The gcodepreview OpenSCAD library*

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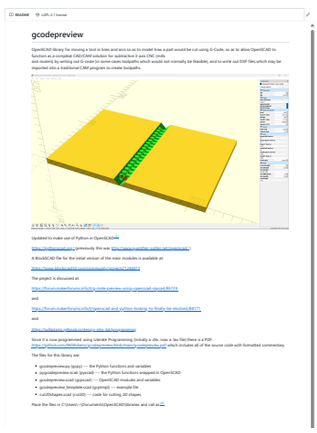
Abstract

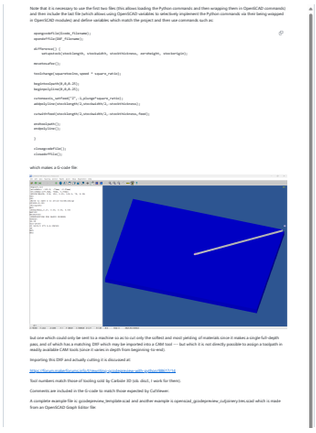
The gcodepreview library allows using PythonOpenSCAD to move a tool in lines and output dxf and G-code files so as to work as a CAD/CAM program for CNC.

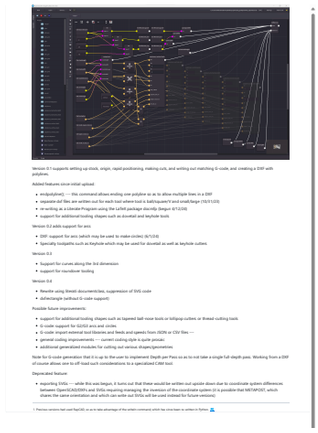
Contents

*This file (gcodepreview) has version number v0.5, last revised 2024/08/10.

1 readme.md







```
rdme # gcodepreview
rdme
rdme OpenSCAD library for moving a tool in lines and arcs
rdme so as to model how a part would be cut using G-Code,
rdme so as to allow OpenSCAD to function as a compleat
rdme CAD/CAM solution for subtractive 3-axis CNC (mills
rdme and routers) by writing out G-code (in some cases
rdme toolpaths which would not normally be feasible),
rdme and to write out DXF files which may be imported
rdme into a traditional CAM program to create toolpaths.
rdme
rdme ![OpenSCAD Cut Joinery Module](https://raw.githubusercontent.com/
         WillAdams/gcodepreview/main/openscad_cutjoinery.png?raw=true)
rdme
rdme Updated to make use of Python in OpenSCAD:[^rapcad]
rdme
rdme [^rapcad]: Previous versions had used RapCAD, so as to take
         advantage of the writeln command, which has since been re-
         written in Python.
rdme
rdme https://pythonscad.org/ (previously this was http://www.guenther-
         sohler.net/openscad/ )
rdme
rdme A BlockSCAD file for the initial version of the
rdme main modules is available at:
rdme
rdme https://www.blockscad3d.com/community/projects/1244473
rdme
rdme The project is discussed at:
rdme
rdme https://forum.makerforums.info/t/g-code-preview-using-openscad-
         rapcad/85729
rdme
rdme and
rdme
rdme https://forum.makerforums.info/t/openscad-and-python-looking-to-
         finally-be-resolved/88171
rdme
rdme and
rdme
rdme https://willadams.gitbook.io/design-into-3d/programming
rdme
rdme Since it is now programmed using Literate Programming
rdme (initially a .dtx, now a .tex file) there is a PDF:
rdme https://github.com/WillAdams/gcodepreview/blob/main/gcodepreview.
         pdf
rdme which includes all of the source code with formatted
rdme commentary.
rdme
rdme The files for this library are:
rdme
rdme  - gcodepreview.py (gcpy) --- the Python functions and variables
rdme  - pygcodepreview.scad (pyscad) --- the Python functions wrapped in
          OpenSCAD
rdme  - gcodepreview.scad (gcpscad) --- OpenSCAD modules and variables
rdme  - gcodepreview_template.scad (gcptmpl) --- example file
rdme  - cut2Dshapes.scad (cut2D) --- code for cutting 2D shapes
rdme
```

```
51 rdme Place the files in C:\Users\\\~\Documents\OpenSCAD\libraries and
        call as:[^libraries]
52 rdme
53 rdme [^libraries]: C:\Users\\\~\Documents\RapCAD\libraries is deprecated
         since RapCAD is no longer needed since Python is now used for
        writing out files)
54 rdme
55 rdme     use <gcodepreview.py>;
56 rdme     use <pygcodepreview.scad>;
57 rdme     include <gcodepreview.scad>;
58 rdme
59 rdme Note that it is necessary to use the first two files
60 rdme (this allows loading the Python commands and then
61 rdme wrapping them in OpenSCAD commands) and then include
62 rdme the last file (which allows using OpenSCAD variables
63 rdme to selectively implement the Python commands via their
64 rdme being wrapped in OpenSCAD modules) and define
65 rdme variables which match the project and then use
66 rdme commands such as:
67 rdme
68 rdme     opengcodefile(Gcode_filename);
69 rdme     opendxffile(DXF_filename);
70 rdme
71 rdme     difference() {
72 rdme         setupstock(stocklength, stockwidth, stockthickness,
                zeroheight, stockorigin);
73 rdme
74 rdme     movetosafez();
75 rdme
76 rdme     toolchange(squaretoolno,speed * square_ratio);
77 rdme
78 rdme     begintoolpath(0,0,0.25);
79 rdme     beginpolyline(0,0,0.25);
80 rdme
81 rdme     cutoneaxis_setfeed("Z",-1,plunge*square_ratio);
82 rdme     addpolyline(stocklength/2,stockwidth/2,-stockthickness);
83 rdme
84 rdme     cutwithfeed(stocklength/2,stockwidth/2,-stockthickness,feed);
85 rdme
86 rdme     endtoolpath();
87 rdme     endpolyline();
88 rdme
89 rdme     }
90 rdme
91 rdme     closegcodefile();
92 rdme     closedxffile();
93 rdme
94 rdme which makes a G-code file:
95 rdme
96 rdme ![OpenSCAD template G-code file](https://raw.githubusercontent.com/
        WillAdams/gcodepreview/main/gcodepreview_template.png?raw=true)
97 rdme
98 rdme but one which could only be sent to a machine so as to
99 rdme cut only the softest and most yielding of materials
100 rdme since it makes a single full-depth pass, and of which
101 rdme has a matching DXF which may be imported into a
102 rdme CAM tool --- but which it is not directly possible
103 rdme to assign a toolpath in readily available CAM tools
104 rdme (since it varies in depth from beginning-to-end).
105 rdme
106 rdme Importing this DXF and actually cutting it
107 rdme is discussed at:
108 rdme
109 rdme https://forum.makerforums.info/t/rewriting-gcodepreview-with-python
        /88617/14
110 rdme
111 rdme Tool numbers match those of tooling sold by Carbide 3D
112 rdme (ob. discl., I work for them).
113 rdme
114 rdme Comments are included in the G-code to match those
115 rdme expected by CutViewer.
116 rdme
117 rdme A complete example file is: gcodepreview_template.scad
118 rdme and another example is openscad_gcodepreview_cutjoinery.tres.scad
119 rdme which is made from an OpenSCAD Graph Editor file:
120 rdme
121 rdme ![OpenSCAD Graph Editor Cut Joinery File](https://raw.
        githubusercontent.com/WillAdams/gcodepreview/main/
```

```
          OSGE_cutjoinery.png?raw=true)
122 rdme
123 rdme Version 0.1 supports setting up stock, origin, rapid
124 rdme positioning, making cuts, and writing out matching
125 rdme G-code, and creating a DXF with polylines.
126 rdme
127 rdme Added features since initial upload:
128 rdme
129 rdme  - endpolyline(); --- this command allows ending one polyline so as
             to allow multiple lines in a DXF
130 rdme  - separate dxf files are written out for each tool where tool is
            ball/square/V and small/large (10/31/23)
131 rdme  - re-writing as a Literate Program using the LaTeX package docmfp
            (begun 4/12/24)
132 rdme  - support for additional tooling shapes such as dovetail and
            keyhole tools
133 rdme
134 rdme Version 0.2 adds support for arcs
135 rdme
136 rdme  - DXF: support for arcs (which may be used to make circles)
            (6/1/24)
137 rdme  - Specialty toolpaths such as Keyhole which may be used for
            dovetail as well as keyhole cutters
138 rdme
139 rdme Version 0.3
140 rdme
141 rdme  - Support for curves along the 3rd dimension
142 rdme  - support for roundover tooling
143 rdme
144 rdme Version 0.4
145 rdme
146 rdme  - Rewrite using literati documentclass, suppression of SVG code
147 rdme  - dxfrectangle (without G-code support)
148 rdme
149 rdme Possible future improvements:
150 rdme
151 rdme  - support for additional tooling shapes such as tapered ball-nose
            tools or lollipop cutters or thread-cutting tools
152 rdme  - G-code: support for G2/G3 arcs and circles
153 rdme  - G-code: import external tool libraries and feeds and speeds from
             JSON or CSV files ---
154 rdme  - general coding improvements --- current coding style is quite
            prosaic
155 rdme  - additional generalized modules for cutting out various shapes/
            geometries
156 rdme
157 rdme Note for G-code generation that it is up to the user
158 rdme to implement Depth per Pass so as to not take a
159 rdme single full-depth pass. Working from a DXF of course
160 rdme allows one to off-load such considerations to a
161 rdme specialized CAM tool.
162 rdme
163 rdme Deprecated feature:
164 rdme
165 rdme  - exporting SVGs --- while this was begun, it turns out that these
             would be written out upside down due to coordinate system
            differences between OpenSCAD/DXFs and SVGs requiring managing
            the inversion of the coordinate system (it is possible that
            METAPOST, which shares the same orientation and which can write
             out SVGs will be used instead for future versions)
```

