reviewed paper

Autostereoscopic Visualization of Landscape - a Research Project

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1 ABSTRACT

High quality visualizations in the discipline of landscape architecture result in an increased client comprehension of the planning situation. The development of regarding techniques is an aim, which has been followed in various differing works. The main objective of the DFG-research project presented here was the improvement of an autostereoscopic presentation technique - the lenticular technique.

The lenticular technique allows for the creation of illustrations with spatial depth. As a result, the visual communication processes could become more intuitive and unambiguous for all participants in the planning process. Misinterpretation of the shown design can be avoided, and the range of possible interpretations is decreased.

Today 3d computer models are used to create autostereoscopic images efficiently. A specific rendering method was developed in order to optimize the outcome furthermore- the VLR-method. The contemporary output medium for this kind of illustration is paper, as it is still dominating in the line of business. Part of the research project included an exhibition of different designs using the autostereoscopic technique and the evaluation of data, gained in an opinion survey connected to the exhibition. The results show a general acceptance of the illustration technique by all participants of the experimental groups and a definite preference by some users. The expected benefits, based on mechanism of spatial perception, could be proven to a large extent. In order to further develop the lenticular technique subject-specifically, optimizations and adjustments of the rendering process are necessary. It may then qualify for a standard presentation method in landscape architecture and related fields of business.

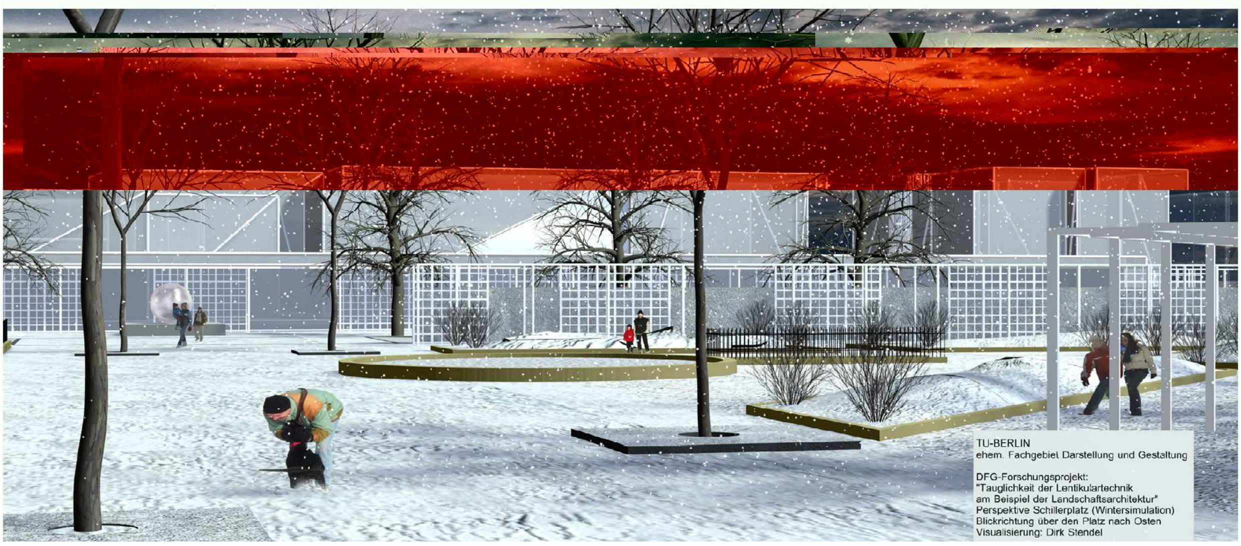

Fig. 0: The image shows a scene rendering of the snowy Schillerplatz in Schweinfurt. The autostereoscopic effect of the original DIN; A1 print was evaluated during the research project.

2 INTRODUCTION

The Deutsche Forschungsgemeinschaft (DFG) approved the research project "Tauglichkeit der Lentikulartechnik für Planungswissenschaften am Beispiel der Landschaftsarchitektur" in October 2005 for a duration of three years until December 2008. The administration and realization of the project was accomplished by Dipl.-Ing. Dirk Stendel at the chair of Prof. Falk Trillitzsch from the Berlin Institute of Technology (TU-Berlin).

The scope of the project covered the examination of the potential of autostereoscopic illustrations in the form of lenticular images[1] in the context of landscape architecture. This technique has been known and used in the field of business for only a few years. Until then the hardware (the lenticular plate) had not been available in relevant sizes (e.g. DIN A0) and the essential 3d computer models had been rather uncommon.

Due to positive results of other research projects especially in the field of communications engineering a significant benefit of the use of lenticular imaging was expected also for the planning sciences.

