Conference Contribution to

Electronic Displays 2004
29.+30.September 2004, Wiesbaden

Multi-User Stereoscopic Displays

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MULTI-USER STEREOSCOPIC DISPLAYS

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ABSTRACT

The paper presents the improvements concerning multi-user stereoscopic displays achieved by research at the IPM-institute. The aim is to present a 3D monitor technology which comes along with almost the same simplicity in using it by several viewers as we all know it from a conventional TV screen, where several people can sit widely scattered in front of it, each of them having a good viewing impression. At the same time, this comparison emphasizes one potential application of the future: 3D television.

In order to get a realistic look-around feeling without jumping (abrupt change of viewing) combined with a wide viewing angle, as much perspectives as possible are required. The use of lenticular sheets with slanted lenses stacked onto the screen forces all perspectives to appear behind each lenticule. Since today the technical achievable resolution doesn't meet the requirements for having one (full-color) pixel for each view, subpixel control combined with subpixel filtering is applied. This workaround might become redundant when miniaturized OLED monitor technology will be available on the market.

Using such methods, IPM is able to present up to 60 perspectives on a 22 inch monitor. The result is a comfortably smooth transition between the different views of 400x1200 each, without color distortions or Moiré effects. Additionally, instead of having several persons looking at the presented object, one viewer can walk around it getting an impression quite close to that provided by a real hologram. The only disadvantage of this configuration is the insufficient sharpness especially in the background because of filter operations. But it is possible to switch to a representation of increased sharpness with 6 views 1600x1200 each, which makes the system very flexible.

These features are especially useful in diagnostics and surgical planning based on medical image data, e.g. CT and MRI. Several doctors can look at one image in parallel, each of them provided with almost the same good viewing impression. This makes diagnostic findings less subjective.

In the future, resolution quality has to be increased further. Additionally, real-time rotations of the presented objects should be possible. This calls for largely improved available hardware as well as for an optimization of the procedures of the IPM.

KURZFASSUNG: STEREOSKOPISCHE MEHRBETRACHTER-MONITORE

Dieser Artikel zeigt die Verbesserungen bzgl. stereoskopischer Mehrbenutzer-Monitore, die die Forschung am IPM hervorgebracht hat. Das Ziel ist die Präsentation einer 3D-Bildschirm-Technologie, die fast genauso einfach von mehreren Betrachtern genutzt werden kann, wie wir es alle vom konventionellen Fernsehen her kennen. Dort können mehrere Personen weit verstreut vor dem Gerät sitzen, wobei bei allen ein guter Sichteindruck entsteht. Dieser Vergleich unterstreicht zugleich eine potenzielle Anwendung der Zukunft: 3D-Fernsehen.

Um ein realistisches Gefühl des Rundumsehens ohne Sprünge (abrupter Wechsel der Ansicht) kombiniert mit einem großen Betrachtungswinkel zu bekommen, sind so viele Perspektiven wie möglich erforderlich. Der Einsatz von auf den Bildschirm montierten Linsenrasterscheiben mit schräg ausgerichteten Linsen erfordert das Erscheinen aller Perpektiven hinter jeder Linse. Da heutzutage die technisch erreichbare Auflösung nicht ausreicht, um ein Pixel für jede Ansicht zu nutzen, wird Subpixel-Ansteuerung in Kombination mit Subpixel-Filterung angewendet. Diese provisorische Lösung könnte überflüssig werden, sobald die miniaturisierte OLED-Technologie auf dem Markt verfügbar ist.

Durch den Einsatz solcher Methoden kann das IPM bis zu 60 Perspektiven auf einem 22-Zoll-Monitor darstellen. Das Ergebnis ist ein angenehm weicher Übergang zwischen den verschiedenen Ansichten, jede in 400x1200, ohne Farbstörungen und Moiré-Effekte. Anstelle mehrerer Personen, die auf das präsentierte Objekt schauen, kann sich zusätzlich ein Betrachter um dieses herum bewegen, wobei nahezu der Eindruck wie bei einem echten Hologramm entsteht. Der einzige Nachteil dieser Anordnung ist die unzureichende Schärfe, speziell im Bildhintergrund, aufgrund der Filteroperationen. Aber es ist möglich, zu einer Darstellung mit erhöhter Bildschärfe bei 6 Ansichten von jeweils 1600x1200 umzuschalten, was das System sehr flexibel macht.
Diese Eigenschaften sind besonders nützlich für die Diagnostik und Operationsplanung, basierend auf Medizin-Bilddaten, z.B. CT und MRT. Mehrere Ärzte können gleichzeitig auf ein Bild schauen, wobei jedem von ihnen ein fast gleich guter Sichteindruck ermöglicht wird. Dies macht Befunde weniger subjektiv.
In Zukunft muss die Auflösungsqualität weiter erhöht werden. Zusätzlich sollten Drehungen der Objekte in Echtzeit möglich sein. Dies erfordert sowohl eine weitgehend verbesserte verfügbare Hardware als auch eine Optimierung der Verfahren des IPM.

