Building a 3D Scanner for $1.99

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ABSTRACT

This memo discusses a simple method to digitize a restricted class of 3D objects. All that is needed is a 2D scanner, a bucket of milk, and a polaroid camera. The class of objects that can be digitized is restricted to the ones that fit inside the bucket, and that do not dissolve in milk. From the camera's point of view, the objects to be scanned must have a functional surface without local minima.

1. Introduction

Commercial 3D scanners can be purchased for a few thousand dollars. Some scanners use a probe of which the position can be determined in a magnetic field. Others use probes that emit ultrasonic sound and use microphones to locate the probe. The precision of these scanners can be quite high, typically within a fraction of a millimeter.

For objects with functional surfaces (depth z is uniquely determined by coordinates x and y) without local minima (no dips) there is a convenient and economical alternative. For one thing, it may take less time to build this scanner than to fill out a purchase order for a real 3D scanner.

2. Method

The objective of 3D digitization is to find a number that approximates the distance from an observer to each point on the surface of an object. The system discussed here is illustrated in Fig. 1.

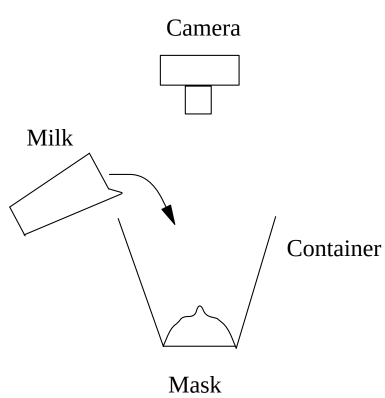

Figure 1 − Apparatus

The object, in this case a dark rubber mask of a face, is placed in the container. The polaroid camera points down towards the mask. The container is filled with low-fat milk in N equal steps ('equal' meaning that each step raises the level of the fluid inside the container by an equal amount). After each step a polaroid photo of the object is taken. The moment that a point disappears under the surface of the fluid is an approximation of its distance to the camera.

For our experiment N was 10. For more accuracy, a larger container and a larger value of N can be used.

The polaroids were digitized with a 2D scanner, lined up and, using simple contrast expansion, a matte for each picture is made. The matte is white for all points below the surface of the milk and solid black elsewhere. The pictures were then averaged to produce a single composite image. The composite is then smoothed using linear interpolation. For the experiment the following little *pico* program was used [Hol87].

```
x {
        int val, sx, ex, dval, dx

        for (y = 0; y < Y; y++)
        for (x = 0; x < X; x = ex+1)
        {       val = old[x,y]
                for (ex = x+1; old[ex,y] == val; ex++)
                        dval=0
                dx   = ex - x
                dval = old[ex,y] - val
                for (sx = x; sx <= ex; sx++)
                        new[sx,y]=(val*dx+((sx-x)*dval))/dx
        }
}
```

3. Conclusions

- The experiment described here showed the feasibility of the method, though not necessarily the full potential. For sufficient accuracy, we found that a step size N larger than 10 is needed. A fluid other than milk, with a lower surface tension, may also improve accuracy.
- With some 2D scanners, the container with the object and the fluid can be placed directly under the scanning head. No polaroid camera is then needed.
- Instead of a series of exposures, a single exposure could be used. The shutter of the camera remains open while the container is filled with fluid. The right aperture of the camera would be the one that produces a full tone scale from brightest (the points that were first covered with fluid and receive the longest exposure) to dark (the points that disappear last and receive the shortest exposure).
- All post processing for this experiment was done interactively with the image editor *pico* [Hol87]. 3D renderings (not shown) were made with a separate program.

4. Reference

Gerard J. Holzmann, "Pico, a picture editor", AT&T Technical Journal, Vol. 66, No. 2, March/April 1987, pp. 2-13.