Hence the main question to be answered in this project was if the lenticular imaging technique may be successfully introduced to and employed in the planning sciences. It was hypothesized that this presentation technique would generate an added value to the displays due to its stereoscopic spatial impact.

If this hypothesis was verified, the lenticular technique could be further developed to create a new visualization standard for the planning sciences.

3 INITIAL CONSIDERATIONS AND BASICS

In the advance to this research project several observations and considerations were made.

First of all, the carrier medium paper still dominates in the presentation context despite of the general digitization of the field of business (Böhm, Zahiri & Benefer, 2008; Kiefer, 2008b; Kiefer, 2008a). The objectives of several different research projects during the past years have been the development and analysis of new communication strategies using digital media. Web based communication platforms, animated images and real-time visualizations - all these technique may help to improve communication processes in the design process, but none of them work with analogous plain paper. Therefore the invention of high quality design displays on paper was one major objective of the DFG-project.

Secondly, there are different reasons why graphical presentations often involve a certain measure of inaccurateness or even have been manipulated. But especially in combination with photorealistic images, the observer's reaction on that more and more leads to a general reluctance ore even suspiciousness to presented drawings (Paar & Rekittke, 2006). It may even have a negative impact on the credibility of the shown contents at all (Warren-Kretschmar & Tiedke, 2005).

Some of the newly developed communication strategies may improve the situation (compare Petschek & Lange, 2004; Stemmer & Mülder, 2006; Schildwächter & Zeile, 2008). Additionally, a high measure of selfchecking and responsibility may help to counteract the lost trust in illustrations. The overall aim needs to be an improved transparency of the planning process and contents and consequently a high level of liability (Sheppard, 2005).

These aims may be achieved by the use of 3d computer models, which are capable of the exact and precise illustration of design contend (compare Stemmer & Mülder, 2006). Furthermore, due to their display precision, 3d computer models may be used to generate high-precision stereoscopic images (compare Buchroithner, et al., 2005; Buchroithner, 2007).

Consequently, the advantages of the lenticular technique creating spatial effects could be combined with the high precision of 3d computer models in order to create liable high quality illustrations on paper.

3.1 Requirements for illustrations

Expectations on illustrations in the planning sciences are variable and become more and more complex. Participants of planning process usually have different professional backgrounds and therefore a differing comprehension for the shown contents. Above all, the composition of groups involved in planning processes tends to become more and more diverse, consisting of an increasing amount of user groups with divergent interests (Bendfeldt & Bendfeldt, 2002).

Traditional graphic means no longer suit the common practice. The conventional graphical communication strategy's of planning contents increasingly fails, if participants with differing or even contrary needs for the presentation of information come together. Especially user groups outside the subject area differ significantly from experts in their need for preparation of visual information. While the first rather prefer lifelike and photo realistic illustrations, experts prefer conceptual and abstract designs (Wastel, 2000).

[1] also known as a „motion-image" ore „flipping-image"

In consideration of the human depth perception it is possible to improve an illustration user-independently. The ability of humans to select and analyse different visual depth cues given around is a fundamental and powerful mechanism for spatial orientation. Specific depth cues can be used in drawings, illustrations and graphic presentations also. Several depth cues have an age-long tradition in landscape architectural illustrations, e.g. object shadows, the linear perspective or the atmospheric perspective. The cumulative impact of several depth cues leads to an improved spatial orientational ability in the observer (Hershenson, 1999; Goldstein, 2002; Deussen, 2007).

Contrary to the common procedures of illustrating, digital presentation media allows for the placing of additional spatial information. The use of motion parallaxes proved to be very effective2[2]. They are used with animations and real-time visualizations. An improved spatial perception of illustrations in the line of business has been confirmed by Petschek & Lange (Petschek & Lange, 2004).

One of the most effective depth cues, particularly within a close ten-meter visual range, only becomes detectable via binocular spatial perception (stereopsis) based on binocular disparities. These disparities are the only means of depth cue which allows an accurate estimation of distance in surrounding space (Leissner, 1980; Boothe, 2002). Their effects intensity and range may almost equals the impact of motion parallaxes (Cutting & Vishton, 1995).

Varying stereoscopic techniques permit the creation of images with depth information. In the context of landscape architecture and -planning the Shutter-method is common in the digital application area (compare Zehner, 2008). Stereoscopy with anaglyphs has been tested with paper media also (Stendel, 2002b; Stendel, 2002a). To Stendels knowledge, stereoscopy with anaglyphs currently is the only technique used in the context of paper-based illustrations in landscape architecture.