INTRODUCTION

The natural visualization of our environment including persons, nature and things has been used as a powerful kind of communication for a long time. Even prehistoric men, long before the existence of any kind of script, made cave paintings reflecting their perceptions, e.g. showing the hunt for animals. A big step forward was the introduction of perspective in sketches and paintings by *Leonardo da Vinci* in medieval times. The idea of stereoscopic imaging was realized at first by *Charles Wheatstone* (1832) and *David Brewster* (1849) in the 19th century. They constructed tools for binocular viewing, so-called stereoscopes, where two different images are presented to the eyes. The upcoming photography evolved in parallel and soon stereo photos could be taken easily with the help of dedicated stereo cameras.
The underlying autostereoscopic approach of 3D monitors of the IPM-institute, using lenticular sheets, was proposed as early as in 1896 by *A. Berthier*. Main reasons avoiding a real breakthrough of this technology (in the field of computers) were

i. costs
ii. difficulties in production (hardware)
iii. difficulties concerning the provision of appropriate source image series (software)

It will be shown that using the hard- and software technology of the IPM-institute none of the three mentioned points is valid any longer. An overview of different types of autostereoscopic displays is given in [1].

PRINCIPLE

The greatest advantage of autostereoscopic methods is the discontinued need for glasses. Combining this with multi-user ability results in a high-quality, multi-purpose 3D monitor. How can we obtain the multi-user property? The idea is quite simple. By multiplexing umpty views instead of two, say 60, a smooth transition can be achieved. Thus we get a better look-around feeling for one user as well as for many viewers looking at the 3D display in parallel. Problems concerning that are:

(a) Moiré effects
(b) coding the information of all the perspectives into one image of the same dimension

