CS & MCS Section B
Hilary Term 2020

Geometric Modelling

Practical 2
Constructive Solid Geometry

1 Introduction and sVLis information

The purpose of this practical is to help you get some hands-on experience of CSG (constructive solid geometry). You will manipulate some 3D graphical shapes and think about the algebraic operations involved.

The bulk of the instructions for this practical detail the steps you need to follow in order to construct the mug using the sVLis geometric modeller.

This year you have the freedom to use any other geometric modeller which offers boolean operations. On the teaching network, you have a choice between `blender` and `openscad`, for which you will need to look up instructions on–line.

2 Tasks

If you decide to use an alternative modeller, adapt these task to fit your environment.

1. **Commands you need with sVLis**

   Download the necessary files from the course webpage.

   You will be modifying the C++ program called `CSGmug.cxx`. To compile your code, you can use the command

   ```
   $ make CSGmug
   ```

   and to run it, use

   ```
   $ ./CSGmug
   ```

   This will cause a graphics window to appear, and in your terminal the computer politely requests '`type any character to finish:`'. If, at any time, you want to close the graphics window and quit the program, you need to type into your terminal window any character followed by `Enter`.

2. **What you can do with the graphics**

   Once you have a graphics window displaying a geometric model, you can turn the model around with your left mouse button, or shift it along with the middle mouse button.

   Keep your mouse over the window and type '`?`'. This will print (in your terminal window) a list of other commands which you can type in the graphics window.

Try a few, such as: `c, w, f, F, h, 0` (zero). Make a note of each as they will be useful later.

3. **Shapes available**

   Now look at the program in the editor window, and focus on this line:

   ```
   result = a_cuboid;
   ```

   This defines the result that gets displayed in the graphics screen. If you look at the lines above it, you will discover that `c` was defined somewhere as a `cuboid`.

   As you can see, there are other shapes available.

4. **Putting together a geometric model**

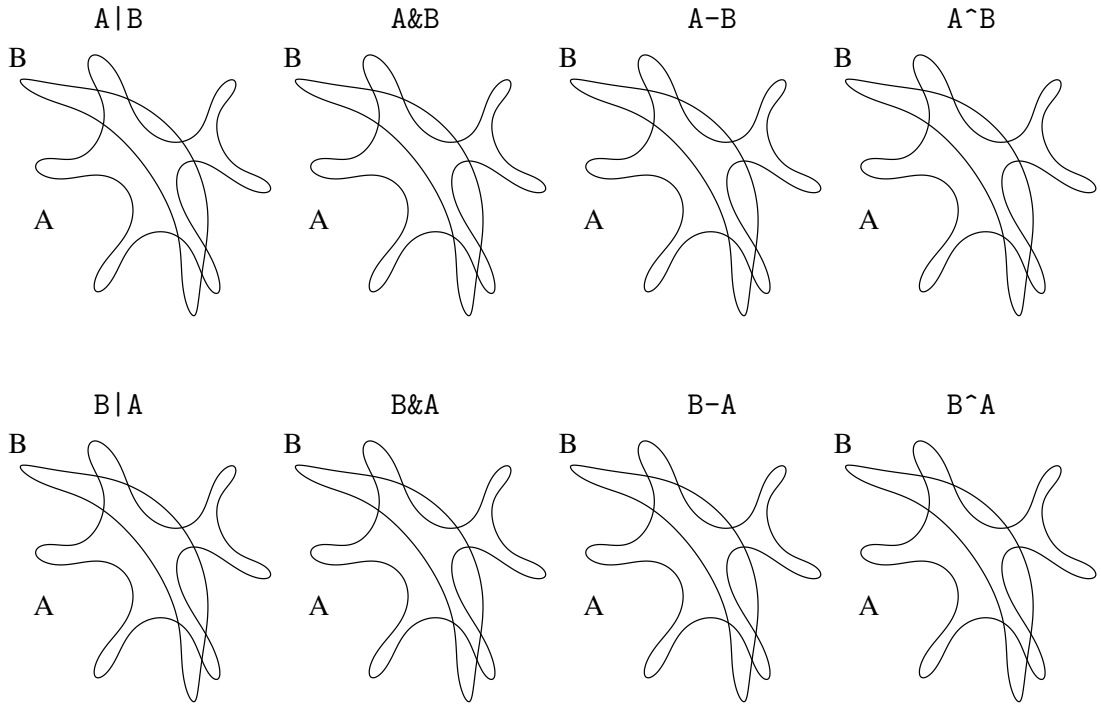
   Now, by selectively uncommenting some of the lines of code, try combining the shapes available with some of the operators `|, &, -, ^`

   `result = a_cuboid | a_sphere;` or `result = a_cuboid & a_sphere;` or `result = a_cuboid - a_sphere;` or `result = a_cuboid ^ a_sphere;`

   What shapes do you get?

5. **Identifying useful operations**

   Based on experiments that you have made with the program, can you now illustrate what these operations will produce? Given the two 2D figures `A` and `B` in the diagrams below, colour in the results of each operation.



6. **Have the manual handy**

   The sVLis manual is available on the webpage.

7. **Ray trace a model**

   The interactive window and some ray tracing functionality can be toggled on or off. The default is to have the interactive window on, but the ray tracing off. The program always makes a `.mod` file.

   Find the code:

```
bool raytrace = false;
sv_integer width=200;  //pixels. 800 is good
sv_integer height=150; //pixels. 600 is good
// Raytrace to file "raytraced.ppm"
if (raytrace)
{
  ...
```

   Switch the `raytrace` variable to `true`. Compile and run you code again. Experiment with different window sizes or viewing parameters.

8. **The sVLis test harness**

   sVLis comes with a test harness (as demonstrated in the lectures). The idea of this program is to provide a rapid way to combine basic primitive shapes without having to go through the edit, compile, run cycle.

   Run the test harness program with

   `$ svlis`

   Follow the on screen instructions and try combining some shapes. Try to load the output of your program (`mug.mod`) into the test harness.

9. **Make a mug (your main task)**

   There are functions to return simple shapes as sets. These are:

   `sv_set cuboid(sv_point most_neg, sv_point most_pos)`

   `sv_set cuboid(sv_box b)`

   both generate the intersection of six planes needed to represent the cuboid required.

   `sv_set cylinder(sv_line l, sv_real r)`

   returns a cylinder with `l` as its axis of radius `r`.

   `sv_set cone(sv_line l, sv_real angle)`

   returns a cone. Or rather half a cone: the half that points the same way as the line.

   `sv_set sphere(sv_point p, sv_real r)`

   returns a sphere centred at `p` of radius `r`.

   `sv_set torus(sv_line l, sv_real big_r, sv_real little_r)`

   returns a torus the major circle of which is perpendicular to the line, and which has its centre at the line's origin. The variable `little_r` is the torus's minor radius.

`sv_set cyclide(sv_line l, sv_point sym, sv_real big_r, sv_real little_r, sv_real rc)`

is a cyclide with its major circle (radius `big_r`) perpendicular to the line and which has its centre at its origin. `little_r + rc` is the biggest minor radius of the cyclide; `little_r - rc` is the smallest minor radius of the cyclide. The cyclide is symmetrical about the direction sym, which obviously must not be parallel to the direction of axis.

Now make a mug that looks like this

Hint: to avoid creating infinitely-thin planes, do not use components that 'just touch'. Overlap them instead.

3 Optional

Model another object, combining at least three primitives.

The software package called SVLIS is a CSG modeller and was developed in the 1990s by a group of researchers at the University of Bath.