 2 seconds of dark screen.

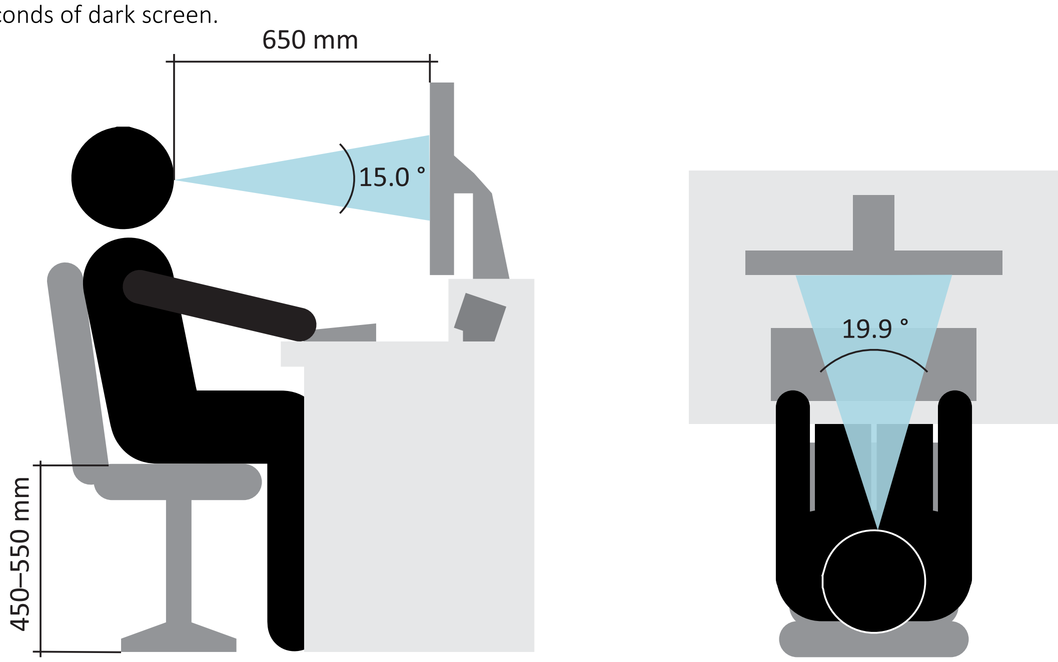


Figure 2: Eye-tracking measuring conditions.

2.3 Observers

We divided 330 photographs into 11 different tests so that each observer could see each motif only once, but with a different manipulation. One of the groups was the reference group, which looked only at unmanipulated photos. Each test included 10 participants, i.e. a total of 110 participants, 50% female and 50% male, 50% under 30 years old and 50% over 30 years old. The average age of all participants was 33.39 years, and the gender distribution was the same for all 11 tests. All participants are from Slovenia and have normal or corrected to normal vision.

