Low Cost 3D perception sensors

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Many sensors like the laser range finder, stereo vision cameras which help in building a depth perception of the world around it in 3D are very costly. Here I present the designs and prototypes of few 3D perception sensors which have been built low cost using components off the shelf. These perception sensors use structured infrared light projection. The design is miniature compared to other 3D sensors like LIDAR, Laser scanner and Time of flight cameras.

The method involves illuminating the object with fringes which are sinusoidal phase shifted. From a series of images of the object illuminated with traveling fringes the phase information of each and every pixel can b e obtained. This pixel level phase information can be mapped to the depth. Also in most of the structured light projects the cost of the projector increases the total cost of experimental setup. To overcome this, a new low cost fringe projector was designed using an IR LED. It is named the "nano-projector" compared to the pocket sized micro projectors. Initially it was thought to use fringes formed by a laser pointer with diffraction grating plates but it requires the fabrication of grating plates which is expensive. Also the use of laser could damage the observer's eyes while experimenting or while using the sensor. To capture IR light a webcamera with its IR filter removed and fitted with visible light filter was used. The cost of micro-film development was more than the camera's cost and hence low cost alternatives were looked into for making the fringe films. The best among such was to print the fringes onto a transparent plastic sheet using a Laser printer. The problem was that the intensity of the fringes formed should to obey the equation below[1]

$I1(x, y)=I'(x, y)+I''(x, y)\cos[\Phi(x, y)-\alpha]$.

When the resulting fringe pattern was magnified the fringe lines were in a zigzagged fashion . This happened because the print head of the printer tried to approximate its position to print the image. To prevent this, lines which were of finite intensity (either 255 or 0) and that were in integral multiples of pixel thickness were drawn and printed. Now the print head's position approximation did not occur. Lines of varying thickness were printed . More are the fringes in the film more will be the detail in the reconstructed 3D model. One more disadvantage of increasing the number of fringe lines within the limited area of the projection film is that it comes at the cost of reduced line thickness; as a result the projected fringes will not form properly. Among all the fringe patterns tried and tested, fringes with 4 lines per mm were chosen. There are two reasons for which the fringe pattern formed using IR light was better. One, the Laser printer heats the sheet a bit, so the density of the print material at the center of the printed pixel was more than the density at the corner. For visible light this was dark enough to be opaque and for IR it was translucent. Thus even the constructed 3D point cloud was better using IR light than the visible light. In general longer wavelength of light diffracts more than the shorter wavelength. The infrared light diffracted more than the shorter wavelengths in the visible light and thus the edges of the fringes formed by infrared light were more blurred than the visible light. This thus resulted in a better 3D point cloud using IR light.The code was developed in C using OpenCv. As miniature as the camera and LEDs can get so will the sensor. Also by using more powerful IR LEDs higher projection distance can be achieved. The IR LEDs used here were able to project the pattern up to a maximum distance of 2 meters as detected by the webcamera. Also the current consumption of the sensor is very low compared to a Laser Range finder.

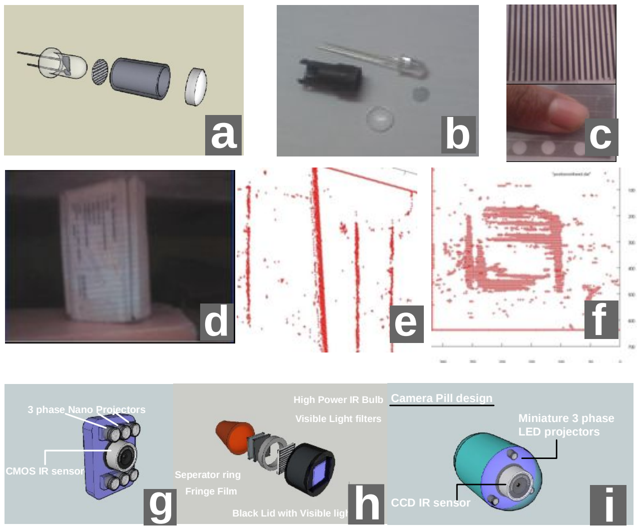

Figure 1.a-1.c show the exploded view, parts used and the fringes printed. 1.d-1.f show the illuminated object and the 3D point cloud in GNUplot.1.g shows the design of a 3D webcamera using nano 3 phase projectors, 1.h shows the design of sensor for autonomous cars,1.i shows camera capsule design.

Each LED's peak current is 15mA and the camera consumes not more than 500mA.Bigger laser range finders like the LMS-200 weigh 4500 gm and have a power consumption of 20W.

Applications: *1)*A 3D web camera capable of generating a 3D point cloud has been designed which just costs 2 dollars higher that the web camera used. It can be used in gaming projects like Natal for getting depth. The smallest sensor presented here weighs only 23 gm.2)The same sensor can be used in autonomous cars.. Because of the simple design of the sensor it can be fitted into a car's headlight.3)A camera pill design is also presented here which compared to the existing camera pill's would help in getting 3D scans of the body's internals (like intestine and esophagus).Use of 3 phase nano-projection will revolutionize medical imaging and diagnosis.4)The sensor because of it miniature design can be fitted into the end effecter of a robots arm. For example it can be used on exploratory rovers arm to get 3D scan of a rock. The rove could then use this information to position a tool head to drill the rock.

References.

[1]Song Zhang,Piesen S.Huang ,"High-resolution real-time three-dimensional shape measurement" Optical Engineering45(12),123601 (Decemeber 20060

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