2 gcodepreview

This library works by using Python code as a back-end so as to persistently store and access variables, and to write out files while both modeling the motion of a 3-axis. CNC machine and if desired, writing out DXR and/or G-code files. Doing so requires a total of three files:

- A Python file: gcodepreview.py (`gcpy`) — this will have variables in the traditional sense which may be used for tracking machine position and so forth
- An OpenSCAD file: pygcodepreview.scad (`pyscad`) — which wraps the Python code in OpenSCAD
- An OpenSCAD file: gcodepreview.scad (`gcpscad`) — which uses the other two files and which is `included` allowing it to access OpenSCAD variables for branching

Each file will begin with a suitable comment indicating the file type and suitable notes:

```
1 gcpy #!/usr/bin/env python
```

```
1 pyscad //!OpenSCAD
2 pyscad
3 pyscad //gcodepreview 0.4
```

```
1 gcpscad //!OpenSCAD
2 gcpscad
3 gcpscad //gcodepreview 0.4
4 gcpscad //
5 gcpscad //used via use <gcodepreview.py>;
6 gcpscad //          use <pygcodepreview.scad>;
7 gcpscad //          include <gcodepreview.scad>;
8 gcpscad //
```

writeln The original implementation in RapSCAD used a command `writeln` — fortunately, this command is easily re-created in Python:

```
3 gcpy def writeln(*arguments):
4 gcpy     line_to_write = ""
5 gcpy     for element in arguments:
6 gcpy         line_to_write += element
7 gcpy     f.write(line_to_write)
8 gcpy     f.write("\n")
```

which command will accept a series of arguments and then write them out to a file object.

2.1 Position and Variables

In modeling the machine motion and G-code it will be necessary to have the machine track several variables for machine position, current tool, depth in toolpath, &c. This will be done using paired functions (which will set and return the matching variable) and a matching (global) variable, as well as additional functions for setting the matching variable(s).

The first such variables are for XYZ position:

mpx • `mpx`

mpy • `mpy`

mpz • `mpz`

Similarly, for some toolpaths it will be necessary to track the depth along the Z-axis as the toolpath is cut out:

tpz • `tpz`

It will further be necessary to have a variable for the current tool:

currenttool • `currenttool`

For each intended command it will be necessary to implement an appropriate aspect in each file. The Python file will manage the Python variables and handle things which can only be done in Python, while there will be two OpenSCAD files as noted above, one which calls the Python code (this will be `used`), while the other will be able to access and use OpenSCAD variables, as well as implement Customizer options (this will be `included`).

Note that as a convention, where it is necessary for a module to coordinate between Python and OpenSCAD, it will be necessary for there to be three separate versions: a `p<foo>` Python definition

for the manipulation of Python variables and any file routines, an o<foo> OpenSCAD module which will wrap up the Python function call, and lastly a <foo> OpenSCAD module which will be <include>d so as to be able to make use of OpenSCAD variables.

psetupstock The first such routine will be appropriately enough, to set up the stock, and perform other initializations — in Python all that needs to be done is to set the value of the persistent (Python) variables:

```
10 gcpy def psetupstock(stocklength, stockwidth, stockthickness, zeroheight
       , stockorigin):
11 gcpy     global mpx
12 gcpy     mpx = float(0)
13 gcpy     global mpy
14 gcpy     mpy = float(0)
15 gcpy     global mpz
16 gcpy     mpz = float(0)
17 gcpy     global tpz
18 gcpy     tpz = float(0)
19 gcpy     global currenttool
20 gcpy     currenttool = 102
```

osetupstock The intermediary OpenSCAD code simply calls the Python version. Note that while the parameters are passed all the way down (for consistency) they are not used.

```
5 pyscad  module osetupstock(stocklength, stockwidth, stockthickness,
              zeroheight, stockorigin) {
6 pyscad      psetupstock(stocklength, stockwidth, stockthickness,
                  zeroheight, stockorigin);
7 pyscad  }
```

setupstock The OpenSCAD code which is called requires that the user set parameters and will create comments in the G-code which set the stock dimensions and its position relative to the zero as set relative to the stock.

