3D-VISUALIZATION TECHNIQUES
- THE COMPLETE LIST -

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ABSTRACT:

It is the intention of this paper, to stimulate the scientific as well as the public interest in virtual spatial visualization.
Therefore this paper deals with fundamentals for virtual spatial data presentation, starting with results, showing the advantages of spatial image data interpretation. Additional basics dealt with include a systematic and complete(!) synoptically overview for stereoscopic techniques, according to the state of the art.

Stereoscopic techniques in this sense mean full virtual spatial visualization techniques only, while data presentations limited to perspective or so called 2.5D projections are not part of this investigation.

Beside well established 3D visualization Technologies, based on stereoscopes, anaglyphs, polarized glasses, liquid crystal shutters, chromadepth glasses etc., it is liked to emphasize, the dynamic Nuoptix method, according to PULFRICH and in particular the improved solid state Felix-3D promise a great future for both, the scientific as well as the public 3D visualization.

It is liked to emphasize, a portable light staff (digital) camera, preferable with remote control, for extreme low altitude photography very successfully has been applied for 2D image mosaics as well as for 3D visualization of antique objects in the ancient city of Patara(Turkey). This rather flexible light staff camera method promises a great future, not only under expedition constraints.

As a first result this paper deals with at least 10 topics, which are still a matter of research, e.g., the optimum base length for close range stereo photography.

An attempt has been carried out, systematically to define remaining research Gaps in 3D visualization, which stimulates for further progress in this field.

1. INTRODUCTION

In the digital age the importance of spatial data presentation and visualization is increasing for tremendous applications, like

- for 3dimensional viewing of synthetic vector data based stereo mates for a better understanding and interpretation of Monument Information System (=MIS) data, including vector data based sketches basic and thematic layers for synoptically as well as for reasons, concerning detail precision,
- for the stereoscopic presentation of architectural and archaeological models, currently in particular increasingly derived from laser scanners etc..
- for practical improvements from a 3dimensional interpretation of MIS related stereo mates for, but not restricted to close range image maps.

The main benefit of 3dimensional data presentation in general is the still underestimated gain of a complete additional dimension.
This means, the 3D product is the "long-range vision" for the provided product of close range imaging to be used for the broad spectrum of close range Deliverals.
For MIS devices allowing a temporary processing of the stereo mates there is no need for a permanent additional storage.
This paper concentrates on basics of virtually 3dimensional data visualization, but neglects perspective or so called 2.5 dimensional data presentations.

As a result of fundamentals of virtually spatial data presentation, including the aids for stereoscopy it deals with the complete list for 3D visualization techniques.
It is liked to emphasize, from a consequently dealing with the principals of spatial data visualization, even the future of the whole computer industry might change.
Here namely the so called FELIX -3D with a solid state 3D screen seems to become a real candidate for a new spatial PC generation in order to replace or to complete the 2dimensional screen generation.
The FELIX-3D solid state is the successor of well known 3D cylindrical Plexiglas tube, both suited for the presentation of 3D Laser based models, to be generated in color and in real time, for a direct autostereoscopic visualization, which means, for unaided eyes.
After dealing with the essentials of advanced 3dimensional MIS data presentation it is consequently reported on methods for stereoscopic viewing of MIS data and on a procedure for a systematic basic research in spatial data visualization. In this context it is shown, this moving back to the basics of spatial data visualization is required and gains a surprising potential for further research. As a first result, there are defined 11 research topics in this particular field of spatial MIS data research.

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2. FUNDAMENTALS OF VIRTUAL SPATIAL DATA PRESENTATION

Basically in a MIS the Spatial position of MIS relevant points is described by its (Cartesian) coordinates. Based on these coordinates the traditional Geometric content of a MIS are

- numeric coordinates of object points, printed in a list or stored on digital storage media and/or
- 2 dimensional digital or analog line maps, namely based on vector data and/or
- 2 dimensional image maps, based on raster data.

In addition to these traditional Geometric deliverables of a MIS the virtually 3dimensional presentation for MIS data, as a modern tool for improved MIS data visualization is highly recommended.

To verify this, two images of the same object, gained from two different viewing positions with at least approximately parallel look directions are required.

It shall clearly be stated, the derived stereo mates can be of real as well as of synthetic origin!

The typically appearance of a stereoscopic impression, while viewing two corresponding stereo mates, is due to the ability of the human 3dimensional viewing sense.