In order to appear spatial, most of the stereoscopic techniques require optical devices right in front of the eyes, e.g. glasses or helmets. These utilities tend to take an unsound or even ridiculous effect and therefore limit the use of the techniques for a professional approach (Kemner, 1989). The utilities are not easily ignored and therefore interfere with the watching of the presented planning contents (Regenbrecht, 1999).

Autostereoscopic techniques - meaning stereoscopic techniques operating without optical devices to be used in front of the observers' eyes - have so far not been used in the context of landscape architecture but promise to be useful. The lenticular technique complies with these requirements and may be used to create paper-based illustrations.

3.1.1 Impact of spatial depht effects

Psychology of perception seems to it that stereoscopic respectively autostereoscopic illustrations have certain advantages over conventional illustrations. First of all, inconclusive visual situations may be interpreted by the observer with a reduced error rate of 11% (Cours, 2004). Secondly, the retentiveness of the information is increased compared to two-dimensional illustrations. This is accounted to the higher feeling of presence in the observer due to the obvious spatiality (Regenbrecht, 1999). Furthermore, the impact of spatial illustrations was proven to be livlier and more fascinating (Cours, 2004; Petschek & Lange, 2004). The time needed for interpretation of the seen is significantly reduced (Kraak, 1988; Cours, 2004).

3.2 The principle of the lenticular-technique

Two components are essential for the mode of operation of the lenticular technique: the lenticular plate (fig. 1) and the adapted lenticular base image (fig. 2). The conventional way of producing the initial image is the interlace-method. Two images taken from different viewpoints of the same scene (so called half images) are allocated to a composite-image (Okoshi, 1976; Bourke, 1999; Buchroithner, Habermann & Gründermann, 2004).

[2] The distance of several objects' positions in relation to the observer's position may vary in space. With respect to the observers movements they seem to move with differing speed through the field of vision. The distance between the starting point and the end point of a change in position of the observer is called motion parallax (Kraak, 1988; Goldstein, 2002)

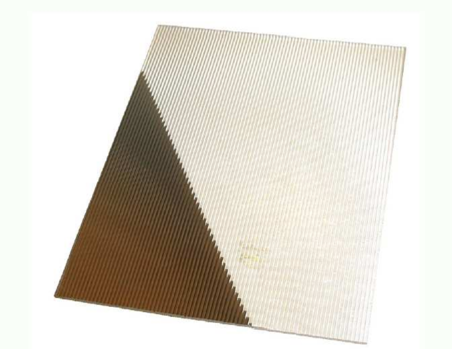

Fig. 1: lenticular plate

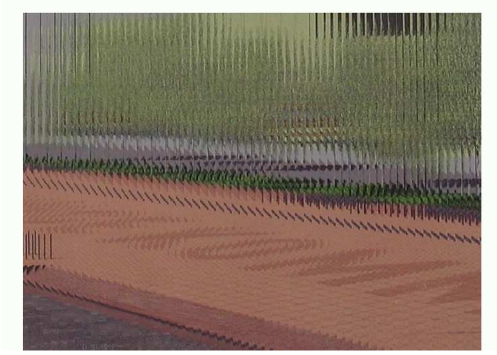

Fig. 2: initial lenticular image

Fig. 3 schematically shows the concurrence of both components. On the basis of the surface structure of the lenticular plate the two interlaced half images are separated again and may be viewed respectively with each eye. This leads to the illustrations spatial impression.

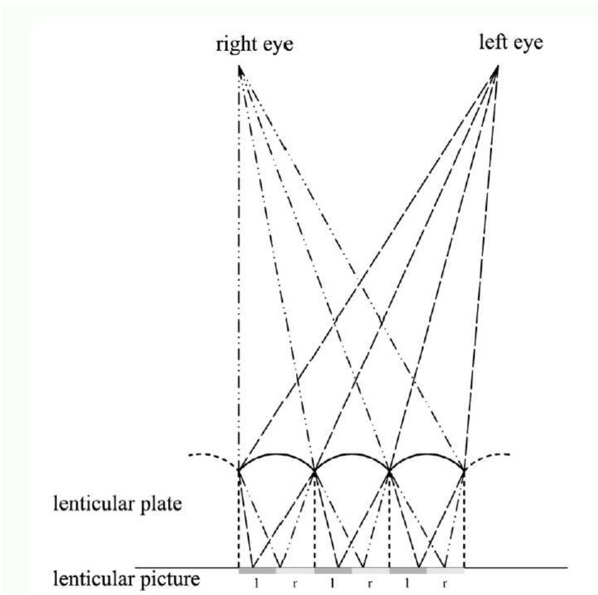

Fig. 3: functional principle of a lenticular image

In the course of the research project, the interlace-method proved to be very complex for the practiceoriented implementation. Detailed knowledge on stereoscopy and stereography is necessary in order to create the half images. Inevitable post processing of the half images outside of the 3d-environment[3] adds to the intricacy. These factors were rated negatively concerning the research objective.