The stockorigin setting is used in an <if then else> structure to position the 3D model of the stock.

```
 9 pyscad module setupstock(stocklength, stockwidth, stockthickness,
               zeroheight, stockorigin) {
10 pyscad   osetupstock(stocklength, stockwidth, stockthickness, zeroheight,
                stockorigin);
11 pyscad //initialize default tool and XYZ origin
12 pyscad   osettool(102);
13 pyscad   oset(0,0,0);
14 pyscad   if (zeroheight == "Top") {
15 pyscad     if (stockorigin == "Lower-Left") {
16 pyscad     translate([0, 0, (-stockthickness)]){
17 pyscad     cube([stocklength, stockwidth, stockthickness], center=false);
18 pyscad       if (generategcode == true) {
19 pyscad       owritethree("(stockMin:0.00mm, 0.00mm, -",str(stockthickness)
                   ,"mm)");
20 pyscad       owritefive("(stockMax:",str(stocklength),"mm, ",str(
                   stockwidth),"mm, 0.00mm)");
21 pyscad       owritenine("(STOCK/BLOCK, ",str(stocklength),", ",str(
                   stockwidth),", ",str(stockthickness),", 0.00, 0.00, ",str(
                   stockthickness),")");
22 pyscad     }
23 pyscad   }
24 pyscad }
25 pyscad      else if (stockorigin == "Center-Left") {
26 pyscad     translate([0, (-stockwidth / 2), -stockthickness]){
27 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
                   ;
28 pyscad     if (generategcode == true) {
29 pyscad owritefive("(stockMin:0.00mm, -",str(stockwidth/2),"mm, -",str(
               stockthickness),"mm)");
30 pyscad owritefive("(stockMax:",str(stocklength),"mm, ",str(stockwidth/2),"
               mm, 0.00mm)");
31 pyscad     owriteeleven("(STOCK/BLOCK, ",str(stocklength),", ",str(
                   stockwidth),", ",str(stockthickness),", 0.00, ",str(
                   stockwidth/2),", ",str(stockthickness),")");
32 pyscad     }
33 pyscad   }
34 pyscad     } else if (stockorigin == "Top-Left") {
35 pyscad     translate([0, (-stockwidth), -stockthickness]){
36 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
                   ;
37 pyscad if (generategcode == true) {
```

```
38 pyscad owritefive("(stockMin:0.00mm, -",str(stockwidth),"mm, -",str(
       stockthickness),"mm)");
39 pyscad owritethree("(stockMax:",str(stocklength),"mm, 0.00mm, 0.00mm)");
40 pyscad owriteeleven("(STOCK/BLOCK, ",str(stocklength),", ",str(stockwidth)
       ,", ",str(stockthickness),", 0.00, ",str(stockwidth),", ",str(
       stockthickness),")");
41 pyscad     }
42 pyscad   }
43 pyscad     }
44 pyscad     else if (stockorigin == "Center") {
45 pyscad //owritecomment("Center");
46 pyscad     translate([(-stocklength / 2), (-stockwidth / 2), -
           stockthickness]){
47 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
           ;
48 pyscad if (generategcode == true) {
49 pyscad owriteseven("(stockMin: -",str(stocklength/2),", -",str(stockwidth
       /2),"mm, -",str(stockthickness),"mm)");
50 pyscad owritefive("(stockMax:",str(stocklength/2),"mm, ",str(stockwidth/2)
       ,"mm, 0.00mm)");
51 pyscad owritethirteen("(STOCK/BLOCK, ",str(stocklength),", ",str(
       stockwidth),", ",str(stockthickness),", ",str(stocklength/2),",
       ", str(stockwidth/2),", ",str(stockthickness),")");
52 pyscad       }
53 pyscad     }
54 pyscad   }
55 pyscad } else if (zeroheight == "Bottom") {
56 pyscad //owritecomment("Bottom");
57 pyscad     if (stockorigin == "Lower-Left") {
58 pyscad     cube([stocklength, stockwidth, stockthickness], center=false);
59 pyscad if (generategcode == true) {
60 pyscad owriteone("(stockMin:0.00mm, 0.00mm, 0.00mm)");
61 pyscad owriteseven("(stockMax:",str(stocklength),"mm, ",str(stockwidth),"
       mm, ",str(stockthickness),"mm)");
62 pyscad owriteseven("(STOCK/BLOCK, ",str(stocklength),", ",str(stockwidth)
       ,", ",str(stockthickness),",0.00, 0.00, 0.00)");
63 pyscad     }
64 pyscad }    else if (stockorigin == "Center-Left") {
65 pyscad     translate([0, (-stockwidth / 2), 0]){
66 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
           ;
67 pyscad if (generategcode == true) {
68 pyscad owritethree("(stockMin:0.00mm, -",str(stockwidth/2),"mm, 0.00mm)");
69 pyscad owriteseven("(stockMax:",str(stocklength),"mm, ",str(stockwidth/2)
       ,"mm, ",str(stockthickness),"mm)");
70 pyscad owritenine("(STOCK/BLOCK, ",str(stocklength),", ",str(stockwidth)
       ,", ",str(stockthickness),",0.00, ",str(stockwidth/2),", 0.00)")
       ;
71 pyscad     }
72 pyscad   }
73 pyscad     } else if (stockorigin == "Top-Left") {
74 pyscad     translate([0, (-stockwidth), 0]){
75 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
           ;
76 pyscad     }
77 pyscad if (generategcode == true) {
78 pyscad owritethree("(stockMin:0.00mm, -",str(stockwidth),"mm, 0.00mm)");
79 pyscad owritefive("(stockMax:",str(stocklength),"mm, 0.00mm, ",str(
       stockthickness),"mm)");
80 pyscad owritenine("(STOCK/BLOCK, ",str(stocklength),", ",str(stockwidth)
       ,", ",str(stockthickness),", 0.00, ", str(stockwidth),", 0.00)")
       ;
81 pyscad   }
82 pyscad }    else if (stockorigin == "Center") {
83 pyscad     translate([(-stocklength / 2), (-stockwidth / 2), 0]){
84 pyscad       cube([stocklength, stockwidth, stockthickness], center=false)
           ;
85 pyscad     }
86 pyscad if (generategcode == true) {
87 pyscad owritefive("(stockMin:-",str(stocklength/2),", -",str(stockwidth/2)
       ,"mm, 0.00mm)");
88 pyscad owriteseven("(stockMax:",str(stocklength/2),"mm, ",str(stockwidth
       /2),"mm, ",str(stockthickness),"mm)");
89 pyscad owriteeleven("(STOCK/BLOCK, ",str(stocklength),", ",str(stockwidth)
       ,", ",str(stockthickness),", ",str(stocklength/2),", ", str(
       stockwidth/2),", 0.00)");
90 pyscad     }
91 pyscad   }
```

```
 92 pyscad }
 93 pyscad if (generategcode == true) {
 94 pyscad     owriteone("G90");
 95 pyscad     owriteone("G21");
 96 pyscad //    owriteone("(Move to safe Z to avoid workholding)");
 97 pyscad //    owriteone("G53G0Z-5.000");
 98 pyscad   }
 99 pyscad //owritecomment("ENDSETUP");
100 pyscad }
```

xpos ypos zpos

It will be necessary to have Python functions which return the current values of the machine position in Cartesian coordinates:

```
 22 gcpy def xpos():
 23 gcpy     global mpx
 24 gcpy     return mpx
 25 gcpy
 26 gcpy def ypos():
 27 gcpy     global mpy
 28 gcpy     return mpy
 29 gcpy
 30 gcpy def zpos():
 31 gcpy     global mpz
 32 gcpy     return mpz
 33 gcpy
 34 gcpy def tzpos():
 35 gcpy     global tpz
 36 gcpy     return tpz
```

psetxpos psetypos psetzpos psettzpos

and in turn, functions which set the positions:

```
 38 gcpy def psetxpos(newxpos):
 39 gcpy     global mpx
 40 gcpy     mpx = newxpos
 41 gcpy
 42 gcpy def psetypos(newypos):
 43 gcpy     global mpy
 44 gcpy     mpy = newypos
 45 gcpy
 46 gcpy def psetzpos(newzpos):
 47 gcpy     global mpz
 48 gcpy     mpz = newzpos
 49 gcpy
 50 gcpy def psettzpos(newtzpos):
 51 gcpy     global tpz
 52 gcpy     tpz = newtzpos
```

and as noted above, there will need to be matching OpenSCAD versions.

getxpos getypos getzpos gettzpos

Note that for routines where the variable is directly passed from OpenSCAD to Python it is possible to have OpenSCAD directly call the matching Python module with no need to use an intermediary OpenSCAD command.

setxpos setypos setzpos settzpos

```
102 pyscad function getxpos() = xpos();
103 pyscad function getypos() = ypos();
104 pyscad function getzpos() = zpos();
105 pyscad function gettzpos() = tzpos();
106 pyscad
107 pyscad module setxpos(newxpos) {
108 pyscad     psetxpos(newxpos);
109 pyscad }
110 pyscad
111 pyscad module setypos(newypos) {
112 pyscad     psetypos(newypos);
113 pyscad }
114 pyscad
115 pyscad module setzpos(newzpos) {
116 pyscad     psetzpos(newzpos);
117 pyscad }
118 pyscad
119 pyscad module settzpos(newtzpos) {
120 pyscad     psettzpos(newtzpos);
121 pyscad }
```

oset

while for setting the variables, it is necessary to have an OpenSCAD module:

```
10 gcpscad module oset(ex, ey, ez) {
```

```
11 gcpscad      setxpos(ex);
12 gcpscad      setypos(ey);
13 gcpscad      setzpos(ez);
14 gcpscad }
```

osettz and some toolpaths will require the storing and usage of an intermediate value for the Z-axis position during calculation:

```
16 gcpscad module osettz(tz) {
17 gcpscad      settzpos(tz);
18 gcpscad }
```

2.2 Tools and Changes

pcurrenttool psettool Similarly Python functions and variables will be used to track and set and return the current tool:

```
54 gcpy def psettool(tn):
55 gcpy     global currenttool
56 gcpy     currenttool = tn
57 gcpy
58 gcpy def pcurrent_tool():
59 gcpy     global currenttool
60 gcpy     return currenttool
```

osettool currenttool and matching OpenSCAD modules set and return the current tool:

```
123 pyscad module osettool(tn){
124 pyscad      psettool(tn);
125 pyscad }
126 pyscad
127 pyscad function current_tool() = pcurrent_tool();
```

2.2.1 toolchange

toolchange and apply the appropriate commands for a `toolchange`. Note that it is expected that this code will be updated as needed when new tooling is introduced as additional modules which require specific tooling are added below.