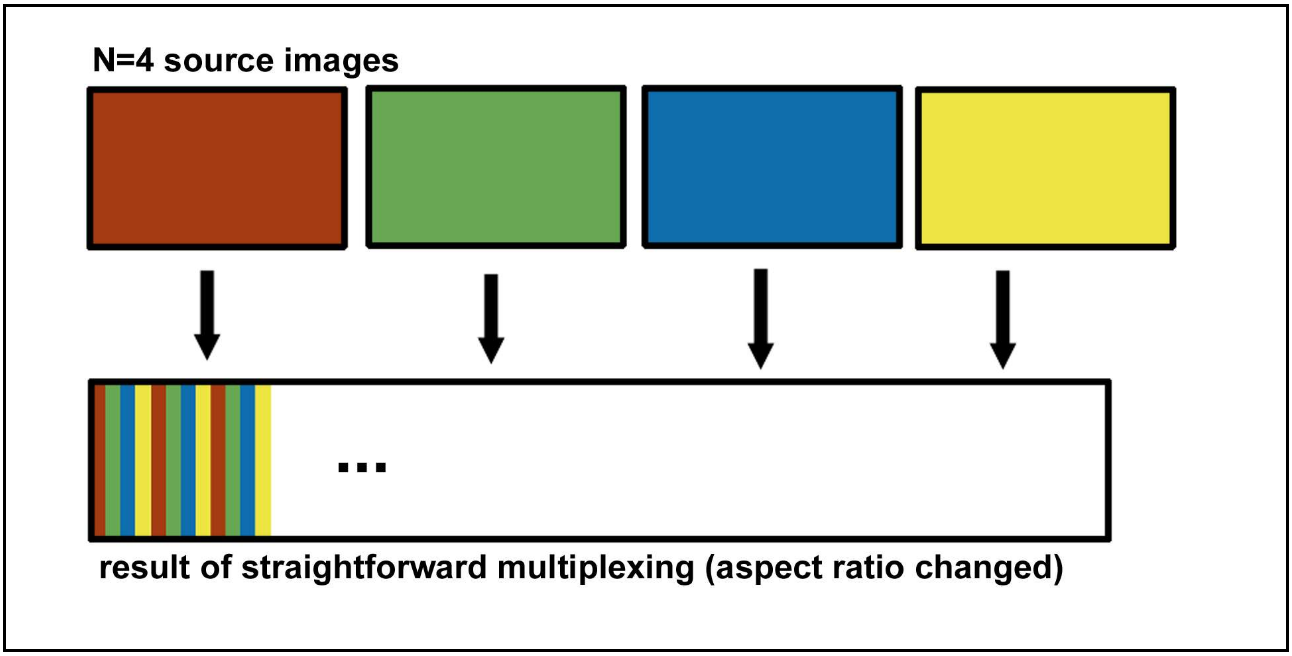

Figure 1: the principle of multiplexing images

The character skew of the lenticules is one appropriate method in order to overcome problem (a). A straightforward approach of multiplexing N images at resolution A x B each would lead to resulting image of NA x B. Obviously, that is a serious distortion in aspect ratio, see Figure 1. There are basic filter operations as preprocessing required, combined with subpixel control and vertical interlacing. Additionally, a high-resolution filtering on subpixel level is very useful. So a multiplexed image under preservation of the aspect ratio and most of the information is obtained, thus solving problem (b). Of course, there is always a decrease in effective resolution, but due to the very high physical resolution used, a satisfactory result meeting the requirements can be obtained, see also Table 1.

IMPLEMENTATION

An overview of all processing steps required to perform is given in the flowchart in Figure 2.

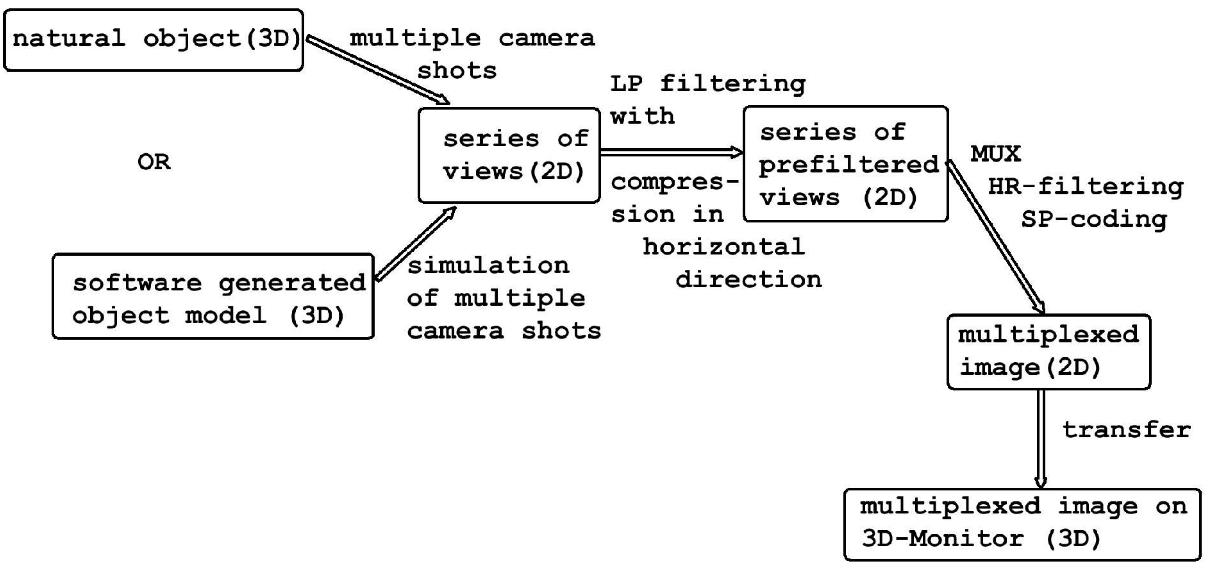

Figure 2: flowchart of all processing steps

As we can see, a starting point for the 3D visualization can be either a natural, real object or an object model generated using common 3D software packages. Of course, it is possible to combine both sources by generating models out of photographies (3D reconstruction) which can be manipulated afterwards. The step of extracting the 2D views from the object (model) is shown in Figure 3.