During the course of the research project a new method for producing the initial image was developed, the VLR method (virtual lenticular rendering method) (Stendel, 2008). This method creates illustrations which improvably meet the demands of the profession. The initial image is created directly during the rendering process of the 3d computer model. The resulting graphical qualities differ from the ones achieved with the established interlace-method and to some extent improve this standard procedure (ebd.).

The VLR method generates a clearer image that is also more stable to movements of the viewer and displays edges more accurately. Especially the perceptible motion parallaxes of the lenticular image add to these advantages. The VLR method encodes these implicitly, which allows a “watching around the corner” to a certain degree. Therefore, these autostereograms always offer two important depth cues: binocular disparities and motion parallaxes[4].

[3] Generally, half images generated from a 3d computer model in a further working process need to be aligned in order to optimize the spatial impact (e.g. with Adobe Photoshop) (compare Waack, 1982). Subsequently, the half images intended for a lenticular image are interlaced with a separate software.
[4] These characteristics are effective independently of a photorealistic or non-photorealistic presentation style.

The generated spatial VLR-image provides a resolution about four times higher than that of a comparable image generated using the interlace method with the same lens parameters. However, the achievable spatial depth of a VLR-image is reduced to about one third of that accomplishable with the interlace method. The maximum viewing angle of an VLR-illustration is enhanced significantly, therefore the examination of the image by a group of people is possible without restrictions to the visibility. Optional viewing distances for VLR-images also are a major advantage over illustrations created with the interlace method: they only allow well-defined viewing standpoints and distances (Sexton, 1992; Lemme, 2006; Peterka, et al., 2007).

Nowadays 3d computer models are a common way of presenting design information in the profession of landscape architecture. In matters of the lenticular technique, 3d computer models are inevitable and take a key role. They are It is regarded as state of the art and therefore understood as a given foundation for further research.

4 RESEARCH SETUP AND PROCEDURE

Four sub questions were looked into in the course of the research project, all being related to the thematic fields of practice-oriented feasibility, potential benefit and assessment of the acceptance within the profession. Risks related to the presentation and interpretation of an autostereoscopic image were identified and discussed. An overall assessment allows the affirmation or rejection of the projects hypothesis.

The research project procedure was structured into several subunits according to the formulated sub questions, namely the conditioning of the basic data and creation of the autostereoscopic image, assessment of first impressions and acceptance by means of a survey during the exhibition of several images and the concluding evaluation of the assessed data.

Several 3d computer models in the context of landscape architecture were obtained, analysed and evaluated according to their scale (e.g. urban development vs. detail planning) and detail precision. Searching for especially qualified sectors of design illustration by means of the lenticular technique, the achievable sharpness of detail was identified. Four different 3d computer models were chosen and subjected to advanced treatment.

competition on urban development

- Guangzhou, China (scale 1:10.000)
- Khalifa City C, Abu Dhabi (scale 1:2.000)

competition on landscape architecture

- Spielbudenplatz, Hamburg (scale 1:500)
- Schillerplatz, Schweinfurt (scale 1:100)

Subsequent editing of the 3d computer models was focused on the best possible photo-realistic implementation. The illustration of plant material in the designs was therefore primarily realised with 3d models as well (X-Frog models of Greenworks Comp., Berlin).

The available model data was then edited further like aspects of season change or systematic completion of the data. Simultaneously illustrations using the lenticular technique were created. This mode of operation allowed a better understanding of stereoscopic specifications related to the 3d computer model as well as graphical needs of the profession. Thus mutual adjustments could be undertaken. At first, the stereoscopic editing of the plans was realised with a separate interlace-software[5] (3DZ-V7).

Working steps like the stereoscopic image acquisition within the 3d rendering software (3d-Studio Max), the subsequent orientation of the half images and the use of the interlace-software all showed the high complexity of the production process of an autostereogram. The expertise for the creation of the half-images, the stereographic adjustments, the image alignment and the final interlacing process will also in the future not be part of the standard knowledge of landscape architects. The present complex process therefore impedes this technique for the practical use.

[5] The interlace-software allows a specific editing of the initial lenticular images with regard to dimensions typical for the profession and according to different lenticular plate sizes. Half images (renderings) created with the 3d computer model were processed and evaluated after a DIN-A4 test series.

Therefore, at this stage of research it was concluded that the complex imaging process had to be simplified. The idea was to create the final stereogram directly during the rendering process of the rendering software and additionally without a simple implement of described steps automatically. One appropriate method could be developed and tried out via systematic analyses and testing.

