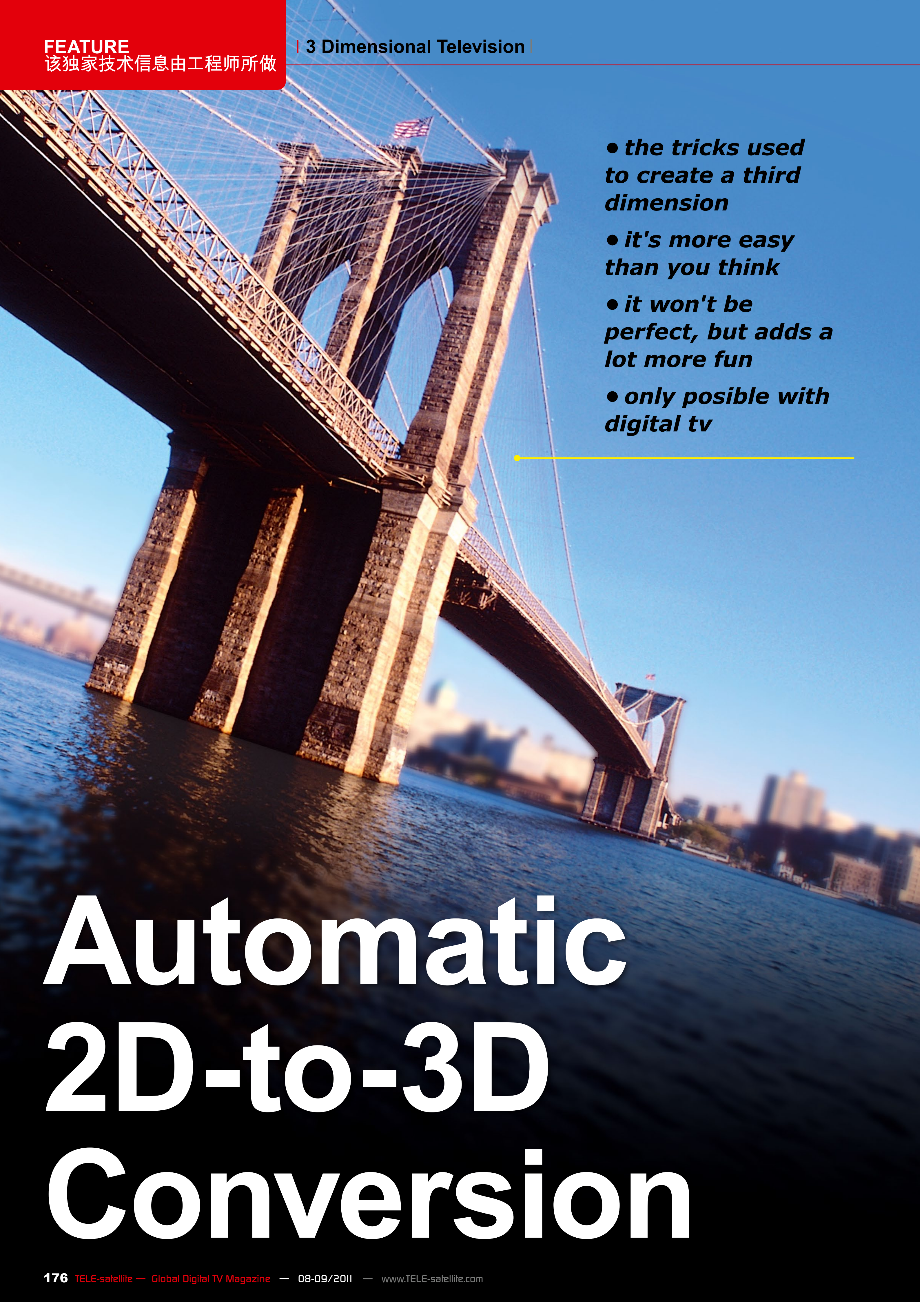

- ***the tricks used to create a third dimension***
- ***it's more easy than you think***
- ***it won't be perfect, but adds a lot more fun***
- ***only posible with digital tv***

# Automatic 2D-to-3D Conversion

# Software automatically creates the third dimension (depth)

**Jacek Pawlowski**

The majority of all television programming content is two-dimensional (width x hight). It is best viewed with one single eye. However, most people are using two eyes, which enables them to notice if an object is closer or farther away. This is the depth, which is the third dimension. But there is not much programming content in 3 dimensions on the market. So what to do, when we all prefer to watch with both our eyes and therefore would welcome the third dimension in all our television viewing?

