Voxels

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Voxels

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Voxel Landscapes and How I Did It
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This document describes the method I used in my demo of a Martian terrain, which can be found at garbo.uwasa.fi:/pc/demo/mars10.zip.
It's similar to a floating horizon hidden line removal algorithm, so you'll find discussion of the salient points in many computer graphics books. The difference is the vertical line interpolation.

First, some general points

The map is a 256x256 grid of points, each having an 8-bit integer height and a colour. The map wraps round such that, calling w(u,v) the height at (u,v), then w(0,0)=w(256,0)=w(0,256)=w(256,256). w(1,1)=w(257,257), etc.

Map co-ords: (u,v) co-ordinates that describe a position on the map. The map can be thought of as a height function h=w(u,v) sampled discretely.

Screen co-ords: (x,y) co-ordinates for a pixel on the screen.

To generate the map

This is a recursive subdivision, or plasma, fractal. You start of with a random height at (0,0) and therefore also at (256,0), (0,256), (256,256). Call a routine that takes as input the size and position of a square, in the first case the entire map.
This routine get the heights from the corners of the square it gets given. Across each edge (if the map has not been written to at the point halfway along that edge), it takes the average of the heights of the 2 corners on that edge, applies some noise proportional to the length of the edge, and writes the result into the map at a position halfway along the edge. The centre of the square is the average of the four corners+noise.
The routine then calls itself recursively, splitting each square into four

quadrants, calling itself for each quadrant until the length of the side is 2 pixels.

This is probably old-hat to many people, but the map is made more realistic by blurring:

```
w(u,v)=k1*w(u,v)+k2*w(u+3,v-2)+k3*w(u-2,v+4) or something.
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Choose k1,k2,k3 such that k1+k2+k3=1. The points at which the map is sampled for the blurring filter do not really matter - they give different effects, and you don't need any theoretical reason to choose one lot as long as it looks good. Of course do everything in fixed point integer arithmetic.

The colours are done so that the sun is on the horizon to the East:

```
Colour=A*[ w(u+1,v)-w(u,v) ]+B
```

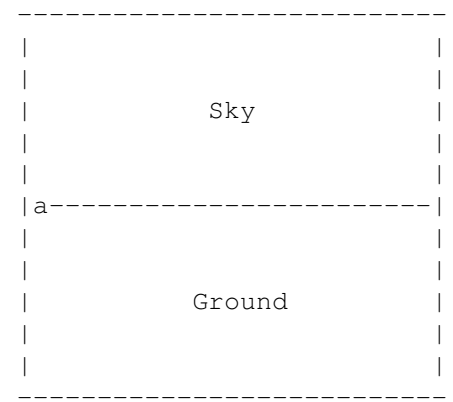
with A and B chosen so that the full range of the palette is used.

The sky is a similar fractal but without the colour transformation.

How to draw each frame

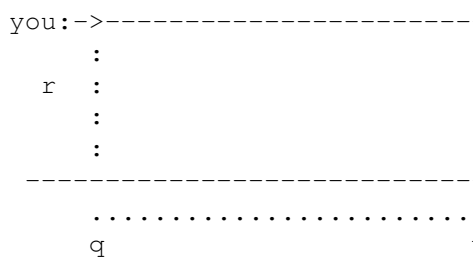
First, draw the sky, and blank off about 50 or so scan lines below the horizon since the routine may not write to all of them (eg. if you are on top of a high mountain looking onto a flat plane, the plane will not go to the horizon).

Now, down to business. The screen is as follows:



Imagine the viewpoint is at a position (p,q,r) where (p,q) are the (u,v) map co-ordinates and r is the altitude. Now, for each horizontal (constant v) line of map from v=q+100 (say) down to v=q, do this:

1. Calculate the y co-ordinate of map co-ord (p,v,0) (perspective transform)



You have to find where the line between P and you intersects with the screen (vertical, just in front of 'you'). This is the perspective transform: y=r/(q-v).

2. Calculate scale factor f which is how many screen pixels high a mountain of constant height would be if at distance v from q. Therefore, f is small for map co-ords far away (v>>q) and gets bigger as v comes down towards q.

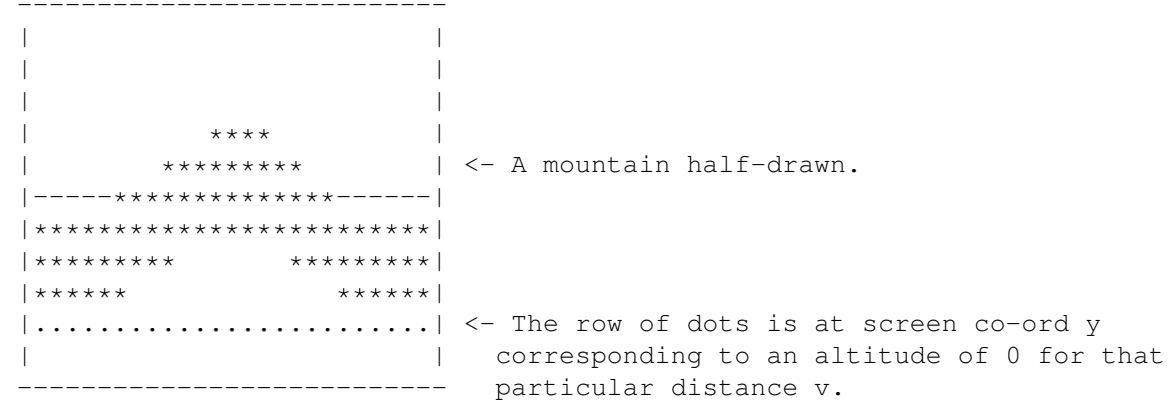
So, f is a number such that if you multiply a height from the map by f, you get the number of pixels on the screen high that height would be. For example, take a spot height of 250 on the map. If this was very close, it could occupy 500 pixels on the screen (before clipping)->f=2.

3. Work out the map u co-ord corresponding to (0,y). v is constant along each line.

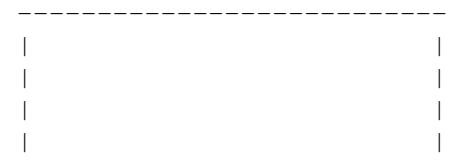
4. Starting at the calculated (u,v), traverse the screen, incrementing the x co-ordinate and adding on a constant, c, to u such that (u+c,v) are the map co-ords corresponding to the screen co-ords (1,y). You then have 256 map co-ords along a line of constant v. Get the height, w, at each map co-ord and draw a spot at (x,y-w*f) for all x.

I.e. the further away the scan line is, the more to the "left" u will start, and the larger c will be (possibly skipping some u columns if c > 1); the closer the scan line, the lesser u will start on the "left", and c will be smaller.

Sorry, but that probably doesn't make much sense. Here's an example: Imagine sometime in the middle of drawing the frame, everything behind a point (say v=q+50) will have been drawn:



Now the screen-scanning routine will get called for v=q+50. It draws in a point for every x corresponding to heights at map positions (u,v) where u goes from p-something to p+something, v constant. The routine would put points at these positions: (ignoring what was there before)



So, you can see that the screen gets drawn from the back, one vertical section after another. In fact, there's more to it than drawing one pixel at every x during the scan - you need to draw a vertical line between (x,y old) to (x,y new), so you have to have a buffer containing the y values for every x that were calculated in the previous pass. You interpolate along this line (Gouraud style) from the old colour to the new colour also, so you have to keep a buffer of the colours done in the last pass.

Only draw the vertical lines if they are visible (ie. going down, y new>y old). The screen is drawn from the back so that objects can be drawn inbetween drawing each vertical section at the appropriate time.

If you need further information or details, mail me or post here... Posting will allow others to benefit from your points and my replies, though.

Thank you for the response I have received since uploading this program.