2.4 Analysis

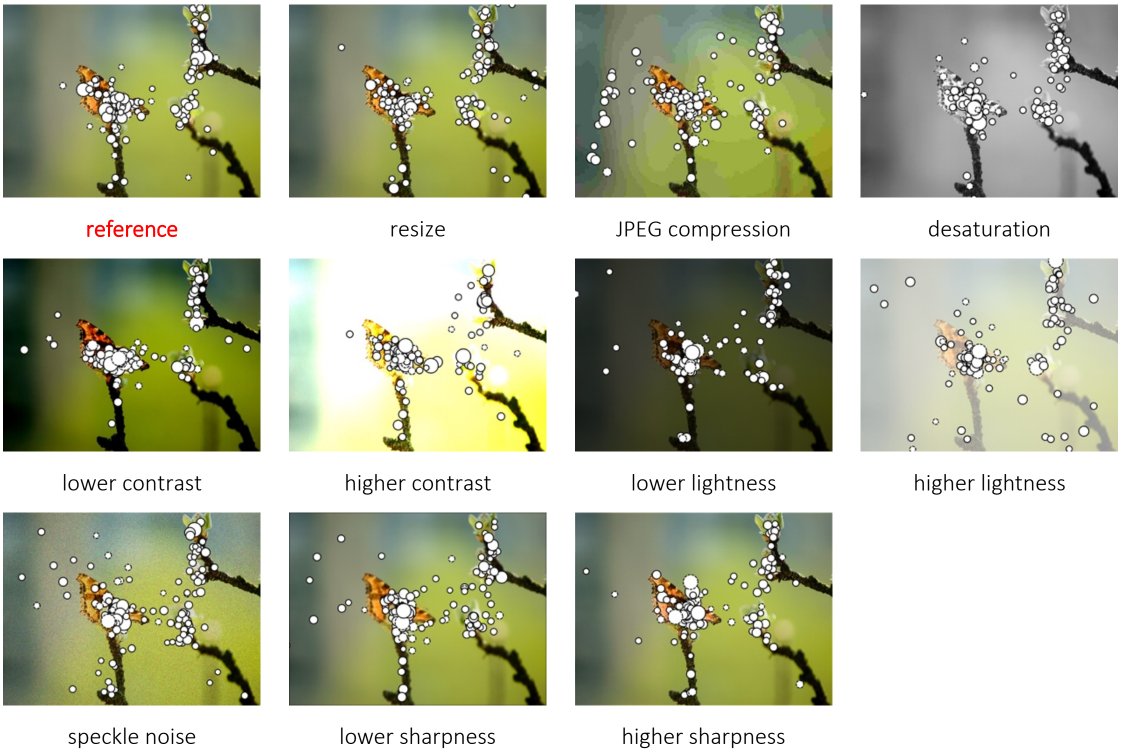
Since the TOBII Studio 3.4.4 software (*Tobii, 2016*) doesn't offer the possibility to analyse the change in the viewer's perception of different images, a new method was developed. We used TOBII Studio 3.4.4 to export duration gaze plots of each photo for all observers together. The gaze plots were exported as black circles in a transparent PNG file format. Since the aim of the research was to find out which parameter most influences the way people look at photos, regardless of the subject, all gaze plots for each parameter were combined. The end result was a cloud of gaze plots for each of the ten quality parameters and for the reference (unmanipulated) photos. Using Mathworks Matlab R2014a, we subtracted the reference cloud from each of the manipulation clouds and used the difference to obtain the result of which parameter most influenced the way the photos were viewed. For this purpose, we developed the following Matlab code:

```
folder = 'folder_name';
files = dir([ folder '/*.png' ]);
fid=fopen([ folder '/result.csv'],'w');
fprintf(fid,'filename,totalPixels,fullPixels\n'); for file = files'
A = imread( [ folder '/' file.name ]);
Z = A(:,:,1) == 0 & A(:,:,2) == 0 & A(:,:,3) == 0; numTransparentPixels
= sum(sum(Z));
numAllPixels = size(A,1) * size(A,2);
numFullPixels = numAllPixels - numTransparentPixels;
fprintf(fid,'%s,',file.name); fprintf(fid,'%d,',numAllPixels);
fprintf(fid,'%d\n',numFullPixels);
end
fclose(fid);
```