You could wait for generic 3D content to be produced over time, but smart software engineers came up with a solution to artificially create the third dimension out of two-dimensional content. So how do they do it? We took a closer look behind the scenes and lifted the curtain to their amazing tricks.

Generally, to convert 2D picture to 3D, we need to make two steps. Step 1 is to assign depth information to various parts of the 2D picture. Step 2 is to show the original picture to one eye and create the additional picture for the second eye. In technical literature, these steps are referred to as: Depth Map Estimation and Depth Image Based Rendering.

Let's first discuss depth estimation. There are various cues our brain uses to asses depth in the observed picture but in the automatic conversion usually the following three ones are most often used:

1. depth from blur
2. vanishing point based estimation
3. depth from motion parallax

"Depth from blur" takes into account the focal sharpness of the different object on the screen assuming that the closer objects are sharper than those further away and the very distant ones are quite hazy – see Figure 1.

**Fig. 1 Depth can be recognized from object sharpness.**

**Fig. 2. Vanishing point – a well know concept to everybody who attended art lessons in school is also a very good clue for picture depth estimation. The boat-house is closer to the vanishing point thus it is farther away than the flowers.**



"Vanishing point based estimation" deals with object perspective. It is very easy to understand when one observes a picture showing architecture – see Figure 2. The closer the object is to the vanishing point, the greater the chance it is "deeper" in 3D.

The two principles described above can be used for both still and moving pictures. The third one is useable only for moving pictures. To put it simple, when you look through the window in a train, you notice that the objects closer to the train are moving back faster than the objects located further away. And the objects located near the horizon seem to not move at all. This principle is used is in "depth from motion parallax" method. Although it may look quite difficult to perform this operation, actually it is easier in MPEG coded pictures than the previous two methods. This method is widely used in 2D-to-3D digital TV conversion.

Depth estimation produces depth map for the picture in which every pixel gets additional 8 bit information depicting its depth (0-255 decimally). 0 is the farthest value and 255 is the closest value. Such maps are then smoothed in special filters and in this way some errors are removed.

Now that we have the original picture plus its depth map, we can start thinking of creating the picture for the second eye. This process combines two operations: object warping and holes filling by averaging textures from neighborhood pixels.

Object warping is explained in Figure 3. Having depth information, the processor can re-project the object in 3D space and then calculate its view as seen from the perspective of the second eye.

Due to warping, objects on the picture are shifted and stretched or squeezed. This is true especially for the near objects. This leads to hole creation in the original picture. The holes need to be filled with something. This is not an easy task for the processor and various algorithms have been proposed to do that in the right way. Of course, the neighboring areas are taken into account but sometimes the hole filling must be more sophisticated. As this is a very specific topic and requires high level math to address it precisely, we will not discuss it in this article.

Based on what has been written above, a reader may come to the conclusion that in the process of converting 2D to 3D there are a lot of small steps in which errors may arise. And this conclusion is generally correct. One cannot fully trust automatic 2D-to-3D conversion. The depth estimation may not work very well in complex pictures, and the hole filling may also create unnecessary noise. Today, only 2D-to-3D conversion done with human interaction can guarantee a really perfect result. This is a very costly approach, but some movies are being converted in this way. However, conversely to what most of us would think, human eye is not a very precise instrument and it tolerates some amount of depth errors. That's why automatic 2D-to-3D conversion produces an artificial 3D picture which in most cases is considered to be significantly better than regular flat 2D.

If you are prepared to tolerate some lack of perfectness, you will enjoy automatic 2D-to-3D conversion. It will surely add more fun to you when both of your eyes pretend you to see something resembling much more closely real life, than the flat two dimensional, what we are all used to in today's television.

