3-Dimensional Digital Terrestrial Television

RAFAEL G. AYESTARÁN[1], JESÚS A. LÓPEZ[1], VANESA LOBATO[2],
VÍCTOR M. PELÁEZ[2], SONIA GARCÍA[2]

[1]Department of Electrical Engineering
Universidad de Oviedo
Campus Universitario
33203 Gijón (Asturias)
SPAIN

[2]Department of R&D
Fundación CTIC
Parque Científico y Tecnológico
33203 Gijón (Asturias)
SPAIN

http://www.tsc.uniovi.es

Abstract - A new Digital Terrestrial Television service based on transmission and visualization of 3D images is presented. This service has been designed to be suitable for domestic users without relevant increase of the final cost for the spectator, being the production of the programs what is modified to generate adequate 3D TV signals. The systems that make possible the implementation of the service have been prototyped and tested including the recording cameras and the visualization subsystem for the domestic environment. Some future development lines have also been defined, taking into account different parameters such as quality of service and final cost for the spectator.

Key-Words – Digital Terrestrial Television, 3D image, Digital Video Broadcasting, services.

1 Introduction

In the recent years, Digital Video Broadcasting (DVB), or Digital Television [1,2], is becoming the standard for European broadcasting services (equivalently, ATSC, Advanced Television System Committee, is the standard in USA and ISDB, Integrated Services Digital Broadcasting, in Japan). Digital Satellite Television (DVB-S) and Digital Cable Television (DVB-C) are widely extended between domestic users, and Digital Terrestrial Television (DVB-T or DTT) will soon replace analog TV in most first-world countries. This scenario leads to the development of new services designed making use of the powerful characteristics of DVB: enhanced teletext services, multi-language broadcast, subtitling, etc. In this paper we present a fully developed service consisting on the broadcasting of three dimensional (3D) contents over a standard DVB platform. In particular, DVB-T features have been considered because of its increasing popularity in Spain and the proximity of the so-called “analog shut-down” planned for 2010.

Minimum monetary value of the domestic visualization system is one of the major requirements for the system designed in the present work. Most of the cost of the whole system is held in the production step where a full compliance with DVB-T standards [3,4] must be achieved.

2 3D-Visualization

All of the many different 3D visualization systems that have been proposed in the literature [5,6] are based on the same principles. A 3-dimensional perception of a scene is based on the observation of two slightly different images taken by each eye. The human brain processes both images creating the effect of depth that corresponds to the third dimension. Any 3D visualization system should present to each eye the corresponding image, and both images (left and right) must be obtained somehow. The main difference between the existing systems is typically the way in which both images are presented: side-by-side layouts, alternate images or different light polarization, among others.

Most of the present techniques are not suitable for DVB-T applications: side-by-side images require an expert spectator; the use of different polarization for the two images cannot even be implemented in TV applications, because only one image should arrive to the visualization subsystem. Among the existing 3D techniques, two have been chosen for evaluation purposes: anaglyphs and shutter glasses visualization.

2.1 Anaglyph images

Anaglyph images are used to provide a stereoscopic 3D effect when viewed with two-color glasses (each lens with a chromatically opposite color, usually red and cyan). Images are made up of two superimposed color layers with an offset between them to produce a depth effect. The picture contains two different filtered colored images, one for each eye. When viewed through the color glasses they reveal to each eye the correspondent image. The brain fuses both images into a three dimensional scene or composition.

The use of a single transmitted image makes this possibility suitable for DVB applications. The colored glasses filter the image corresponding to each eye. In fact, anaglyphs have been used previously in analog TV 3D experiences. However, anaglyphs have two major drawbacks. On the one hand, the treatment of the color information in the receiver is critical so that ghosting effects could arise if the reproduced colors do not match the glasses lenses colors. Furthermore, the color information of the resulting 3D image is distorted by the colored lenses decreasing the final quality of service (QoS).

On the other hand, anaglyph-based systems present an extremely low price for the final user which represents their most important advantage.