The test results showed that the new methodical approach of the VLR method indeed produces feasible results that partially even show an improved image quality (compare chapter 3.1). In addition, the method simplifies the imaging process as desired. After a mathematical analysis and a parameter optimization the method could be generally improved and enhanced to better suit the needs of landscape architecture. Until an automation of the process will be possible[6], the current process is divided into several different steps like manual adjustments and setting of the components[7].

Subsequently, the final presentation images were created as described. Using the example of plan view maps and supplemental perspective illustrations with spatial depth effects further aspects were examined. In these examples seasonal changes were considered and displayed (fig. 0/9). The illustration of seasonal changes allows an in-depth analysis of the potential for detail display of the lenticular technique (e.g. flying autumn foliage or snow fall) and enhanced the spectrum of different atmospheres in the illustrations.

The surveys for acceptance of and reaction on the lenticular images were performed during a variety of events of different nature in order to obtain a maximum variation of professional expertise and competence in visualization.

First assessments and evaluations were undertaken at the conference „Digital design in landscape architecture 2008“ at the Anhalt University of Applied Sciences, Dessau. Following, a seminar was held at the department "Darstellung und Gestaltung" (Prof. Schittek) at Leibnitz University, Hannover, and a lecture was executed at the department "CALA" [8] (Dr. Lömker) at Technical University Dresden. Closing the survey stage, the "Lange Nacht der Wissenschaften" was attended at the Technical University Berlin (fig. 4).

Fig. 4: Presentation of the research project at the „Lange Nacht der Wissenschaften“ at the Technical University of Berlin, June 2008

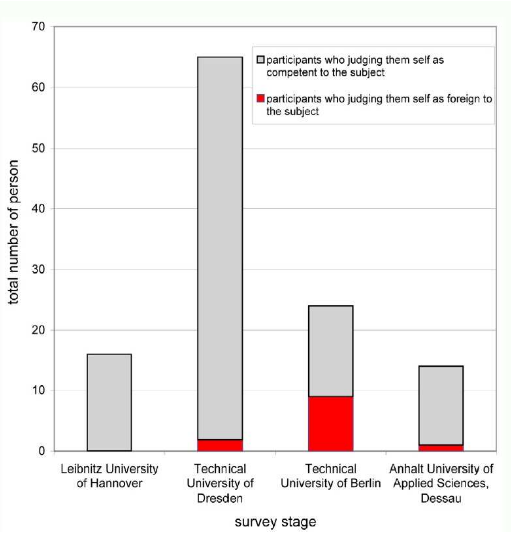

Fig. 5: Number of interviewees

The audience of the survey was composed of professional landscape architects especially qualified in the field of visualization, students of architecture and landscape architecture of lower semesters as well as graduate students and lay people.

Fig. 5 shows the quantitative distribution of the interviewees in the different events. The images had been presented on an easel due to the rigidity of the lenticular plates (fig. 4). In each case after the presentations

6 a plug-in solution for 3d rendering software is preferred

7 Due to the complex production process and the premature stage of the VLR-technique it was decided to reduce the amount of example illustrations and the amount of interviews. Two DIN-A0 lenticular images and according 2d images were produced, presented and evaluated. With an improved method, the original propositions may be followed.

8 computer application in the field of architecture and landscape architecture

group discussions and one-on-one interviews took place respectively. First reactions, doubts and suggestions were gathered. 119 questionnaires each of 20 individual questions plus notes on the interviews were evaluated. The survey covered questions on believed potential for the techniques application and graphical demands on the images quality. The gained insights were incorporated in the further development of the method. The estimated applicability and the favoured fields of application (competitions, exhibitions, presentation) were evaluated as well.

5 RESULTS

The evaluation results influenced by the new graphical characteristics of applied VLR-method are not applicable to the lenticular technique in general. From that point of view the descriptions below are specific to the VLR-method, but lay the foundations to compare and to figure out special features of other methods (e.g. interlace-method) simultaneously.

5.1.1 general tendency

The last question of the four page questionnaire was a question of principle: “Which way of illustrating Your designs would You prefer? 3d or 2d?“. 43,7% preferred the autostereoscopic 3d visualization, 56,3% settled for the conventional 2d. According to that, the majority of the respondents would not apply the introduced technique.

But: major differences occur in the answers of the different user groups at different presentation occasions. At the “Lange Nacht der Wissenschaften” and at the conference in Dessau about 67% preferred the 3d visualization. At these events, mainly professionals with a research focus on visualization and lay people from other (planning) professions were attending. At the events in Dresden and Hannover a contrary result was obtained. Only 34,9% and 23,5% respectively of the mainly collegiate audience voted for the 3d illustrations. Interestingly, additional commentaries relate the benefit of the lenticular technique to certain user groups and fields of education.