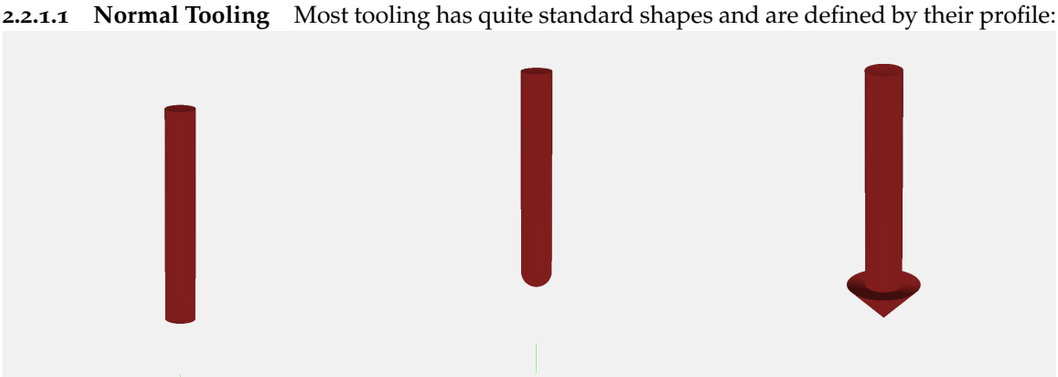
Note that the comments written out in G-code correspond to that used by the G-code previewing tool CutViewer (which is unfortunately, no longer readily available).

It is possible that rather than hard-coding the tool definitions, a future update will instead read them in from an external file — the `.csv` format used for tool libraries in Carbide Create seems a likely candidate and worth exploring.

Note that there are many varieties of tooling and not all will be implemented, especially in the initial version of this project

2.2.1.1 Normal Tooling

Most tooling has quite standard shapes and are defined by their profile:



- Square (#201 and 102) — able to cut a flat bottom, perpendicular side and right angle their simple and easily understood geometry makes them a standard choice (a radiused form with a flat bottom, often described as a "bowl bit" is not implemented as-of-yet)
- Ballnose (#202 and 101) — rounded, they are the standard choice for concave and organic shapes
- V tooling (#301, 302 and 390) — pointed at the tip, they are available in a variety angles and diameters and may be used for decorative V carving, or for chamfering or cutting specific angles (note that the commonly available radiused form is not implemented at this time, *e.g.*, #501 and 502)

```
20 gcpscad module toolchange(tool_number,speed) {
21 gcpscad     osettool(tool_number);
22 gcpscad if (generategcode == true) {
23 gcpscad      writecomment("Toolpath");
24 gcpscad      owriteone("M05");
25 gcpscad //      writecomment("Move to safe Z to avoid workholding");
26 gcpscad //      owriteone("G53G0Z-5.000");
27 gcpscad //      writecomment("Begin toolpath");
28 gcpscad      if (tool_number == 201) {
29 gcpscad        writecomment("TOOL/MILL,6.35, 0.00, 0.00, 0.00");
30 gcpscad      } else if (tool_number == 202) {
31 gcpscad        writecomment("TOOL/MILL,6.35, 3.17, 0.00, 0.00");
32 gcpscad      } else if (tool_number == 102) {
33 gcpscad        writecomment("TOOL/MILL,3.17, 0.00, 0.00, 0.00");
34 gcpscad      } else if (tool_number == 101) {
35 gcpscad        writecomment("TOOL/MILL,3.17, 1.58, 0.00, 0.00");
36 gcpscad      } else if (tool_number == 301) {
37 gcpscad        writecomment("TOOL/MILL,0.03, 0.00, 6.35, 45.00");
38 gcpscad      } else if (tool_number == 302) {
39 gcpscad        writecommment("TOOL/MILL,0.03, 0.00, 10.998, 30.00");
40 gcpscad      } else if (tool_number == 390) {
41 gcpscad        writecomment("TOOL/MILL,0.03, 0.00, 1.5875, 45.00");
```

2.2.1.2 Tooling for Keyhole Toolpaths Keyhole toolpaths (see: subsection 3.2 are intended for use with tooling which projects beyond the the narrower shaft and so will cut usefully underneath the visible surface. Also described as "undercut" tooling, but see below.

There are several notable candidates for such tooling:

- Keyhole tools — intended to cut slots for retaining hardware used for picture hanging, they may be used to create slots for other purposes
- Dovetail cutters — used for the joinery of the same name, they cut a large area at the bottom which slants up to a narrower region at a defined angle
- Lollipop cutters — normally used for 3D work, as their name suggests they are essentially a (cutting) ball on a narrow stick (the tool shaft), they are mentioned here only for compleatness' sake and are not (at this time) implemented

```
42 gcpscad      } else if (tool_number == 375) {
43 gcpscad        writecomment("TOOL/MILL,9.53, 0.00, 3.17, 0.00");
```

```
44 gcpscad      } else if (tool_number == 814) {
45 gcpscad        writecomment("TOOL/MILL,12.7, 6.367, 12.7, 0.00");
```

2.2.1.3 Thread mills The implementation of arcs cutting along the Z-axis raises the possibility of cutting threads using "thread mills". See: https://community.carbide3d.com/t/thread-milling-in-metal-on-the-shapeoko-3/5332

Note that it will be necessary to to define modules (see below) for each tool shape.

With the tools delineated, the module is closed out and the tooling information written into the G-code.

```
46 gcpscad      }
47 gcpscad        select_tool(tool_number);
48 gcpscad        owritetwo("M6T",str(tool_number));
49 gcpscad        owritetwo("M03S",str(speed));
50 gcpscad    }
51 gcpscad }
```

2.2.1.4 Roundover tooling It is not possible to represent all tools using tool changes as coded above which require using a `hull` operation between 3D representations of the tools at the beginning and end points. Tooling which cannot be so represented will be implemented separately below, see paragraph 2.2.2.2.

tool number selecttool

2.2.1.5 Selecting Tools There must also be a module for selecting tools: `select_tool` which will select the matching module for 3D modeling and pass the appropriate parameters to that module:

```
53 gcpscad module select_tool(tool_number) {
54 gcpscad //echo(tool_number);
55 gcpscad   if (tool_number == 201) {
56 gcpscad     gcp_endmill_square(6.35, 19.05);
57 gcpscad   } else if (tool_number == 202) {
58 gcpscad     gcp_endmill_ball(6.35, 19.05);
59 gcpscad   } else if (tool_number == 102) {
60 gcpscad     gcp_endmill_square(3.175, 19.05);
61 gcpscad   } else if (tool_number == 101) {
62 gcpscad     gcp_endmill_ball(3.175, 19.05);
63 gcpscad   } else if (tool_number == 301) {
64 gcpscad     gcp_endmill_v(90, 12.7);
65 gcpscad   } else if (tool_number == 302) {
66 gcpscad     gcp_endmill_v(60, 12.7);
67 gcpscad   } else if (tool_number == 390) {
68 gcpscad     gcp_endmill_v(90, 3.175);
```

For a keyhole tool:

```
69 gcpscad   } else if (tool_number == 375) {
70 gcpscad     gcp_keyhole(9.525, 3.175);
```

and dovetail tool:

```
71 gcpscad   } else if (tool_number == 814) {
72 gcpscad     gcp_dovetail(12.7, 6.367, 12.7, 14);
```

Once all tools have been defined the if statement and module may be closed:

```
73 gcpscad   }
74 gcpscad }
```

2.2.2 3D Shapes for Tools

Each tool must be modeled in 3D using an OpenSCAD module.