2.2 Shutter glasses

Another 3D technique that is becoming popular in computer applications is the use of shutter glasses for stereoscopic visualization. In this technique, the images corresponding to each eye are combined using different time slots (usually alternative frames or lines) and the LCD lenses of the glasses become dark and transparent alternatively and in synchronization with the frame rate (or the display refresh rate). In this manner, each eye only receives its corresponding image. This technique is also implemented using different time slots for alternative fields, instead of frames, for the two images. In both implementations, flickering is not noticeable for sufficiently high refresh rates.

The main advantage of this technique is that it is not affected by ghosting and it does not distort the color information. However, at conventional TV refresh rates, the effective frame rate is reduced by a factor of 2 which is enough to show flickering. Additionally, the price of the system for the domestic user is greater than anaglyph-based solutions, although cheap viewing systems can be found with an equivalent cost to digital television decoders.

3 Definition and implementation

A complete prototype of the 3D-DTT service has been designed and implemented including the recording and processing of 3D images in the production studio, the transmission of a proper DVB-T signal, and a domestic visualization scenario.

The following sections describe in detail each subsystem and how it has been defined and implemented.

3.1 Camera positioning

The most important feature of a 3D recording system is that it must record two images simultaneously. Some models of dual cameras have been developed and are available for commercial use. A simpler solution based on the use of two small adjacent cameras imitating the human visual caption system has been designed as a prototype. These two images must be captured taking into account the properties of human vision, so an exhaustive trigonometric study of the recording system is required to determine the correct position of the two cameras in order to create a realistic stereoscopic effect.

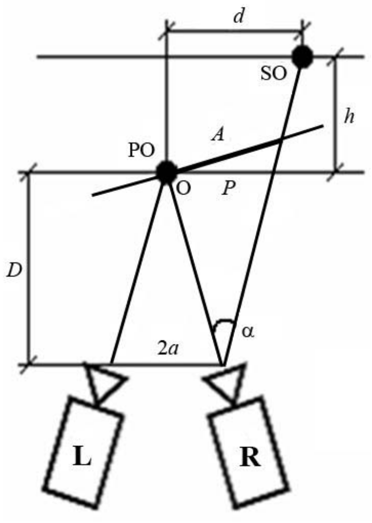

Fig. 1. *Camera layout for 3D recording.*

In the general case depicted in Fig. 1, two cameras (left and right) record two images. The distance between cameras is $2a$, the principal object (PO) is placed at a distance D from the plane of the cameras, and its position is considered to be the origin. A secondary object (SO) is placed at a position defined as (d,h). At this point, the goal is to determine the virtual distance A that must be considered to properly represent the real positions of the two objects. This parameter will be used to relate all the distances involved in the recording process and hence to select a proper position for the cameras. It is worth mentioning that parallel camera geometry may be selected as a particular case of the general geometry.

The following relations determine the position of any object in a 3D scene so that each camera records the same image that the corresponding eye would perceive. For example, considering the right camera in Fig. 1, the following relations can be easily stated:

$$A = \sqrt{D^2 + a^2}\,\tan(\alpha) \qquad (1)$$

$$\alpha = \tan^{-1}\left(\frac{a}{D}\right) + \tan^{-1}\left(\frac{d-a}{D+h}\right) \qquad (2)$$

Substituting (2) in (1):

$$A = \sqrt{D^2 + a^2}\,\frac{ah + Dd}{D(D+h) - a(d-a)} \qquad (3)$$

where the distance *A* is expressed in terms of known parameters. The maximum value of the angle *α* depends on the characteristics of the camera and it defines the maximum value for the virtual distance, A_{max}. The horizontal distance *P* between SO position and O (center of the scene) may be derived as follows:

$$P = P_{\max}\frac{A}{A_{\max}} = P_{\max}\frac{ah + Dd}{D(D+h) - a(d-a)}\frac{1}{\tan(\alpha_{\max})} \qquad (4)$$

where P_{max} represents the maximum horizontal distance between SO and O, and hence $2P_{max}$ is the width of the image. From this expression, we can obtain the horizontal position where the PO must be place in each camera, P_L and P_R:

$$P_L = P_{\max}\frac{-ah}{D(D+h) + a^2}\frac{1}{\tan(\alpha_{\max})} \qquad (5)$$

$$P_R = P_{\max}\frac{ah}{D(D+h) + a^2}\frac{1}{\tan(\alpha_{\max})} \qquad (6)$$

The same relations apply to the left camera. The adequate position of the cameras and the geometric properties of the scene can be calculated according to these expressions.