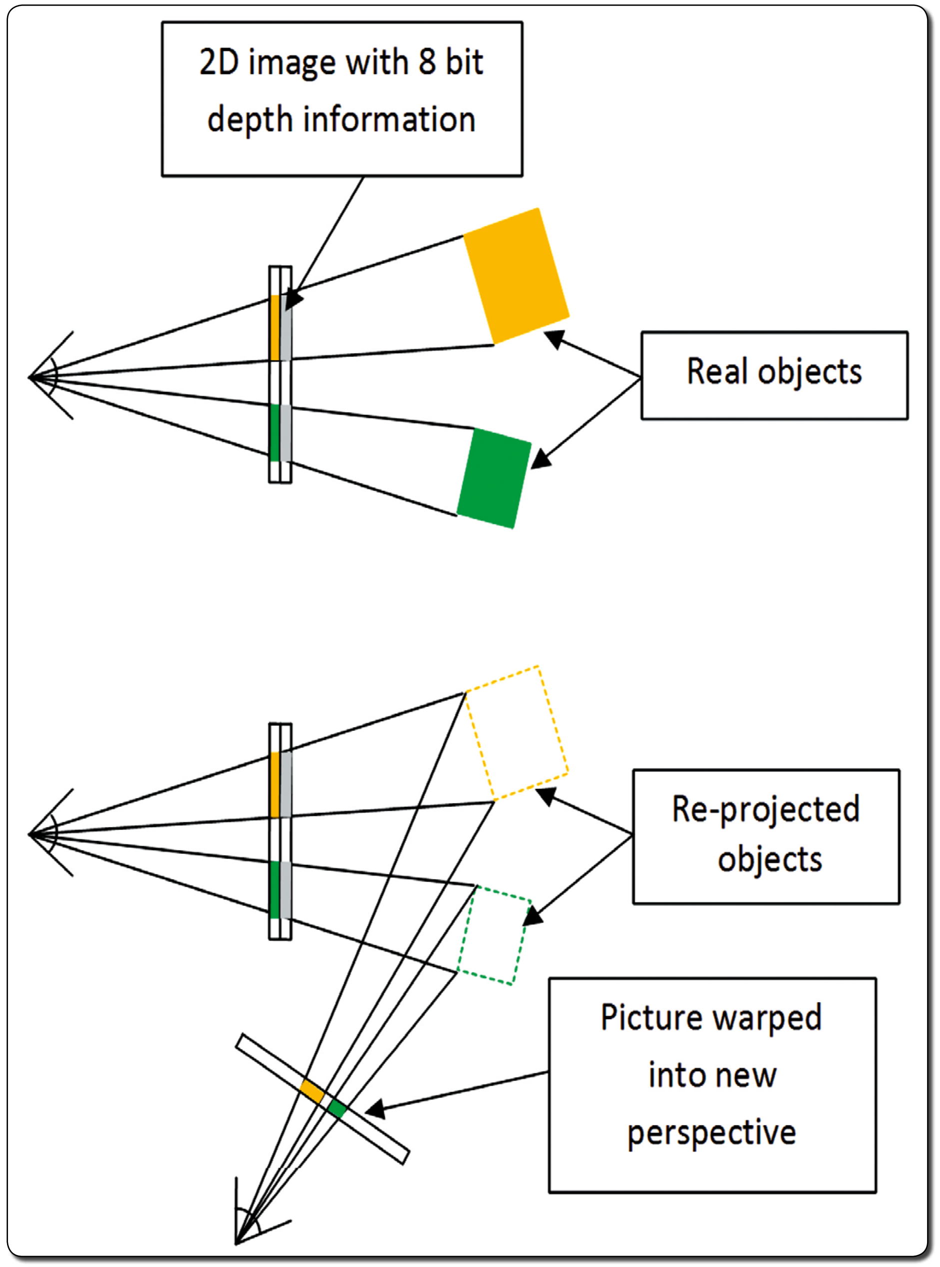


**Fig. 3. Object warping – creating new perspective for the second eye.**