2.2.2.1 Normal toolshapes Most tools are easily implemented with concise 3D descriptions which may be connected with a simple `hull` operation:

gcp endmill square

```
76 gcpscad module gcp_endmill_square(es_diameter, es_flute_length) {
77 gcpscad   cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=
               es_flute_length, center=false);
78 gcpscad }
```

gcp keyhole

```
80 gcpscad module gcp_keyhole(es_diameter, es_flute_length) {
81 gcpscad   cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=
               es_flute_length, center=false);
82 gcpscad }
```

gcp dovetail

```
84 gcpscad module gcp_dovetail(dt_bottomdiameter, dt_topdiameter, dt_height,
             dt_angle) {
85 gcpscad   cylinder(r1=(dt_bottomdiameter / 2), r2=(dt_topdiameter / 2), h=
               dt_height, center=false);
86 gcpscad }
```

gcp endmill ball

```
88 gcpscad module gcp_endmill_ball(es_diameter, es_flute_length) {
89 gcpscad   translate([0, 0, (es_diameter / 2)]){
90 gcpscad     union(){
91 gcpscad       sphere(r=(es_diameter / 2));
92 gcpscad       cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=
                   es_flute_length, center=false);
93 gcpscad     }
94 gcpscad   }
95 gcpscad }
```

gcp endmill v

```
 97 gcpscad module gcp_endmill_v(es_v_angle, es_diameter) {
 98 gcpscad   union(){
 99 gcpscad     cylinder(r1=0, r2=(es_diameter / 2), h=((es_diameter / 2) / tan
                    ((es_v_angle / 2))), center=false);
100 gcpscad     translate([0, 0, ((es_diameter / 2) / tan((es_v_angle / 2)))]){
101 gcpscad       cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=((
                      es_diameter * 8) ), center=false);/// tan((es_v_angle / 2)
                      )
102 gcpscad     }
103 gcpscad   }
104 gcpscad }
```

2.2.2.2 Concave toolshapes While normal tooling may be represented with a single `hull` operation betwixt two 3D toolshapes, concave tooling such as roundover/radius tooling require multiple slices of the tool shape which are then `hull`ed together. Something of this can be seen in the manual work-around for previewing them: https://community.carbide3d.com/t/using-unsupported-tooling-in-carbide-create-roundover-cove-radius-bits/43723.

Ideally, it would be possible to simply identify such tooling using the tool # in the code used for normal toolshapes as above, but the most expedient option is to simply use a specific command for this. Since such tooling is quite limited in its use and normally only used at the surface of the part along an edge, this separation is easily justified.

Because it is necessary to divide the tooling into vertical slices and call the hull operation for each slice the tool definitions are tightly coupled with the module. Note that there are two
radiuscut different modules, the public-facing version which includes the tool number:

```
106 gcpscad module radiuscut(bx, by, bz, ex, ey, ez, radiustn) {
107 gcpscad     if (radiustn == 56125) {
108 gcpscad         radiuscuttool(bx, by, bz, ex, ey, ez, 0.508/2, 1.531);
109 gcpscad     } else if (radiustn == 56142) {
110 gcpscad         radiuscuttool(bx, by, bz, ex, ey, ez, 0.508/2, 2.921);
111 gcpscad     } else if (radiustn == 312) {
112 gcpscad         radiuscuttool(bx, by, bz, ex, ey, ez, 1.524/2, 3.175);
113 gcpscad     } else if (radiustn == 1570) {
114 gcpscad         radiuscuttool(bx, by, bz, ex, ey, ez, 0.507/2, 4.509);
115 gcpscad     }
116 gcpscad }
```

which then calls the actual `radiuscuttool` module passing in the tip radius and the radius of the rounding. Note that this module sets its quality relative to the value of `$fn`.

```
118 gcpscad module radiuscuttool(bx, by, bz, ex, ey, ez, tool_radius_tip,
              tool_radius_width) {
119 gcpscad n = 90 + $fn*3;
120 gcpscad step = 360/n;
121 gcpscad
122 gcpscad hull(){
123 gcpscad     translate([bx,by,bz])
124 gcpscad     cylinder(step,tool_radius_tip,tool_radius_tip);
125 gcpscad     translate([ex,ey,ez])
126 gcpscad     cylinder(step,tool_radius_tip,tool_radius_tip);
127 gcpscad }
128 gcpscad
129 gcpscad hull(){
130 gcpscad translate([bx,by,bz+tool_radius_width])
131 gcpscad cylinder(tool_radius_width*2,tool_radius_tip+tool_radius_width,
              tool_radius_tip+tool_radius_width);
132 gcpscad
133 gcpscad translate([ex,ey,ez+tool_radius_width])
134 gcpscad   cylinder(tool_radius_width*2,tool_radius_tip+tool_radius_width,
                tool_radius_tip+tool_radius_width);
135 gcpscad }
136 gcpscad
137 gcpscad for (i=[0:step:90]) {
138 gcpscad     angle = i;
139 gcpscad     dx = tool_radius_width*cos(angle);
140 gcpscad     dxx = tool_radius_width*cos(angle+step);
141 gcpscad     dzz = tool_radius_width*sin(angle);
142 gcpscad     dz = tool_radius_width*sin(angle+step);
143 gcpscad     dh = dz-dzz;
144 gcpscad     hull(){
145 gcpscad         translate([bx,by,bz+dz])
146 gcpscad             cylinder(dh,tool_radius_tip+tool_radius_width-dx,
                        tool_radius_tip+tool_radius_width-dxx);
```

```
147 gcpscad          translate([ex,ey,ez+dz])
148 gcpscad              cylinder(dh,tool_radius_tip+tool_radius_width-dx,
                             tool_radius_tip+tool_radius_width-dxx);
149 gcpscad          }
150 gcpscad      }
151 gcpscad }
```

2.2.3 tooldiameter

It will also be necessary to be able to provide the diameter of the current tool. Arguably, this would be much easier using an object-oriented programming style/dot notation.

One aspect of tool parameters which will need to be supported is shapes which create different profiles based on how deeply the tool is cutting into the surface of the material at a given point. To accommodate this, it will be necessary to either track the thickness of uncut material at any given point, or, to specify the depth of cut as a parameter which is what the initial version will implement.

tool diameter The public-facing OpenSCAD code simply calls the matching OpenSCAD module which wraps the Python code:

```
153 gcpscad function tool_diameter(td_tool, td_depth) = otool_diameter(td_tool,
              td_depth);
```

otool diameter the matching OpenSCAD function calls the Python function:

```
129 pyscad function otool_diameter(td_tool, td_depth) = ptool_diameter(td_tool
             , td_depth);
```

ptool diameter the Python code returns appropriate values based on the specified tool number and depth:

```
 62 gcpy def ptool_diameter(ptd_tool, ptd_depth):
 63 gcpy     if ptd_tool == 201:
 64 gcpy         return 6.35
 65 gcpy     if ptd_tool == 202:
 66 gcpy         if ptd_depth > 3.175:
 67 gcpy             return 6.35
 68 gcpy         else:
 69 gcpy             return 0
 70 gcpy     if ptd_tool == 102:
 71 gcpy         return 3.175
 72 gcpy     if ptd_tool == 101:
 73 gcpy         if ptd_depth > 1.5875:
 74 gcpy             return 3.175
 75 gcpy         else:
 76 gcpy             return 0
 77 gcpy     if ptd_tool == 301:
 78 gcpy         return 0
 79 gcpy     if ptd_tool == 302:
 80 gcpy         return 0
 81 gcpy     if ptd_tool == 390:
 82 gcpy         return 0
 83 gcpy     if ptd_tool == 375:
 84 gcpy         if ptd_depth < 6.35:
 85 gcpy             return 9.525
 86 gcpy         else:
 87 gcpy             return 6.35
 88 gcpy     if ptd_tool == 814:
 89 gcpy         if ptd_depth > 12.7:
 90 gcpy             return 6.35
 91 gcpy         else:
 92 gcpy             return 12.7
```

tool radius Since it is often necessary to utilise the radius of the tool, an additional command to return this value is worthwhile:

```
155 gcpscad function tool_radius(td_tool, td_depth) = otool_diameter(td_tool,
             td_depth)/2;
```

(Note that zero (0) values will need to be replaced with appropriate code.)