3 RESULTS

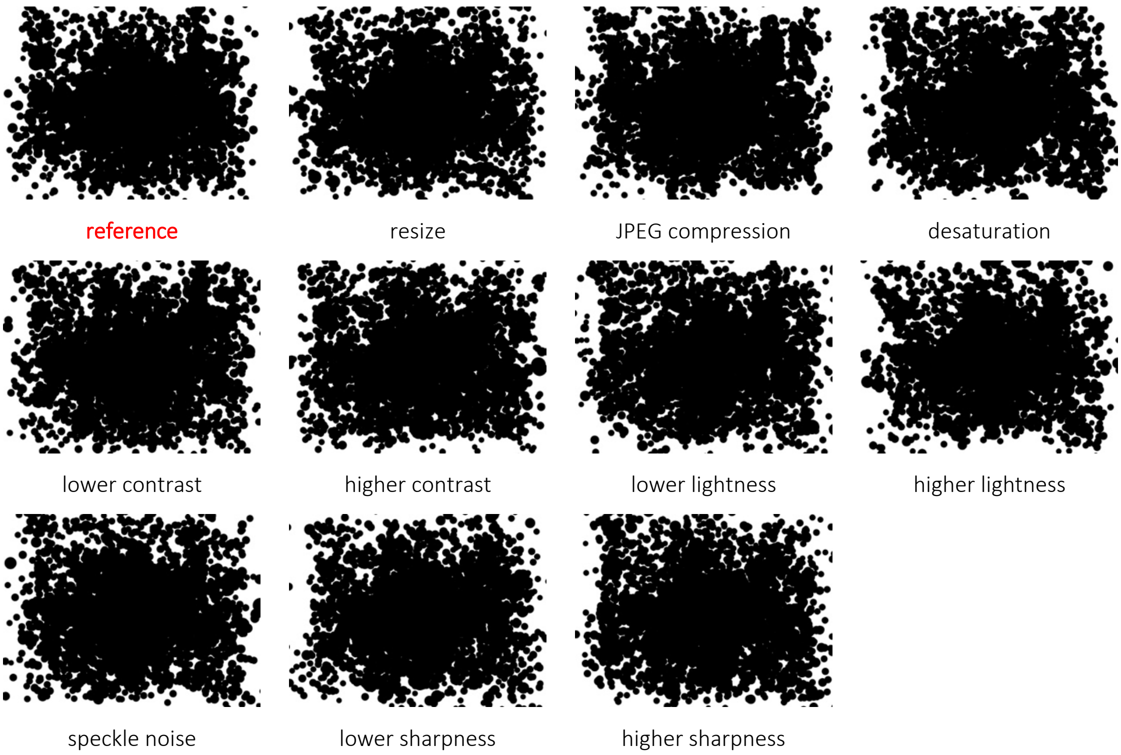
The TOBII Studi software offers many ways to export measurement data. When we tried to find the most suitable way, we quickly realised that there is no direct way to find out, how observers look at some photos differently from others. Since our research hypothesis was that the greater the change in viewing, the greater the impact of the distortion on the communication value of the photo, it was crucial to determine how the way viewers viewed the photo changed as a function of the distortion.
When visualising the data collected, there is a way to display the data in the form of fixation points or duration gaze plots, where the spots where the gaze stopped are shown in a form of a circle. The larger the circle, the longer the fixation of the eye was at that point. Table 2 clearly shows the difference in the collected fixation points of all observers at different distortions of the same image. The same data was exported for all 330 photos analysed. If we look at the "circle cloud" that appears on each photo after the export, we can see that there are already some quickly recognisable differences between differently distorted/manipulated photos. For example, the compressed photo offers much more data that appears in the form of posterisation in the background, and these details attracted many more views than in the reference photo.

Table 2: Duration gaze plot of all the different manipulations on one of the photos used in the test



It was not the aim of this research to determine the exact data for each of the photographs in the novel image database. The most important variable was the way in which the photos were distorted/manipulated. The novel image database consists of very different photos (Figure 1) that were carefully selected based on their detail complexity and colour variety. In this way, all the data collected for each photo was based on the distortion (Table 3).

Table 3: Combined gaze duration representation of all different manipulations on all photos used in the test.



The total coverage area of each duration gaze plot cloud represents the area observed by all 110 observers when observing the respective distortion on each photographic motif used. The more the total area deviates from the reference cloud, the more the way the observers perceived the distorted image has changed and the greater the influence of a distortion – in a negative sense, of course. This is where our developed Matlab programme (subsection 2.4) came into play as we counted all the black pixels on each of the exported clouds shown in Table 2. The calculation of the percentage by which the total area changed compared to the reference image is shown in Figure 3.