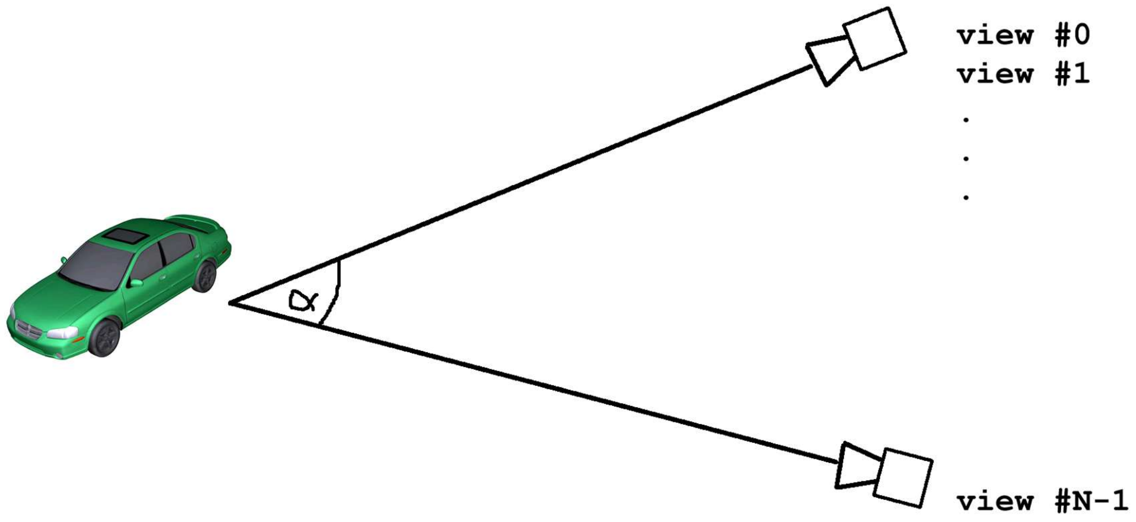

Figure 3: generation of N views using a viewing angle alpha

The next step is the preprocessing for the multiplexing itself. A horizontal low-pass filtering is performed in such a way that the resulting image width fits exactly for the main step, multiplexing with subpixel coding and high resolution filtering. Additionally, the principle of interlacing, which is well-known from television, is used to increase the possible number of perspectives at the expense of vertical resolution.
The subpixel coding makes use of an important cognitive property of the human visual system. It is much more sensitive to brightness information than to color. So one can spread color information up to a certain degree without any noticeable decay in quality as long as the luminance average in the neighborhood is preserved. This results in a horizontal resolution gain of factor three [2].
These image processing steps are concluded by the presentation on a 3D monitor. The IPM uses high precision lenticular glasses with an arbitrary character skew of the lenticules. It is the software which is general enough to work properly with any lensslope.
The following two types of 3D monitors have already been presented (Table 1):

number of perspectives	***resulting resolution horizontal***	***resulting resolution vertical***
6	1600	1200
60	400	1200

Table 1: parameters of the 3D monitors of the IPM

In an advcanced configuration, both types are integrated in a switchable unit. The obvious advantage is that a concentration on only one aspect in the trade-off between *resulting horizontal resolution* and *number of perspectives* is no longer required. Depending on the actual requirement, one can easily adjust the system to it.

EXPERIMENTAL RESULTS

An important step to evaluate the configuration was to perform resolution measurements. The most interesting point is the depth dependance of it. A 3D "test street" with a linear frequency increase from center outwards has been created. Different subjects were asked to estimate the border line between distorted (Moiré) and undistorted regions. Obviously, that can give an idea about the critical frequencies indicating resolution capabilities.

Since one black and one white stripe constitute one period respectively, Table 1 predicts critical frequencies of 800 resp. 200. Empirically (see Figure 4), we could find quite a good coincidence for the 60 perspectives, whereas for 6 perspectives the value found practically was significantly lower than the theoretically calculated one. Mainly, this seems to be due to an introduction of Moiré effects already in the rendering phase. Anyway, the usefulness of the filter operations could be demonstrated clearly.