Many interviewees having voted for 2d from specified their doubts due to the complexity of the process, high costs ore the current image quality (30 persons of 67 total). Current knowledge on the software-based automation and the intended and potential further development of the VLR-method may weaken these concerns. Counting these interviewees as potential proponents to-be, the average approval amounts to approximately 70% making it the majority. Future surveys are likely to produce results in the order of magnitude mentioned above, if further improvement of the technique is successful.

5.1.2 Fields of Application and Chances for Implementation

Professional fields of application mentioned by the interviewees were competitions (42%), exhibitions (78%), formal presentations (53%) and construction signs (36%). Exhibitions were rated better than “wellsuitable” and seen as the most promising field of application. Presentations, competitions and building information boards (construction signs) currently only nearly pass. Here also differences in the addressed user groups are verifiable (fig. 6). The graph for the survey at the Technical University of Berlin demonstrates the very positive reaction to the technique. Since most of the interviewees had been lay people, especially this user group attests an added-value.

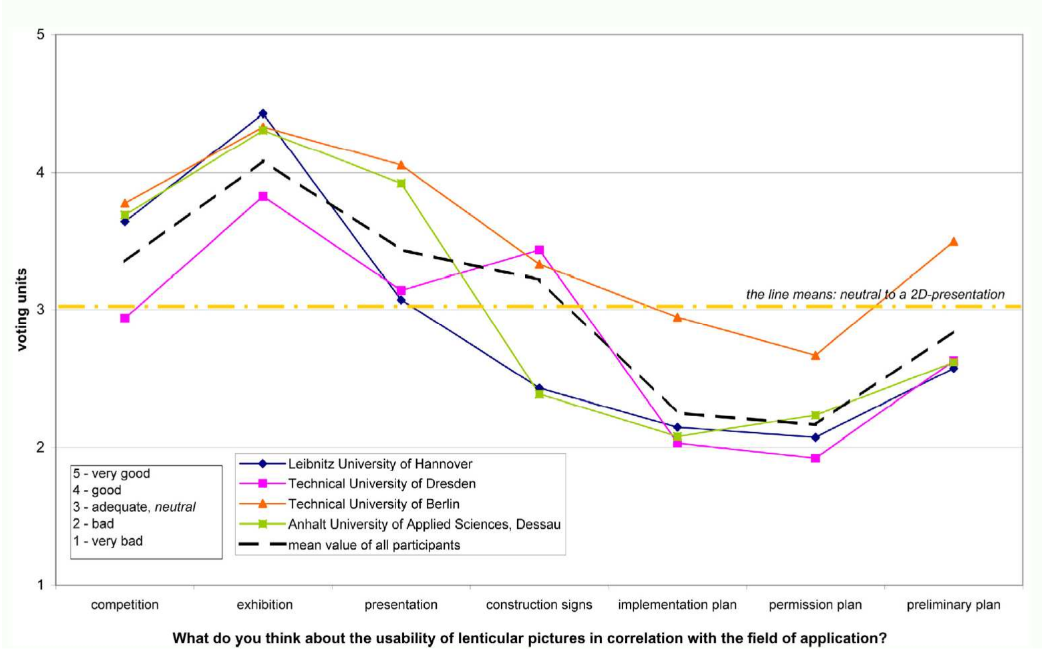

Fig. 6: professional fields of application of the lenticular technique

General tendencies occur beyond the consideration of different user groups. Implementation planning and permit planning as well as preliminary planning were rated ill-suited. 90% of the interviewees would invest additional time of four or more hours in the illustration process. Nearly 70% would be inclined to invest an additional 150€ or more.

The current additional working time amounts to about two or three hours not having calculated the time needed for producing the 3d computer model. A lenticular plate of DIN-A0 size currently cost less than 150€. Comparing this information to the considerations in 5.1.1, a vast majority might in the future approve of the technique.

5.1.3 Image details and their perception

Most of the survey questions covered optical-technical details like image resolution (fig. 7) and their effect on the spatial perception. The evaluation of the image resolution achieves below average results. This is accounted to the method of operation of a lenticular plate (see 3.2), which currently is unable to produce the resolutions of 150-230 dpi the profession is accustomed to. The lenticular grid lowers the initial resolution generally. The visible resolution of the presented illustrations equalled 50 dpi horizontally[9]. The vertical resolution is not manipulated by the lenticular grid and remained at 250 dpi. Considering this data, the evaluation outcome may be interpreted positively. The development of the last few years in printer technology and processing power will allow the production of lenticular images of comparable quality in the near future.