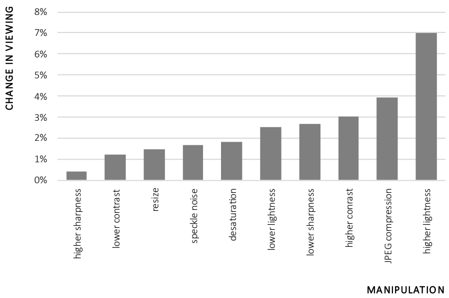


Figure 3: Change in viewing for each manipulation for every tested photo

4 DISCUSSION

The main aim of the research was to determine which photo distortion or manipulation most changes the way a photo is viewed. The way the photos were selected in the novel image database allowed us not to look just at the exact subject, but also at the average of all the photos. In this way, a final conclusion could be drawn that could really show the influence of different distortions on the communication value of photographs.

The manipulations analysed were selected on the basis of the practical use of photography in the real examples. Since photographic equipment, conditions and reproduction techniques often result in distorted photographs, where in many cases editors have to choose the best from the worst for publication, it is important to know what kind of distortion most changes the way we look at photographs. Sharpness, contrast, noise, lightness, compression and resize distortion were chosen in the end as these are the most common photographic errors we deal with. The data presented in Figure 3 shows us that increasing sharpness has the least impact on the viewing of the photographs (only 0.4% change). The result is predictable, as increased sharpness does not have a negative impact on image quality. The result also gives us an indication that our newly developed analysis method provides correct results. Second best was the lower contrast (1.2% change) and third best was the resizing effect (1.5% change). The result of the resize effect is somewhat surprising, as the artefacts that occur after resizing the photo to a larger format are clearly visible to the naked eye. We concluded that the reason for this lies in the observation conditions under which we tracked the eye movement. The observers were not looking at the photos on the full screen, but in a smaller format (Figure 2), and therefore the effect did not have as big an impact as it should. The second worst distortion is speckle noise (1.7% change), followed by desaturation (1.8% change). We see that the influence of colour is not that important for the communication value of photos, as we mainly perceive shapes and details. Lower lightness changed the way observers looked at the photos by 2.5%, lower sharpness by 2.7% and higher contrast by 3.0%. The greatest change was measured with JPEG compression (4%) and higher lightness (7.0%). JPEG compression results in the appearance of posterization artefacts, which are clearly visible in areas that normally have smooth gradients. As this posterization appears as details, it is very predictable that the change in viewing will be higher as the artefacts attract the viewer's eyes. The absolute worst result was measured at a higher lightness where the difference between subjects/objects and background is no longer as clear and seems to fade.

Almost all of the results are not surprising despite the effect of the size change and give the newly developed analysis method a solid foundation that can be used for further use cases.

5 CONCLUSIONS

Despite the fact that eye-tracking is a well-developed method, there are still many new ways in which we can analyse the collected data. TOBII Studio offers many different data exports, and the way we use them determines the form we want to interpret the final results. Since eye-tracking is mainly used to measure user experience, readability, the effectiveness of graphic design or the positioning of packaging on retail shelves, photography is not usually one of the most commonly analysed data formats. Therefore, there is much more room and opportunity to develop new methods.

As our research shows, we have succeeded in developing a method to analyse the data export of duration gaze plots in a way that provides usable and easy-to-understand results, not only in science but also in the real world, e.g. in advertising. Having a way to determine which distortion of a photo is more appropriate for publication can be critical to successful transfer of message. In use cases such as news, education or even printed publications, it is important to be able to decide which photo can better convey the desired message. Ultimately, successful communication with the target audience is the main goal of marketing and therefore the main goal of many industries. And as photography has become and continues to become an increasingly important communication medium, the need to understand its effectiveness is stronger than ever.

As we have successfully proven that the newly developed method works, we propose to integrate it into analysis software, such as TOBII Studio. A solution that works "at the push of a button" would bring the technology closer to industry, not just science.

6 ACKNOWLEDGEMENTS

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