3.2 3D-Camera design

As mentioned before, two small cameras have been chosen to be combined into a single 3D recording system. The cameras have been selected taking into consideration the following parameters:

Size: according to the trigonometric study, the positions of the two cameras have to be obtained from the geometric properties of the scene to be recorded. Typically this fact leads to reduced distances, similar to the distance between human eyes. Professional or domestic cameras cannot be placed so closely because of their dimensions, so a solution based on two webcams has been considered.

Resolution: Most of the available webcams have lower resolutions than DVB-T standards. Although post-processing could be performed, some high resolution cameras can be obtained at a reasonable price.

Price: The academic purpose of the prototypes imposes low cost solutions even in the production studio.

All these conditions have been taken into account to choose two high-resolution webcams Logitech Quickcam® Pro 9000, with resolution up to 1600×1200 pixels (fixed to 720×576 for DTT applications), 30 fps, 24 bits/pixel, small dimensions and a price around 100 €. Of course, the resulting recording system does not comply with professional specifications, but its performance is adequate for a system with academic purposes.

3.3 Image processing tool

The recording system provides two images that must be processed and combined into a single 3D image to be transmitted. A software tool has been developed to deal with such processing.

The software tool has been developed using MatLab® Image Acquisition Toolbox. It has been designed to control simultaneously the two cameras when they are connected via USB ports to a computer. Software calibration has been implemented to correct imperfect positioning of the cameras as well as to control the parallax of the desired 3D image.

Once the cameras have been calibrated and the images are being recorded, the software is able to create 3D images online, using any of the above-described techniques: anaglyphs and images for shutter glasses visualization.

Some of the features of the software tool are:

- Graphic Interface
- High compatibility with different cameras
- Geometric interpretation of the scene
- Online 3D image recording
- Configurable output video files
- Software calibration of imperfect camera positioning
- 3D video preview

3.4 Integration into a DVB-T system

Once the 3D image has been obtained, it must be transmitted using the DVB-T standards but taking into consideration its properties, so that the transmitted and received images keep 3D information.

A block diagram of a DVB-T transmission system is plotted in Fig. 2.

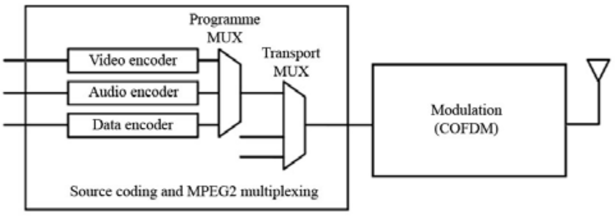

Fig. 2. *Schematic DVB-T transmission system.*

The first block in a transmission system is a video and audio encoder. The video and audio format is defined in the DVB-T standards to be MPEG2 with a video resolution of 720×576 pixels. A semiprofessional software encoder has been chosen for the presented system: Mainconcept® MPEG Encoder. It is important to notice that shutter images require keeping alternative even and odd lines (or frames, depending on the type of 3D images used), otherwise 3D information would be lost. This fact leads to inefficient video compression, but it is not avoidable without loss of 3D information. When anaglyphs are used standard encoding can be applied.

The following step consists on the generation of the Transport Stream (TS). TS is generated using Rohde-Schwarz® DVM-400 Digital Video Measurement System, a hardware able to generate and analyze TS. The academic purpose of the work presented in this paper makes this hardware especially suitable for its inclusion in the system.

A multiplexer has also been included in order to include other programs in the TS. The DVP® D9600 has been chosen and integrated in the system.

Finally, COFDM modulation is performed using the Promax® MO-170 modulator at a frequency of 474 MHz.

The complete DVB-T transmission system is plotted in Fig. 3.