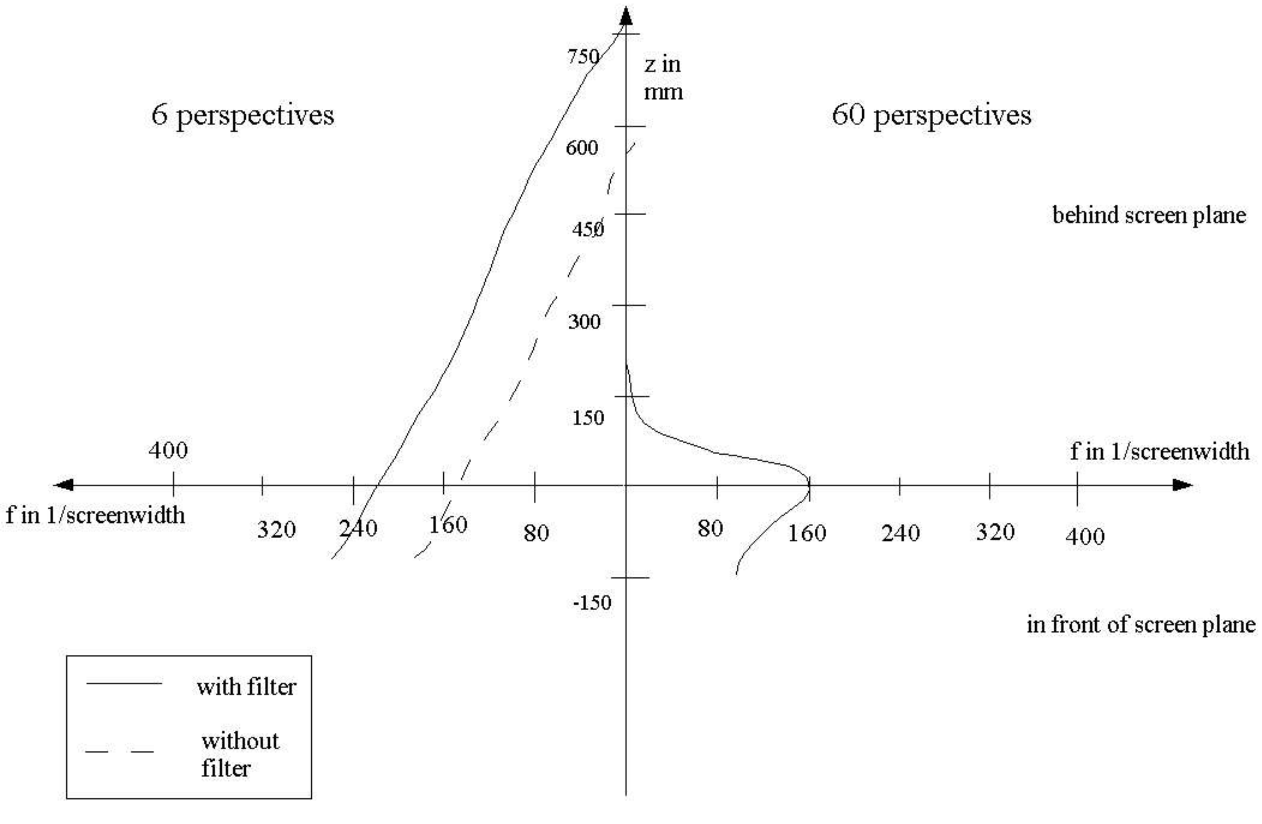

Figure 4: measurement results

CONCLUSION

Since the basic hardware equipment parts are based on series-production, which then just have to be combined to a running system, reasonable pricing is achieved. Problems (i) and (ii) are solved. By looking at Figure 2 we can see that even problem (iii) is manageable just by choosing one of the two given image series creation approaches.

The filter quality could be proofed by the increase in resolution. Using 60 perspectives, a smooth transition between views, having a sufficient resolution, too, is achieved. Resolution can be increased further by switching to 6 perspectives.

APPLICATIONS

The two most promising fields of application are without doubt medicine and 3D television. Non-invasive examination methods as US (*Ultrasound*), CT (*Computed Tomography*) and MRI (*Magnetic Resonance Imaging*) are spreading more and more. They are much more comfortable for patients than e.g. endoscopy.

Clinical doctors don't like 3D glasses at all. If they accept a 3D visualization method, autostereoscopic monitors will be the only choice. Even if a certain group of doctors decided strictly not to use any 3D monitor, a supplementary use in teaching would be an option for them as well.

A TV set is a today's standard equipment. That indicates a high market potential for 3D TV sets. But the huge number of existing devices creates the problem of compatibility. It's worth looking at the first television revolution of about 1960, when color TV sets started to replace monochromes. The only chance for the market placement of the new devices was to broadcast color TV signals compatible with the old black-and-white devices. Engineers and scientists succeeded in creating the broadcasting standards *NTSC*, *PAL* and *SECAM*. Since the bandwidth is already completely used, even the blanking interval turned out to be useful for video text transmission, the only option for a 2D compatible 3D broadcasting is the combination of several channels [3].

A more prospective approach will try to combine the digital revolution (*HDTV*) with the introduction of 3D television. Offering multiple steps forward in parallel, users could be convinced to invest money in completely new units, since such a technological breakthrough normally ensures modernity for some, let's say 10, years.

ACKNOWLEDGEMENTS

We would like to thank all our colleagues for their support. This work was funded in part by the Bundesministerium für Bildung und Forschung (BMBF), FKZ: 01BD155.

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