2.3 File Handling

For writing to files it will be necessary to have commands for each step of working with the files.

popengcodefile There is a separate function for each type of file, and for DXFs, there are multiple file

popendxffile
popendxlgblffile
popendxflgsqfile
popendxflgVfile
popendxfsmblfile

instances, one for each combination of different type and size of tool which it is expected a project will work with. Each such file will be suffixed with the tool number.

popendxfsmsqfile
popendxfsmVfile

```
gcpy def popengcodefile(fn):
gcpy     global f
gcpy     f = open(fn, "w")
gcpy
gcpy def popendxffile(fn):
gcpy     global dxf
gcpy     dxf = open(fn, "w")
gcpy
gcpy def popendxlgblffile(fn):
gcpy     global dxflgbl
gcpy     dxflgbl = open(fn, "w")
gcpy
gcpy def popendxflgsqfile(fn):
gcpy     global dxfldsq
gcpy     dxflgsq = open(fn, "w")
gcpy
gcpy def popendxflgVfile(fn):
gcpy     global dxflgV
gcpy     dxflgV = open(fn, "w")
gcpy
gcpy def popendxfsmblfile(fn):
gcpy     global dxfsmbl
gcpy     dxfsmbl = open(fn, "w")
gcpy
gcpy def popendxfsmsqfile(fn):
gcpy     global dxfsmsq
gcpy     dxfsmsq = open(fn, "w")
gcpy
gcpy def popendxfsmVfile(fn):
gcpy     global dxfsmV
gcpy     dxfsmV = open(fn, "w")
gcpy
gcpy def popendxfKHfile(fn):
gcpy     global dxfKH
gcpy     dxfKH = open(fn, "w")
gcpy
gcpy def popendxDTfile(fn):
gcpy     global dxfDT
gcpy     dxfDT = open(fn, "w")
```

oopengcodefile
oopendxffile

There will need to be matching OpenSCAD modules for the Python functions.

```
pyscad module oopengcodefile(fn) {
pyscad     popengcodefile(fn);
pyscad }
pyscad
pyscad module oopendxffile(fn) {
pyscad     echo(fn);
pyscad     popendxffile(fn);
pyscad }
pyscad
pyscad module oopendxflgblfile(fn) {
pyscad     popendxflgblfile(fn);
pyscad }
pyscad
pyscad module oopendxflgsqfile(fn) {
pyscad     popendxflgsqfile(fn);
pyscad }
pyscad
pyscad module oopendxflgVfile(fn) {
pyscad     popendxflgVfile(fn);
pyscad }
pyscad
pyscad module oopendxfsmblfile(fn) {
pyscad     popendxfsmblfile(fn);
pyscad }
pyscad
pyscad module oopendxfsmsqfile(fn) {
pyscad     echo(fn);
pyscad     popendxfsmsqfile(fn);
pyscad }
pyscad
pyscad module oopendxfsmVfile(fn) {
pyscad     popendxfsmVfile(fn);
pyscad }
```

```
164 pyscad
165 pyscad module oopendxfKHfile(fn) {
166 pyscad     popendxfKHfile(fn);
167 pyscad }
168 pyscad
169 pyscad module oopendxfDTfile(fn) {
170 pyscad     popendxfDTfile(fn);
171 pyscad }
```

opengcodefile Which has matching OpenSCAD commands:

```
157 gcpscad module opengcodefile(fn) {
158 gcpscad if (generategcode == true) {
159 gcpscad     oopengcodefile(fn);
160 gcpscad     echo(fn);
161 gcpscad     owritecomment(fn);
162 gcpscad     }
163 gcpscad }
```

For each DXF file, in addition to opening the file in the file system there will need to be a

opendxffile Preamble

```
165 gcpscad module opendxffile(fn) {
166 gcpscad   if (generatedxf == true) {
167 gcpscad       oopendxffile(str(fn,".dxf"));
168 gcpscad //     echo(fn);
169 gcpscad       dxfwriteone("0");
170 gcpscad       dxfwriteone("SECTION");
171 gcpscad       dxfwriteone("2");
172 gcpscad       dxfwriteone("ENTITIES");
173 gcpscad     if (large_ball_tool_no >  0) {    oopendxflgblfile(str(fn,".",
                    large_ball_tool_no,".dxf"));
174 gcpscad       dxfpreamble(large_ball_tool_no);
175 gcpscad     }
176 gcpscad     if (large_square_tool_no >  0) {    oopendxflgsqfile(str(fn
                    ,".",large_square_tool_no,".dxf"));
177 gcpscad       dxfpreamble(large_square_tool_no);
178 gcpscad     }
179 gcpscad     if (large_V_tool_no >  0) {    oopendxflgVfile(str(fn,".",
                    large_V_tool_no,".dxf"));
180 gcpscad       dxfpreamble(large_V_tool_no);
181 gcpscad     }
182 gcpscad     if (small_ball_tool_no >  0) { oopendxfsmblfile(str(fn,".",
                    small_ball_tool_no,".dxf"));
183 gcpscad       dxfpreamble(small_ball_tool_no);
184 gcpscad     }
185 gcpscad     if (small_square_tool_no >  0) {    oopendxfsmsqfile(str(fn
                    ,".",small_square_tool_no,".dxf"));
186 gcpscad //     echo(str("tool no",small_square_tool_no));
187 gcpscad       dxfpreamble(small_square_tool_no);
188 gcpscad     }
189 gcpscad     if (small_V_tool_no >  0) {    oopendxfsmVfile(str(fn,".",
                    small_V_tool_no,".dxf"));
190 gcpscad       dxfpreamble(small_V_tool_no);
191 gcpscad     }
192 gcpscad     if (KH_tool_no >  0) {    oopendxfKHfile(str(fn,".",KH_tool_no
                    ,".dxf"));
193 gcpscad       dxfpreamble(KH_tool_no);
194 gcpscad     }
195 gcpscad     if (DT_tool_no >  0) {    oopendxfDTfile(str(fn,".",DT_tool_no
                    ,".dxf"));
196 gcpscad       dxfpreamble(DT_tool_no);
197 gcpscad     }
198 gcpscad   }
199 gcpscad }
```

