

# A Simple Stereoscopic Endoscope

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## ABSTRACT

A very simple method is described for producing and viewing stereoscopic endoscopic images.

The addition of two simple prisms to the end of a conventional television-monitored endoscope with a simple viewing device produces a stereoscopic endoscope which appears to be suitable for surgical use.

**Key Words:** Stereoscopic, Endoscope.

## INTRODUCTION

The typical endoscope is a Cyclopean device. The image it produces is comparable to that which one sees with one eye closed. There is considerable loss of depth perception which, in turn, makes manipulation of instruments slow, awkward and at times possibly hazardous.

There have been a number of attempts to produce and market stereoscopic endoscopes, but these do not seem to have had any significant success. There are at least two obvious drawbacks to the units we know about. The first is price. At least one commercial unit is quoted at \$60,000. The other drawback is the need for special elaborate viewing screens or glasses.

We have developed a design that involves only a simple modification of existing endoscopes and a simple television monitor viewing device consisting of only four small front surface mirrors.

## MATERIAL AND METHODS

Attempts to build stereoscopic endoscopes have run into practical difficulties of cost and of the need for clumsy viewing devices such as shuttered blinking glasses or polarized glasses.

None of these seem to have been entirely satisfactory. In particular, difficulties have been mentioned from trying to view objects that are very close to the end of the endoscope. This is easy to understand. Imagine trying to reconcile the images of an object held at the tip of the nose as seen by the two eyes. The practical problem appears to be due to difficulty in getting two optical paths close enough together to produce the necessary small angle between them.

The device described here seems to avoid these problems. It is quite simple and easily applied to an existing endoscopic television system. Image quality is excellent, and the perception of three dimensions is comparable to and in fact somewhat better than that of the unaided eyes since the endoscope views from a much shorter distance than the unaided eye does.

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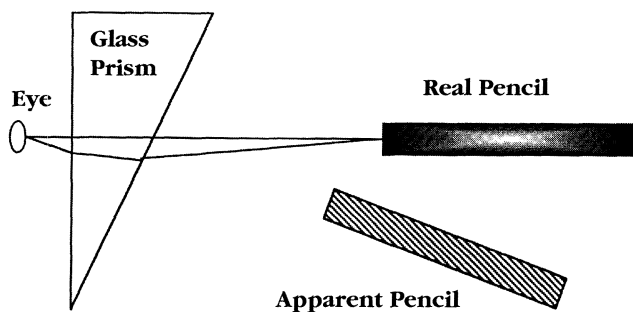
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In order to produce a three-dimensional stereoscopic image, it is necessary to acquire and deliver to the two eyes slightly different images of a three-dimensional object corresponding to the different angles at which the two eyes would view directly.

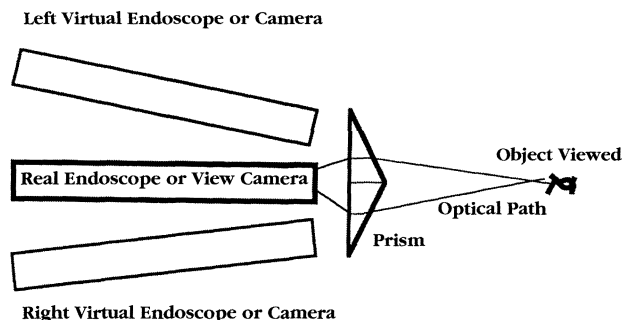
For reasons of cost and stability, it is advantageous to acquire both images with a single television camera. The camera can be either at the end of a rod or optically connected to the end of the rod by means of a coherent optical fiber bundle. In our device, the necessary two angle input is produced by two small prisms attached to the lens of a conventional endoscope.

If one observes an object say 15 to 25 cm from the eye, and then inserts a shallow angle (30 degrees for example) glass prism in front of the eye, the object appears to move sideways by 4 to 6 cm (Figure 1). At least this will be one's initial impression. On closer examination, one observes that the image of the object also appears rotated at an angle to the original line of sight. The effect is most easily observed by holding a pencil in such a way that one eye is looking exactly along the length of the pencil so that the sides are not visible. When a prism is inserted in the optical path, the image is shifted and one side of the pencil becomes visible, as if the pencil had been rotated around a vertical axis.

A similar result occurs in the television image produced through an endoscope. If a small prism, once again about 30 degrees, is inserted into one side of the object field of the endoscope, two images of the object in front of the endoscope are seen, of which one appears as if viewed slightly from one side. This is exactly what one needs to produce a stereoscopic image pair except that, for reasons of optical symmetry and common focus of the two images,



**Figure 1. The apparent shift of position and rotation of an object viewed through a prism.**



**Figure 2. Production of virtual endoscopes by means of double prism.**

one uses two prisms in reverse orientation as shown in Figure 2.

