A New Scanning Method for Super-Multiview 3-Dimensional Image Display System

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3-D display systems (See [1], [2], [3], [4] and references therein.) can be implemented in various ways. The fundamental mechanism for implementing these can be classified into two categories: spatial multiplexing; and time multiplexing. 3-D display systems utilizing optical plates such as lenticular screens, parallax barriers, and holographic screens that are used to generate viewing zones belong to spatial multiplexing scheme. Field-sequential binocular stereoscopic video with polarizing LCD shutter glasses are time-multiplexing type.

3-D display systems that utilize spatial multiplexing scheme are suffering from the resolution limitations of the display devices as the number of images to be presented increases. On the other hand, systems based on time multiplexing scheme have to solve the speed limitations of electronics and switching speed of CRT or LCD projectors if one wants to increase the number of images for alleviating the unnaturalness of discrete parallaxes and better viewing zones. Electroholographic display systems [5, 6, 7] using a polygon mirror and galvanometer scanner or LCD records and displays the data based on a spatial multiplexing, and thus suffers from the limitation of the resolution. Multiview 3D display systems with CRT projectors and holographic screens [8] are utilizing basically time multiplexing, and thus speed of electronics and switches are limiting factors. Even though spatiotemporal multiplexing [9] can increase the number of images that can be presented by a factor of 2, there exists fundamental limitation that the number of images cannot increase dramatically without any special breakthrough technologies.

The concept of Focused Light Array (FLA) in the Super-MultiView region can solve these problems by presenting simultaneously as many images as one wants, which are superimposed but separated by less than the pupil size. An implementation of the FLA using a galvanometer and a polygon mirror [10] has been demonstrated by TAO with the simultaneous scanning of the 45 images. Polygon mirror and galvanometer scanners, however, have their own disadvantages, and thus a smarter scanning system is needed for a better quality of FLA system.

In this paper, we propose a new laser beam scanning method for Super-MultiView(SMV) 3-D image display systems using a curvature-compensated tapered-cylindrical mirror scanner (From now on, we will use the acronym CCMS for short.) which is attached to two sinusoidally vibrating membranes.

Our goal is to determine the curvature function $f(x)$ of the CCMS based on the requirement that the scanning speed of the laser beam be constant over the screen such that the distribution of the light intensity is uniform. From the reflection law, we can find a differential equation whose solution is the curvature that we have to find. It can be shown that the differential equation is highly nonlinear. Runge-Kuta method did not work for our case. To solve this problem, we need to linearize the nonlinear differential equation, and this can be done by assuming that the function $f(x)$ does not change too much in the vibrating range compared with the distance D, where D is the distance between the screen and the scanner. Then we can write $D-f(x_m)$ as a constant r, where $r=f(0)$. Fig. 1 shows the result of the linearization process. At

$t = t_m$, we obtain the slope as [11]

$$f'(x_m) = \frac{(D-r) - \sqrt{(D-r)^2 + m^2 p^2}}{mp} \tag{1}$$

and the linear curvature function f(x) can be written as $f_m(x) = a_m x + b_m$ where a_m is given by Eq. (1) with $a_0 = 0$, and b_m is determined iteratively from the initial condition, with $b_0 = r = f_0(0)$.

Based on these analyses, some computer computations have been performed to verify the concept of the proposed system by demonstrating some example designs for the case when the size of the screen is 400 mm x 300 mm with 640 x 480 resolution, and the distance between the CCMS and the screen has been set to be D = 100 mm. With these parameters and the maximum deviation of the membrane A = 10, r = 1, (See Fig. 2.) A = 1, r = 0.3, and A = 4, r = 1, (The results of the last two is not shown in this paper.) the computer computation results have shown that they are just scaled down for each case. The ratio of the depth of the mirror to the maximum deviation was always 0.3. This means that we can design CCMS as small as we want, depending upon the types of the vibrating membranes.

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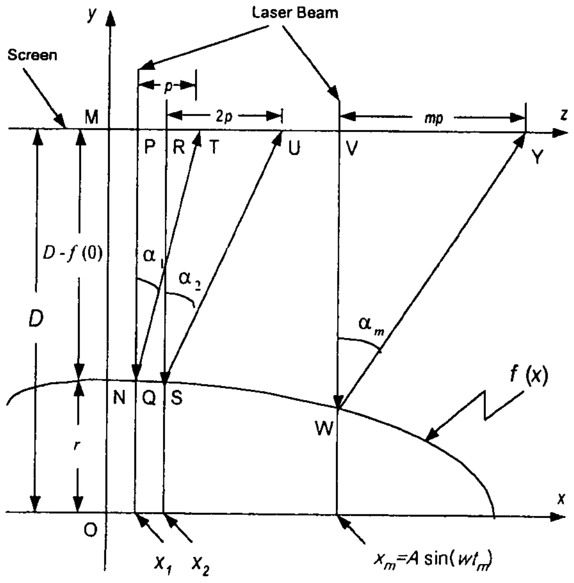

Fig. 1 Curvature-Compensated Mirror Scanner

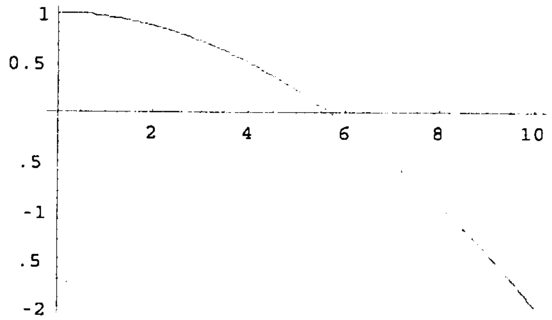

Fig. 2 A resultant curvature function of the sample CCMS when A=10mm, r=1 mm.