2.3.1 Writing to files

writedxf Once files have been opened they may be written to. There is a base command:

```
134 gcpy def writedxf(*arguments):
135 gcpy     line_to_write = ""
136 gcpy     for element in arguments:
137 gcpy        line_to_write += element
138 gcpy     dxf.write(line_to_write)
139 gcpy     dxf.write("\n")
```

and for each tool/size combination, an appropriate command:

writedxflgbl
- Ball nose, large (lgbl)

writedxfsmbl
- Ball nose, small (smbl)

writedxflgsq
- Square, large (lgsq)

writedxfsmsq
- Square, small (smsq)

writedxflgV
- V, large (lgV)

writedxfsmV
- V, small (smV)

writedxfKH
- Keyhole (KH)

writedxfDT
- Dovetail (DT)

```
141 gcpy def writedxflgbl(*arguments):
142 gcpy     line_to_write = ""
143 gcpy     for element in arguments:
144 gcpy         line_to_write += element
145 gcpy     dxflgbl.write(line_to_write)
146 gcpy     print(line_to_write)
147 gcpy     dxflgbl.write("\n")
148 gcpy
149 gcpy def writedxflgsq(*arguments):
150 gcpy     line_to_write = ""
151 gcpy     for element in arguments:
152 gcpy         line_to_write += element
153 gcpy     dxflgsq.write(line_to_write)
154 gcpy     print(line_to_write)
155 gcpy     dxflgsq.write("\n")
156 gcpy
157 gcpy def writedxflgV(*arguments):
158 gcpy     line_to_write = ""
159 gcpy     for element in arguments:
160 gcpy         line_to_write += element
161 gcpy     dxflgV.write(line_to_write)
162 gcpy     print(line_to_write)
163 gcpy     dxflgV.write("\n")
164 gcpy
165 gcpy def writedxfsmbl(*arguments):
166 gcpy     line_to_write = ""
167 gcpy     for element in arguments:
168 gcpy         line_to_write += element
169 gcpy     dxfsmbl.write(line_to_write)
170 gcpy     print(line_to_write)
171 gcpy     dxfsmbl.write("\n")
172 gcpy
173 gcpy def writedxfsmsq(*arguments):
174 gcpy     line_to_write = ""
175 gcpy     for element in arguments:
176 gcpy         line_to_write += element
177 gcpy     dxfsmsq.write(line_to_write)
178 gcpy     print(line_to_write)
179 gcpy     dxfsmsq.write("\n")
180 gcpy
181 gcpy def writedxfsmV(*arguments):
182 gcpy     line_to_write = ""
183 gcpy     for element in arguments:
184 gcpy         line_to_write += element
185 gcpy     dxfsmV.write(line_to_write)
186 gcpy     print(line_to_write)
187 gcpy     dxfsmV.write("\n")
188 gcpy
189 gcpy def writedxfKH(*arguments):
190 gcpy     line_to_write = ""
191 gcpy     for element in arguments:
192 gcpy         line_to_write += element
193 gcpy     dxfKH.write(line_to_write)
194 gcpy     print(line_to_write)
195 gcpy     dxfKH.write("\n")
196 gcpy
197 gcpy def writedxfDT(*arguments):
198 gcpy     line_to_write = ""
199 gcpy     for element in arguments:
```

```
200 gcpy          line_to_write += element
201 gcpy      dxfDT.write(line_to_write)
202 gcpy      print(line_to_write)
203 gcpy      dxfDT.write("\n")
```

owritecomment
dxfwriteone
dxfwritelgbl
dxfwritelgsq
dxfwritelgV
dxfwritesmbl
dxfwritesmsq
dxfwritesmV

Separate OpenSCAD modules will be used for either writing out comments in G-code (.nc) files or adding to a DXF file — for each different tool in a file there will be a matching module to write to it.

```
173 pyscad module owritecomment(comment) {
174 pyscad     writeln("(",comment,")");
175 pyscad }
176 pyscad
177 pyscad module dxfwriteone(first) {
178 pyscad     writedxf(first);
179 pyscad //    writeln(first);
180 pyscad //    echo(first);
181 pyscad }
182 pyscad
183 pyscad module dxfwritelgbl(first) {
184 pyscad     writedxflgbl(first);
185 pyscad }
186 pyscad
187 pyscad module dxfwritelgsq(first) {
188 pyscad     writedxflgsq(first);
189 pyscad }
190 pyscad
191 pyscad module dxfwritelgV(first) {
192 pyscad     writedxflgV(first);
193 pyscad }
194 pyscad
195 pyscad module dxfwritesmbl(first) {
196 pyscad     writedxfsmbl(first);
197 pyscad }
198 pyscad
199 pyscad module dxfwritesmsq(first) {
200 pyscad     writedxfsmsq(first);
201 pyscad }
202 pyscad
203 pyscad module dxfwritesmV(first) {
204 pyscad     writedxfsmV(first);
205 pyscad }
206 pyscad
207 pyscad module dxfwriteKH(first) {
208 pyscad     writedxfKH(first);
209 pyscad }
210 pyscad
211 pyscad module dxfwriteDT(first) {
212 pyscad     writedxfDT(first);
213 pyscad }
```

Since it is not convenient to stitch together and then write out multiple elements, the most expedient thing to do is to have discrete commands for each possible number of arguments, one through thirteen.

```
215 pyscad module owriteone(first) {
216 pyscad     writeln(first);
217 pyscad }
218 pyscad
219 pyscad module owritetwo(first, second) {
220 pyscad     writeln(first, second);
221 pyscad }
222 pyscad
223 pyscad module owritethree(first, second, third) {
224 pyscad     writeln(first, second, third);
225 pyscad }
226 pyscad
227 pyscad module owritefour(first, second, third, fourth) {
228 pyscad     writeln(first, second, third, fourth);
229 pyscad }
230 pyscad
231 pyscad module owritefive(first, second, third, fourth, fifth) {
232 pyscad     writeln(first, second, third, fourth, fifth);
233 pyscad }
234 pyscad
235 pyscad module owritesix(first, second, third, fourth, fifth, sixth) {
236 pyscad     writeln(first, second, third, fourth, fifth, sixth);
```

```
pyscad }
pyscad
pyscad module owriteseven(first, second, third, fourth, fifth, sixth,
    seventh) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh);
pyscad }
pyscad
pyscad module owriteeight(first, second, third, fourth, fifth, sixth,
    seventh,eighth) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth);
pyscad }
pyscad
pyscad module owritenine(first, second, third, fourth, fifth, sixth,
    seventh, eighth, ninth) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth, ninth);
pyscad }
pyscad
pyscad module owriteten(first, second, third, fourth, fifth, sixth,
    seventh, eighth, ninth, tenth) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth, ninth, tenth);
pyscad }
pyscad
pyscad module owriteeleven(first, second, third, fourth, fifth, sixth,
    seventh, eighth, ninth, tenth, eleventh) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth, ninth, tenth, eleventh);
pyscad }
pyscad
pyscad module owritetwelve(first, second, third, fourth, fifth, sixth,
    seventh, eighth, ninth, tenth, eleventh, twelfth) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth, ninth, tenth, eleventh, twelfth);
pyscad }
pyscad
pyscad module owritethirteen(first, second, third, fourth, fifth, sixth,
    seventh, eighth, ninth, tenth, eleventh, twelfth, thirteenth) {
pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
        eighth, ninth, tenth, eleventh, twelfth, thirteenth);
pyscad }
```

dxfwrite dxfpreamble

2.3.1.1 Beginning Writing to DXFs

The dxfwrite module requires that the tool number be passed in, and that value will be used to write out to the appropriate file with a series of `if` statements.

```
gcpscad module dxfwrite(tn,arg) {
gcpscad if (tn == large_ball_tool_no) {
gcpscad     dxfwritelgbl(arg);}
gcpscad if (tn == large_square_tool_no) {
gcpscad     dxfwritelgsq(arg);}
gcpscad if (tn == large_V_tool_no) {
gcpscad     dxfwritelgV(arg);}
gcpscad if (tn == small_ball_tool_no) {
gcpscad     dxfwritesmbl(arg);}
gcpscad if (tn == small_square_tool_no) {
gcpscad     dxfwritesmsq(arg);}
gcpscad if (tn == small_V_tool_no) {
gcpscad     dxfwritesmV(arg);}
gcpscad if (tn == DT_tool_no) {
gcpscad     dxfwriteDT(arg);}
gcpscad if (tn == KH_tool_no) {
gcpscad     dxfwriteKH(arg);}
gcpscad }
gcpscad
gcpscad module dxfpreamble(tn) {
gcpscad //    echo(str("dxfpreamble",small_square_tool_no));
gcpscad     dxfwrite(tn,"0");
gcpscad     dxfwrite(tn,"SECTION");
gcpscad     dxfwrite(tn,"2");
gcpscad     dxfwrite(tn,"ENTITIES");
gcpscad }
```

beginpolyline dxfbpl

2.3.1.2 DXF Lines and Arcs

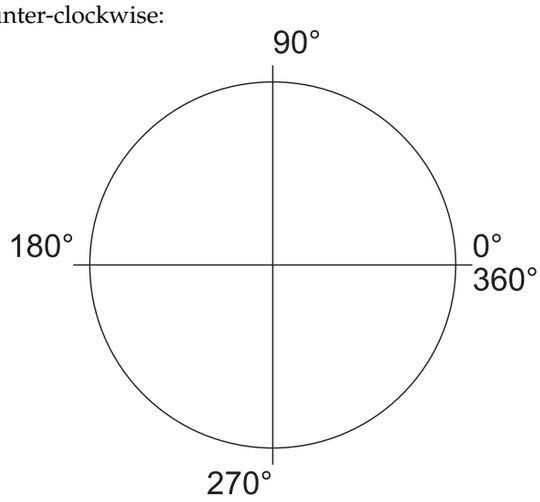
Similarly, each each element which may be written to a DXF file

will have a user module as well as an internal module which will be called by it so as to write to the file for the current tool.