In principal a synthetic stereo mate will be obtained from a Geometric manipulation of the original image, by adding appropriate horizontal parallaxes values to the original monoscopic image.

This way for a 3 dimensional presentation of MIS data is of course open for vector as well as for raster data.

In figure 1 are presented advantages from using stereo mates for image data visualization. In detail, as a sample, in figure 1 there the interpretation results of different topographic features as interpreted in original images of extremely high resolution in comparison with digital images showing 2.5 m, 5m, 10m, 15 m, 20m and 40 m ground Pixel size. As higher the values in the diagram, as higher the accuracy of interpretation. From the sketch in figure 1 it is a remarkable result, the stereo mates will highly improve the MIS data visualization in general, which is indicated in particular for buildings and for object features (DTM), see figure 1.

Traditionally the horizontal parallaxes values are close related to the object space and in particular to differences in object heights. Apart from this, the actual meaning of the horizontal parallaxes may vary extremely due to different application aspects of the map respectively the MIS data to be spatial visualized. For example, the 3rd dimension in the spatial MIS data provided, can represent variations in temperature, in the restoration or production progress as well in frequency (of visiting) and color (relicts), etc..

3. METHODS FOR STEREOSCOPIC VIEWING OF MIS DATA

Independent of the nature of the horizontal parallaxes, an attempt for a systematic investigation of the complete list of virtually stereo aids according to the state of the art, has been carried out.

The principles of the 3dimensional viewing technology have been categorized according to

* methods for the spatial presentation of stereo mates projected without contact,
* methods for the separation of spatial presented stereo mates projected in contact and
* methods using virtually 3 D models

Sticking to appropriate virtually stereo data representation, no part of this investigations are, e.g., methods using simple central perspective effects and/or shadow effects, "2.5 D effects" by permanent moving of a queue of central perspective images or "continuous profiling", which are methods for 3D data determination by combining a successive queue of profiles, but not own methods for virtually 3D data presentation, similar holds for the Moiré effect, while materialized 3D appearance, including the 3D mirror effect and real models are no methods for virtually but for real 3dimensional presentation.

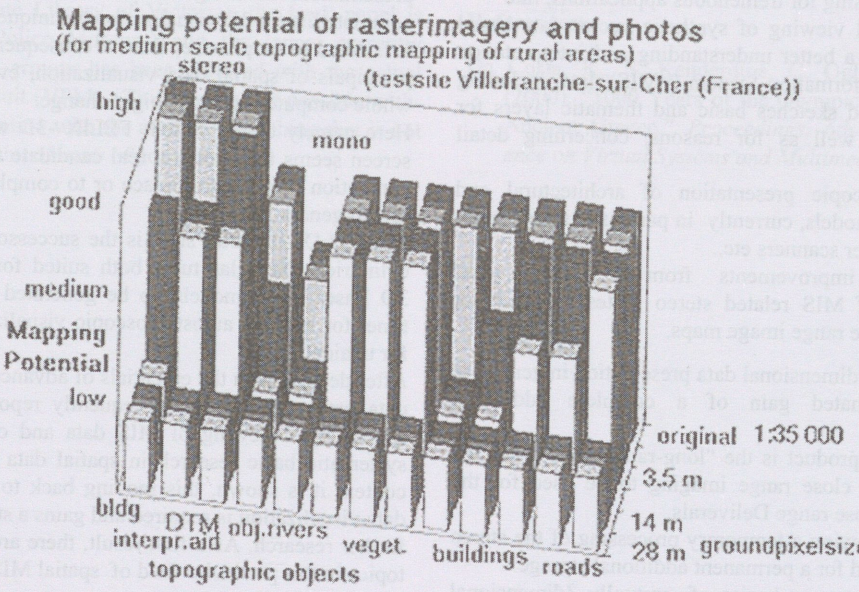

Figure 1. Results of advantages from Spatial image data interpretation

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Complete list of the Stereoscopic Methods for Virtual Spatial Data:
Status: September 2002

Constraints: At least 2 stereo mates of real and/or synthetic origin, showing the same object, as imaged from different positions, approximately perpendicular to a base line, showing satisfactory parallel imaging directions.

