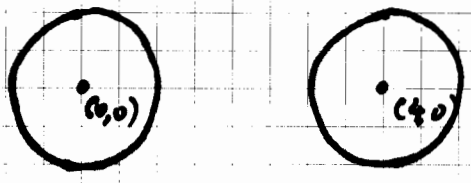
Computer Science Tripos Part II 2005

Paper 7 Question 3

NAD — Advanced Graphics

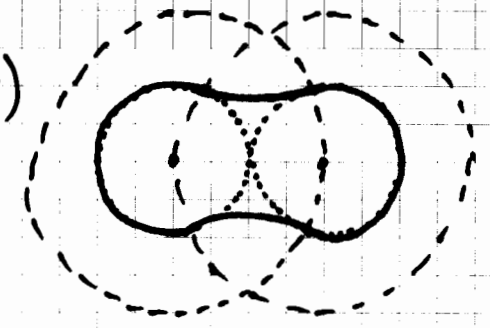
Advanced Graphics

(a) (i)



The blobs do not interact
They are perfect circles separated by a space equal to the diameter of one circle.

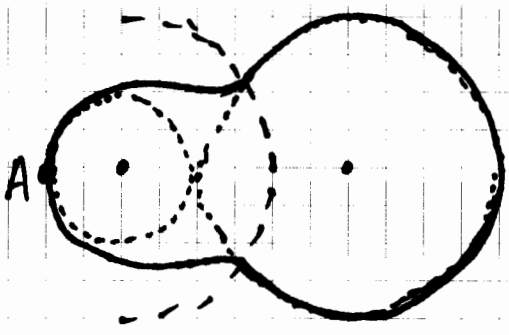
(ii)



.... $\equiv g = \frac{1}{2}$ (at $R_i/2$) --- $\equiv g = 0$ (at R_i)

A peanut shape, with a slight waist. The surface follows the $g = \frac{1}{2}$ line outside the other point's circle of influence (i.e. where $g = 0$)

(iii)



..... $\equiv g = \frac{1}{2}$ --- $\equiv g = 0$ for P_1

The curve follows $g_2 = \frac{1}{2}$ outside P_1's sphere of influence but only touches $g_1 = \frac{1}{2}$ at point A

(b) The Marching Cubes algorithm is expected here.

Select a resolution, Δ, and bounds on the region of space you want to draw: $x_{min}, x_{max}, y_{min}, y_{max}, z_{min}, z_{max}$

Calculate $F(x_{min} + i.\Delta, y_{min} + j.\Delta, z_{min} + k.\Delta)$ for all (i, j, k) such that $i, j, k \geq 0$ and $x_{min} + i.\Delta \leq x_{max}$, etc.

Let $l = \left\lfloor \frac{x_{max} - x_{min}}{\Delta} \right\rfloor$, m and n similar for y and z

$(l+1) \times (m+1) \times (n+1)$

Have a 3D array of boolean, B, of appropriate size. Store True in $B(i,j,k)$ if $F \geq \frac{1}{2}$, False otherwise.

Now, generate the triangles to be drawn

```
For i = 0 to l-1
    For j=0 to m-1
        For k=0 to n-1
            lookup the entry* indexed by
                B(i,j,k), B(i+1,j,k), B(i+1,j+1,k),
                B(i,j+1,k), B(i,j+1,k+1), B(i+1,j+1,k+1),
                B(i+1,j,k+1), B(i,j,k+1)
            and draw the triangles stored there offset
            by (x_min + i.Δ, y_min + j.Δ, z_min + k.Δ)
```

* The entries refered to above are a table of 256 list of triangles to be drawn in each of the 256 possible combinations of Trues and Falses. By reflection, rotation and ~~or~~ negation, this reduces to only 14 unique cases. Here are some examples:

Key points are: the vertices of the triangles lie at the centres of edges; the triangles divide the True vertices from the False.

[There are several optimisation & improvements which could be made but this does the job requested by the question.]

(c)(i) $F(\underset{\sim}{P}) = \max_{i=1}^{n} g(|\underset{\sim}{P} - \underset{\sim}{P}_i|, R_i)$

(ii) $F(\underset{\sim}{P}) = \min_{i=1}^{n} g(|P - P_i|, R_i)$

(iii) $F(\underset{\sim}{P}) = \min(g(|P - P_A|, R_A), 1 - g(|P - P_B|, R_B))$

gives $A \setminus B$

CONTEXT

This covers two lectures: • voxels & blobby objects
• CSG (constructive solid geometry)

(a) requires reasonable understanding of what the equations do
(b) is bookwork but requires the student to extract the core of the algorithm from the morass of details
(c) (i) and (ii) were lectured; (iii) is an interesting extension

PRELIMINARY MARKING SCHEME

(a) 1 mark for roughly right
1 mark for completely right

(i), (ii) & (iii) 2 — 6

(b)
- select resolution
- select bounds
- calculate F at each point
- check $F \geq \frac{1}{2}$
- look at every box (loop over i, j, k)
- use lookup table to draw triangles
- draw them in the right place
- details of the lookup table
- overall structure of answer

2 — 10

(c) (i) max

(ii) min

(iii) min (g, 1-g)

2 — 4

20