[9] None the less the snow flakes in the winter illustration (fig. 0) were easily to be identified. Small fonts in the images were readable as well and could be positioned in the spatial environment easily.

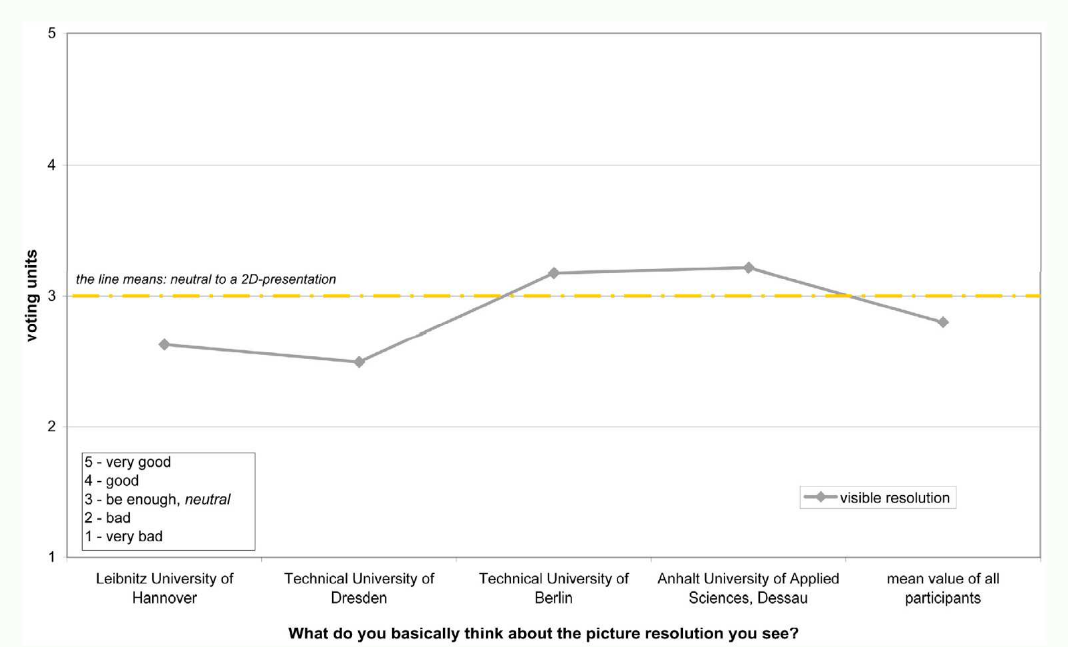

Fig. 7: Evaluation of the visible image resolution compared to an according 2d image

The spatial depth of the illustrations was recognised as obvious and very obvious by more than 50%, despite the fact that the computed visual spatial depth only amounted to a few centimetres. 70% of the interviewees saw need for improvement of the effect. Also the motion parallaxes are rated beneficial for the illustration by approx. 70%. General differences and a beneficial change compared to a 2d illustration were acknowledged by more than 82% of the interviewees. Written commentaries often attested a more lively atmosphere. The enhanced unambiguousness of the spatial illustrations was rated moderate to very clearly by 56% of the people. Thus these illustrations are more comprehensible than according 2d illustrations (fig. 8).