The stereoscopic perception ability while viewing on 2 corresponding stereo mates is due to the human 3D viewing sense

3D viewing Method:	subj./obj. percept.	color perception	PC suitability	format limits	Stereo viewing aids:
1. Methods for stereo viewing without contact of in minimum 2 overlapping stereo mates, vertically or horizontally arranged, in particular for autostereoscopic visualization for "ortho" or "pseudo" as well as for normal and/or cross 3D visualization:					
1.1 "mounted" 3D views	subject.	true color	limited	apprx.6cm strip	autostereoscop.
1.2 Magic Eye/random dot	subject.	Random color	limited	apprx.6cm strip	autostereoscop.
1.3 Cyber Space	subject.	color	yes		direct proj.
1,4 stereoscopes:					
1,4.1 lens stereoscopes	subject.	true color	limited	apprx.6cm strip	lenses,see fig.5,6
1.4.2 prism stereoscopes	subject.	true color	(yes)		lenses/prisms
...incldg.prism stereoscopes of wedge shaped lenses for 3D vertical"mounted"strips (KMQ) see fig.7					
1.4.3mirror stereoscopes.	subject.	true color	yes	appr.23 cm strips	lenses/mirror
1.4.4 without lens(pigeon)	subject.	true color	yes	larger size	mirror,see fig.3
1.4.5 lenticular lenses (e.g.,"3D postcards")	objective	true color	Yes	larger size	autostereoscopic "stereoscopes"
2. Methods for the 3D visualization technology based on stereomates, with alternate projection or in contact:					
2.1 Anaglyphs(compl.col.)	subject.	b./w. only?	yes	larger size	e.g.red/green gl
2.2Cromadepth (spec.spl)	subject.	false color	(yes)	larger size	3D gl:spectr,spl.
2.3.1 Polarizing filters	subject.	true color	slideshows	larger size	polariz. glasses
2.3.2 Tektronix	subject.	true color	PC and TV	screen size	polariz. glasses
2.4(liquid crystal) Shutter	subject.	true color	PC and TV	variable	shutterglasses
2.5 NUOPTIX(PULFRICH)	subject.	true color	PC and TV	variable	one eye: dark gl.
3. Methods using virtually 3D models					
3.1 (FELIX-3D)Rot.Screen	objective	false color	New Gener?	tube size	autostereoscop.
3.2 /FELIX-)3D Solid State	objective	false color		cube size	autostereoscop.
3.3 hologramtechnologies	objective	false color			autostereoscop.

Table 1. The Complete List for Virtual 3D Visualization Techniques.

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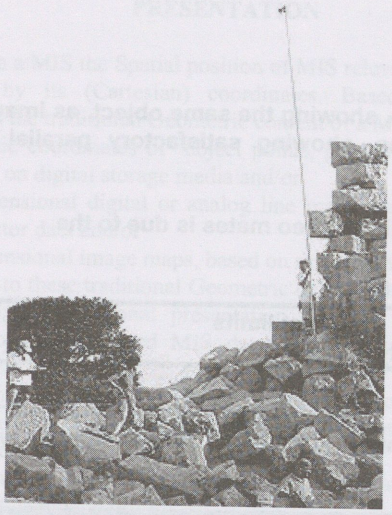

Figure 2. Portable light staff camera according to SCHUHR for extremely low altitude photography (quasi ground truth) as well as for 3D photography, even under expedition constraints, in action.

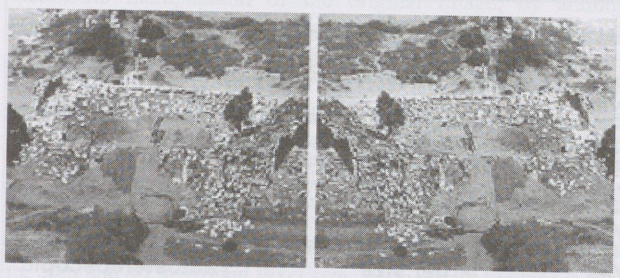

Figure 3. Result of a stereoview of the antique houses of parliament (Bouleuterion) in the ancient capital PATARA of the province of Lycia (Turkey) as derived with Schuhr's light staff camera. This are "pigeon" stereo mates for the right side image to be viewed in(!) a perpendicular mirror, while(!) the left side image shows the true view.

4. TOPICS FOR FUTURE RESEARCH IN SPATIAL DATA VISUALIZATION

A systematic identification of research topics in spatial data visualization here results from dealing, with the current and future tasks for MIS applications.