3.5 Receiver

The reception subsystem has been intended to emulate domestic characteristics. For this reason, a conventional domestic DTT decoder and a conventional CRT TV have been chosen. It is important to point out that LCD displays have been disregarded as current shutter-glasses commercial technology is not guaranteed to work properly with LCD displays. However, manufacturers of 3D hardware are introducing new technologies able to work on LCD displays, and in some cases even based on autostereoscopic displays, that could be considered for future prototypes.

Fig. 3. *DVB-T transmission system.*

3.6 3D Visualization

The final visualization of the transmitted 3D images differs depending on the used technology, anaglyph or shutter images. Anaglyph visualization only requires colored-lens glasses. However, the color filters only work properly if the display correctly reproduces the original colors of the image. Otherwise, ghosting effects may appear.

If shutter-glasses are selected for final visualization, an adequate 3D receiver must be incorporated. A low cost solution has been chosen for prototyping: eDimensional® VirtualFX 3D TV Converter. This hardware has an approximate price of 50€ including one pair of glasses. The synchronization module reads the 3D information from a 3D image and generates a synchronization signal that controls the glasses creating the desired 3D effect. This module may be easily integrated in a domestic reception environment as an additional decoder.

It is interesting to point out that the final visualization has been found to be the weakest point of the system. When anaglyph images are used, the final QoS is low independently of the visualization system, but its sensibility to color management makes it unpredictable. When shutter technology is used, the need for specific hardware represents an additional cost for the user. Currently, 3D technology is not oriented to massive market, so the hardware prices remain high. Low cost solutions, as the one chosen for this prototype, do not comply with minimum quality requirements for commercial use in DTT applications. It is expected that future developments yield quality enhancement and price reduction in 3D hardware.

4 Experiments

Most of the parameters usually specified to evaluate the quality of a video application are subjective, as they are relate to human perception of the scene. This fact lead to a set of experiments proposed to different spectators whose experiences have been analyzed and averaged.

Both anaglyph and shutter images have been recorded and transmitted, being visualized by independent spectators in domestic environments. After the experiment, a Mean Opinion Score (MOS) test was performed to evaluate the QoS (0 = very bad; 5 = perfect). The answers obtained from a set of 30 spectators have been averaged obtaining the results presented in Table I.

Parameter	*Anaglyph*	*Shutter*
Image quality	3.1	4.2
3D effect	4.0	4.8
Flickering	5.0	1.3
Utility	2.6	4.0

Table I. *Quality test results.*

From the answers given by the spectators we can extract the following conclusions: the shutter technology provides a more realistic 3D effect and higher image quality. However, flickering is quite important and might fatigue the spectator. Anaglyph images are not considered an adequate alternative to shutter images. All the spectators recommend further work in the reduction of the flickering.

5 Conclusions

A new service designed for DTT applications has been designed and prototyped. It consists on the generation, transmission and visualization of 3D scenes without an important increase of cost for the final spectator. Most of the cost is supported by the production studio.

A complete prototype has been developed, from the recording and processing of the 3D image to the final visualization in a domestic environment, including DVB-T transmission and reception.

Finally, QoS has been evaluated through the averaging of a subjective opinion test. The answers indicate that shutter technology is preferred by the final spectator, although further work must be done in reducing the flickering effect.

Although the prototype has been developed for academic purposes, all the modules are compatible with professional systems so that the final QoS could be increased without needing to redesign, simply substituting the used equipment by professional hardware (cameras, MPEG2 encoder, etc.).

Acknowledgement

This work has been partially supported by the “Gobierno del Principado de Asturias”, by the “Fundación CTIC” and by Cajastur.

References:

[1] H. Benoit, *Digital Television,* John Wiley and Sons, 1997.

[2] C. Pérez Vega, J. M. Zamanillo Saiz de la Maza. *Fundamentos de Televisión analógica y digital*. Universidad de Cantabria, 2003.

[3] ETSI EN 300 744: “Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television”.

[4] ETSI TR 101 190: “Digital Video Broadcasting (DVB); Implementation guidelines for DVB terrestrial services; Transmission aspects”.

[5] A. W. Judge, *Stereoscopic Photography*. Ghose Press, 2007.

[6] B. Girod, G. Greiner, H. Niemann, *Principles of 3D Image Analysis and Synthesis*, Kluwer Academic Publishers, 2000.