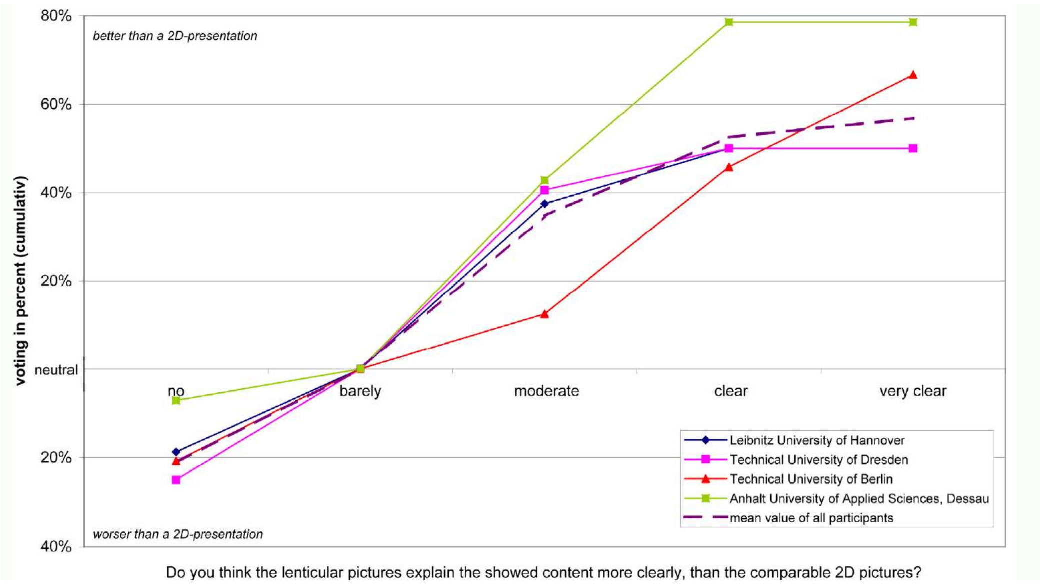

Fig. 8: perceived unambiguousness with regard to contents of the lenticular images compared to an according 2d image

5.1.4 Discussion contributions

Technical as well as content related contributions were made during the interviews at the open discussions.

Technical:

Light reflection on the lenticular plate depended very much on the illumination of the exhibition room. It was rated in a wide range between unremarkable and very distracting. Due to the optical mode of operation of the lenticular plate, the illumination is a fundamental parameter for the 3d effect. At the moment a correlation between the different group results and the according room illumination may not be verified. The illumination at the Anhalt University of Applied Sciences (very brightly and diffusely illuminated foyer) and at the Technical University of Berlin at the “Lange Nacht der Wissenschaften” (separate spotlights) was ideal. The according survey groups gave the best evaluations. At the Technical University of Dresden (lecture hall) and the Leibniz University of Hannover (seminar room) the exhibition conditions were less bright and either illuminated from side windows or from above with artificial light. The according groups gave a discretely different and more sceptical evaluation of the 3d technique. The possible correlation of the mentioned facts needs to be investigated further, since it may prove essential for the techniques success. In addition to the scepticism concerning the production process of the lenticular illustrations, possible complications connected to the transport of large-size plans were mentioned. At present the inelasticity of the illustrations will reduce the possible fields of application to exhibitions and formal presentations, where a certain amount of time is taken for preparations.

Content-related:

Beyond the spatial effect of the presented illustrations, the general necessity of photo-realistic perspectives was discussed. The objective of the research project to create images as photo-realistic as possible, was opposed by the professional audience. The variety of styles in designs was mentioned as very important in order to be able to evaluate the technical potential and advantages of the lenticular technique. Lay people appraised the photo-realism as helpful for a better understanding[10]. The user dependent value of the lenticular technique was discussed intensely. The added-value was mainly attributed to lay addresses. It was rated unnecessary for communication processes within the profession. To the authors knowledge, this sort of mere within the profession communication is comparatively rare.

6 CONCLUSION

The expected added-value of the lenticular images has been recognised by about half of the interviewees. In this respect the objective of the project could be verified.

The use of the lenticular technique facilitates the specified demands on illustrations mentioned in 3.1. This kind of illustration technique allows a better comprehension of the planning contents and therefore leads to an increased transparency and reliability of the whole planning process. Provided that the planning situations known to the observer, manipulations of the scene are more easily discovered in spatial illustrations. The demanded illustration qualities may be met. The implementation requirements basically lead to an automated correctness[11].

The survey results as well as the general appreciation show no fundamental reservation to the lenticular technique. A general acceptance is verified.

In the authors opinion this acceptance is to some degree connected to the print medium paper. How the evaluation results my change with a digital application of the lenticular technique is not known and needs to be investigated.

The mentioned problems of the current display quality may be reduced or even erased with further improvement of the technique. It is to be expected that the general acceptance and the potential for practical application may reach more than 70% (see 5.1.1). It then may become a standard visualization technique in the field of planning disciplines.

The mathematical analysis of data concerning the VLR-method shows room for improvement of the current spatial qualities of the generated images. Constructional changes of the lenticular plates will possibly allow an increase of the achievable spatial depth from 3-5cm to about 50cm. The image quality may be improved by an automation of the VLR-process within the rendering software and the specification as a complete parallax image (integral image).

Due to similar demands on illustrations across different planning professions (architecture, urban development, traffic planning, cartography etc.) the transferability of the research results may be possible.

[10] Non-photo-realistic images may be produced just as easily. The different user groups reaction to the styles of illustration should be investigated further.

[11] The necessity of 3d computer models and the subsequently impossible manipulation of the contents with image rocessing software, e.g. Photoshop are two reasons for that.

Discussion results supported this estimation. The wide-spread use of the lenticular technique in the professional context therefore seems possible.

Fig. 9: The image shows a scene rendering of the Schillerplatz in Schweinfurt at summer time. The autostereoscopic effect of the riginal DIN A1 print was evaluated during the research project.

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