Figure 3 shows toy soldiers, chess pieces and a scale viewed through a Karl Storz endoscope (Karl Storz Endoscopy, Belgium N.V.) with the double prism. Each is a 30 degree prism about 4 mm on the diagonal. The endoscope image is viewed through a television system. The full height of the soldier is about 23 mm and the part of the chess piece showing is about 15 mm. They appear to differ from their real size as compared to the scale in the picture due to the extreme optical divergence that occurs when objects are so close to the viewing device (in this case about 30 mm distant).

There are two sets of three images each shown in Figure 3. In each case the middle and the right images are as they would be seen by the two eyes and are therefore correctly oriented to view with a conventional map viewer or stereopticon with the leftmost image covered. The left image is the same as the right image but located on the page so that it can be viewed with the middle image by crossing one's eyes to superimpose the two with the rightmost image covered.

Neither of the above methods is suitable for use in a surgical environment, but there are a number of other ways of presenting two different images to the two eyes. Among these are virtual reality headgear containing two separate small television displays, polarizing displays with polarizing glasses or time sequential displays with shuttered glasses. None of these seem really satisfactory. Virtual reality headgear currently available does not have enough resolution to avoid aliasing. Polarizing or shuttered glasses are awkward and cause over 50% loss in visible ambient light.



Figure 3. Views of toy soldier, two small chess pieces, and a scale as seen through an endoscope with double prism. The middle image and right image can be viewed together through a map reader. The left image and middle image together can be viewed by crossing one's eyes to superimpose the two images.

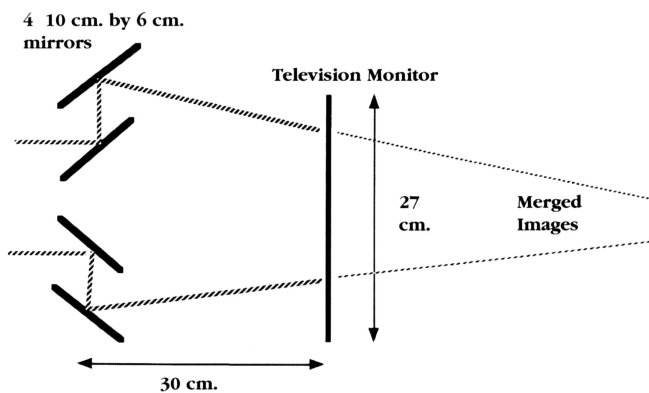


Figure 4. Schematic diagram of four mirror viewing.

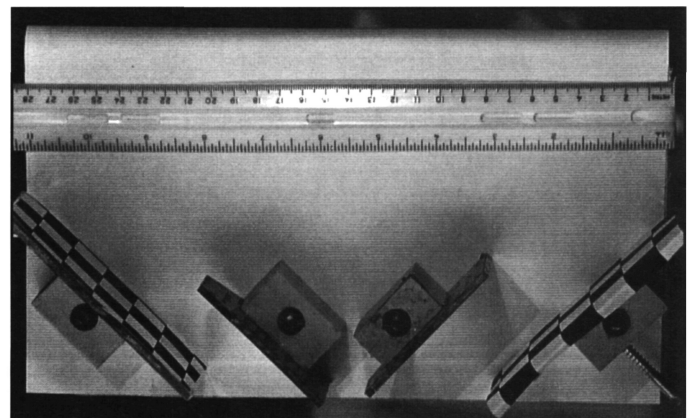


Figure 5. Photograph of four mirror viewing device.

The prototype system we use is considerably simpler than those above. Both images appear on a single television screen. Therefore, all that is required is to optically slide one image across the other so that they are correctly lined up for the expected convergence of the two eyes. This is easily done with two periscopes each consisting of two mirrors. The configuration is shown in **Figure 4**.

In the photograph (**Figure 5**), two of the mirrors have been covered with checkered paper to avoid photographing the reflection of the surrounding room. The mirror on the right is provided with a handle (a wood screw) to allow it to be rotated to accommodate differing eye separations and to correct for small errors in horizontal alignment. The outer mirror on the left is adjustable in tilt to correct small errors in vertical alignment. These are all the adjustments the system requires.

## RESULTS

This system appears to solve the problem of providing a stereoscopic endoscopic system which is comfortably viewed for extended periods of time with adequate resolution for surgical use. It is reasonably tolerant to changing eye position but, in its current implementation, only over a short distance. We have considered the possibility of having it automatically swivel around and move up and down to follow the surgeon's position, but we have been assured that for many kinds of surgery this is unnecessary.