In this respect a so called " Research Gap Matrix for MIS " has successfully been applied. It is liked to emphasize, the strongly systematic aspect of this Research Gap Matrix for MIS will become of great importance for international exchange and stimulation.

The idea behind this matrix is, to list the detailed current and future abilities and products. Referring to figure 4, the research gap matrix for MIS typical abilities and products are visualization and visualization effects in Mono (VIS.MONO) and in Stereo (3 D), analogue (INTERP.ANA) and digital (DIG.) results of the interpretation etc.. Apart from the topic on spatial data visualization, additional fields for MIS research are numeric coordinates of Ground Control Points (NUM.C.GCP), the definition and handling of topographic objects (TOP.OB), the Digital Elevation Model (D.E.M.), the analogue presentation of maps (MAPS:ANA), research for digital line maps (DIG.) as well as for analogue and digital photomaps (PHOTOMAP and DIG.)

Of course, even for this very general sample, much space is left for particular own additions, which might lead to surprising cognitions, but can rarely claim for completeness. After this, within the sample matrix, the MIS devices are listed columnwise. The term "MIS devices" here stands for a Workstation or PC based MIS, including the hard- and software for periphery instruments, like scanners, digitizers, plotters etc..

To define more detailed research topics for spatial data visualization, it is advisable to split the column for MIS devices according to these aspects. Though, currently special purpose computers are more and more disappearing from the Market, the term "MIS devices", better known as "GIS-devices" is according to practical, increasingly software related requirements.

Today MIS devices are mainly dealing with vector data, while digital image processing systems are more dealing with raster data. This distinguishing recently more and more becomes obsolete.

Matrix fields in figure 4 showing a column, indicate "already successfully solved" achievements, while the matrix fields indicated by a square stand for an open field for further research. In this context the need for international research does not mean, the activities in this particular area have to start from the beginning, but from the authors point of view, here still a great job is waiting for scientific as well as for practical work.

Of course an extension of this approach to the broad spectrum of MIS technology is highly recommended. For international exchange in the procurement of (3D-) products, this approach shall be applied in a modified way: The methods, the state, the progress, congresses hold, publications etc., shall be exchanged wide via the world web.

It is liked to emphasize, in this context algorithms in particular are seen as an important Market gap for the future. As a first result from dealing with this "Research Gap Matrix for MIS" a list of 11 additional topics for research gaps in spatial data visualization has been obtained:

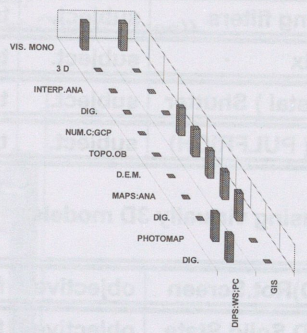

Figure 4: Research Gap Matrix for MIS and Digital Photogrammetric Systems (DIPS)

(1) The generation of a lost or so far not existed stereo mate:

A lost or missing stereo mate preferable should be taken from the real object. If at least a 3dimensional model of the object is available, the single picture can be projected onto the real

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(white) model and the stereo mates can be taken by stereo photographs. Virtual stereoscopic MIS data presentation using digital stereo mates can follow this idea:

For MIS data the real model is replaced by the 3dimensional model data, while the optical projection of the single photo onto the model is replaced by mathematical projection and the stereo mates are not obtained from stereo photographs but by applying mathematical projection equations calculating the synthetic horizontal parallaxes values.

Within this context it is highly recommended, to use the mathematical model according to Egels and Massou d'Autume of the IGN (Paris) for the generation of stereo mates. This quasi universal model so far has successfully been applied for digital image rectification purposes. It is suited to calculate Digital Terrain Model data and, depending on the situation, it allows partly to neglect equalization approaches. For tasks which require map accuracy, like photomaps (of facades), mosaiking, multisensor imagery and data fusion, a digital Geometric pixel by pixel image restitution is needed, preferably applying the indirect rectification method.

In particular the converting of this kind of filtered image raster data (e.g. in TIF-format) into vector data (e.g., DXF format), as for instance carried out by the ENVI Program system, promises great progress for automated map production, also including the stereo mate.

(2) The Geometric potential of (available) stereo imagery; considering the effect of the so called stereoscopic exaggeration, see figure 5:

Figure 5. Sample for 3D exaggeration for a mountainous Landscape under expedition contraints:
Due to baselines of approximately 200m length from image to image for the foreground the stereoscopic effect disappears, while the mountainous background shows stereoscopic exaggeration, in particular for the combination of the left and right stereo mate (400m baseline)

(3) The complete history for stereo imagery, including the stereo photo plasticon, see figure 6:

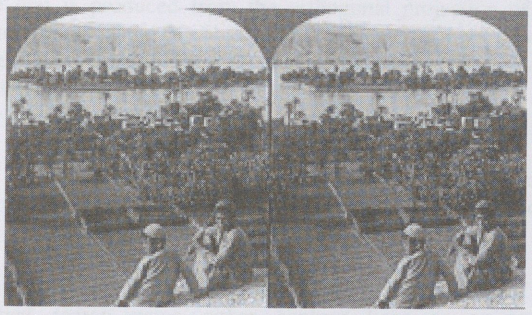

Figure 6. The "Paradise Garden of Eden" as situated in the valley of the river Euphrates is one highlight for 3dimensional visualization of the Stereoscope Agency http://stereoview.forU.de,
a close-range image of a long-range vision history

(4) The benefit of combining day- and night MIS stereo mates;

(5) The benefit of (synthetic) stereo panorama imagery;

(6) The effect of different pixel sizes for the MIS stereo mates, see figure 7:

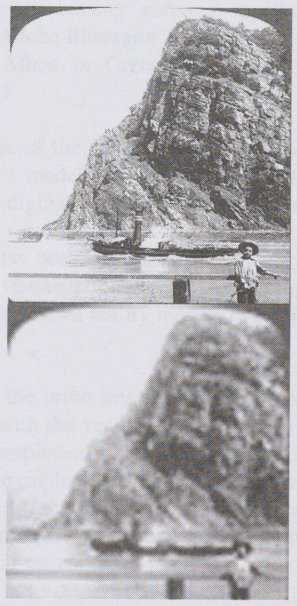

Figure 7. Lorelei Landscape (Germany): Vertical stereoview mounting as a 3D image sample

- to be viewed with stereo wedge glasses (KMQ-method) and
- as a sample for stereo mates showing different pixel size (40 μ on top, 200 μ below)

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(7) The presentation of terrestrial stereo image blocks;

(8) The extension of the optical sharpness within a model, using different focal lengths for the stereo mates;

(9) The simulation of the perception of the "natural" appearance of the object dimensions;

(10) The Market potential for stereo imagery

4. CONCLUSION

It is liked to emphasize, moving back to the to the Roots in spatial data visualization gains a surprising potential for advanced practical MIS application, as well as for further research, in particular with respect to the third dimension.

A systematic approach to define research gaps in basics of MIS as presented, is highly recommended and stimulates for further progress.

Today real Market gaps for MIS and MIS related close range Deliverals only can be seen in connection with digital methods.

According to this, beside others, for MIS devices mainly the following fields for research on basics of spatial data visualization are left:

- The field of 3dimensional visualization for MIS, which is still unsatisfactory. So far all systems depend on aided eyes.
- All systems? The progress in Laser based PCs, showing a real 3D screen is just in an increasing phase. Currently the "3D-tube" using a cylindrical screen, successfully is replaced by the FELIX-3D solid state, which for the very first time allows autostereoscopic viewing from any side!
- Still a problem and from that a field for international research is the production of line maps and stereo mates from digital raster data, though, namely within this field, many activities successfully have been carried out.
- Another big field for international research is, to manage the problem of digital interpretation in an efficient way. This is of course mainly a question of improvements in algorithms and software, which might also include tendencies of artificial intelligence.
- Another field for further research in connection with the problem as mentioned before, is the efficient manipulation of half tone image raster data to derive sufficient digital vector data, representing that area, but requiring reduced storage capacity.
- An additional matter for international research for MIS devices is, to solve the problem of multi layer digital interpretation in an efficient way. This problem includes, e.g., the realistic simulation of propagation.

Summarizing, improvements namely are expected in modeling, software improvement, instrumentation, Analysis and standards etc.. (Spatial) MIS of today consequently requires digital solutions in order to tackle with the enormous working load, like to provide and to maintain MIS products of high quality.

As a matter of fact, like in all parts of the daily life, the recent development in MIS and in the field of spatial data visualization in particular, must deal with the world wide web.

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