There are two notable elements which may be written to a DXF:

- a line: LWPOLYLINE is one possible implementation
- ARC — a notable option would be for the arc to close on itself, creating a circle

DXF orders arcs counter-clockwise:



Note that arcs of greater than 90 degrees are not rendered accurately, so, for the sake of precision, they should be limited to a swing of 90 degrees or less. Further note that 4 arcs may be stitched together to make a circle:

```
dxfarc(small_square_tool_no,10,10,5,0,90);
dxfarc(small_square_tool_no,10,10,5,90,180);
dxfarc(small_square_tool_no,10,10,5,180,270);
dxfarc(small_square_tool_no,10,10,5,270,360);
```

A further refinement would be to connect multiple line segments/arcs into a larger polyline, but since most CAM tools implicitly join elements on import, that is not necessary.

There are three possible interactions for DXF elements and toolpaths:

- describe the motion of the tool
- define a perimeter of an area which will be cut by a tool
- define a centerpoint for a specialty toolpath such as Drill or Keyhhole

and it is possible that multiple such elements could be instantiated for a given toolpath.

```
228 gcpscad module dxfpl(tn,xbegin,ybegin,xend,yend) {
229 gcpscad     dxfwrite(tn,"0");
230 gcpscad     dxfwrite(tn,"LWPOLYLINE");
231 gcpscad     dxfwrite(tn,"90");
232 gcpscad     dxfwrite(tn,"2");
233 gcpscad     dxfwrite(tn,"70");
234 gcpscad     dxfwrite(tn,"0");
235 gcpscad     dxfwrite(tn,"43");
236 gcpscad     dxfwrite(tn,"0");
237 gcpscad     dxfwrite(tn,"10");
238 gcpscad     dxfwrite(tn,str(xbegin));
239 gcpscad     dxfwrite(tn,"20");
240 gcpscad     dxfwrite(tn,str(ybegin));
241 gcpscad     dxfwrite(tn,"10");
242 gcpscad     dxfwrite(tn,str(xend));
243 gcpscad     dxfwrite(tn,"20");
244 gcpscad     dxfwrite(tn,str(yend));
245 gcpscad }
246 gcpscad
247 gcpscad module dxfpolyline(tn,xbegin,ybegin,xend,yend) {
248 gcpscad if (generatedxf == true) {
249 gcpscad     dxfwriteone("0");
250 gcpscad     dxfwriteone("LWPOLYLINE");
251 gcpscad     dxfwriteone("90");
252 gcpscad     dxfwriteone("2");
253 gcpscad     dxfwriteone("70");
254 gcpscad     dxfwriteone("0");
255 gcpscad     dxfwriteone("43");
256 gcpscad     dxfwriteone("0");
257 gcpscad     dxfwriteone("10");
258 gcpscad     dxfwriteone(str(xbegin));
```

```
259 gcpscad     dxfwriteone("20");
260 gcpscad     dxfwriteone(str(ybegin));
261 gcpscad     dxfwriteone("10");
262 gcpscad     dxfwriteone(str(xend));
263 gcpscad     dxfwriteone("20");
264 gcpscad     dxfwriteone(str(yend));
265 gcpscad     dxfpl(tn,xbegin,ybegin,xend,yend);
266 gcpscad     }
267 gcpscad }
```

dxfa dxfarc

As for other files, we have two versions, one which accepts a `tn` (tool number), writing only to it, while a publicly facing version writes to the main DXF file *and* writes to the specific DXF file for the specified tool.

```
269 gcpscad module dxfa(tn,xcenter,ycenter,radius,anglebegin,endangle) {
270 gcpscad     dxfwrite(tn,"0");
271 gcpscad     dxfwrite(tn,"ARC");
272 gcpscad     dxfwrite(tn,"10");
273 gcpscad     dxfwrite(tn,str(xcenter));
274 gcpscad     dxfwrite(tn,"20");
275 gcpscad     dxfwrite(tn,str(ycenter));
276 gcpscad     dxfwrite(tn,"40");
277 gcpscad     dxfwrite(tn,str(radius));
278 gcpscad     dxfwrite(tn,"50");
279 gcpscad     dxfwrite(tn,str(anglebegin));
280 gcpscad     dxfwrite(tn,"51");
281 gcpscad     dxfwrite(tn,str(endangle));
282 gcpscad }
283 gcpscad
284 gcpscad module dxfarc(tn,xcenter,ycenter,radius,anglebegin,endangle) {
285 gcpscad if (generatedxf == true) {
286 gcpscad     dxfwriteone("0");
287 gcpscad     dxfwriteone("ARC");
288 gcpscad     dxfwriteone("10");
289 gcpscad     dxfwriteone(str(xcenter));
290 gcpscad     dxfwriteone("20");
291 gcpscad     dxfwriteone(str(ycenter));
292 gcpscad     dxfwriteone("40");
293 gcpscad     dxfwriteone(str(radius));
294 gcpscad     dxfwriteone("50");
295 gcpscad     dxfwriteone(str(anglebegin));
296 gcpscad     dxfwriteone("51");
297 gcpscad     dxfwriteone(str(endangle));
298 gcpscad     dxfa(tn,xcenter,ycenter,radius,anglebegin,endangle);
299 gcpscad     }
300 gcpscad }
```

The original implementation of polylines worked, but may be removed.

```
302 gcpscad module dxfbpl(tn,bx,by) {
303 gcpscad     dxfwrite(tn,"0");
304 gcpscad     dxfwrite(tn,"POLYLINE");
305 gcpscad     dxfwrite(tn,"8");
306 gcpscad     dxfwrite(tn,"default");
307 gcpscad     dxfwrite(tn,"66");
308 gcpscad     dxfwrite(tn,"1");
309 gcpscad     dxfwrite(tn,"70");
310 gcpscad     dxfwrite(tn,"0");
311 gcpscad     dxfwrite(tn,"0");
312 gcpscad     dxfwrite(tn,"VERTEX");
313 gcpscad     dxfwrite(tn,"8");
314 gcpscad     dxfwrite(tn,"default");
315 gcpscad     dxfwrite(tn,"70");
316 gcpscad     dxfwrite(tn,"32");
317 gcpscad     dxfwrite(tn,"10");
318 gcpscad     dxfwrite(tn,str(bx));
319 gcpscad     dxfwrite(tn,"20");
320 gcpscad     dxfwrite(tn,str(by));
321 gcpscad }
322 gcpscad
323 gcpscad module beginpolyline(bx,by,bz) {
324 gcpscad if (generatedxf == true) {
325 gcpscad     dxfwriteone("0");
326 gcpscad     dxfwriteone("POLYLINE");
327 gcpscad     dxfwriteone("8");
328 gcpscad     dxfwriteone("default");
329 gcpscad     dxfwriteone("66");
```

```
330 gcpscad      dxfwriteone("1");
331 gcpscad      dxfwriteone("70");
332 gcpscad      dxfwriteone("0");
333 gcpscad      dxfwriteone("0");
334 gcpscad      dxfwriteone("VERTEX");
335 gcpscad      dxfwriteone("8");
336 gcpscad      dxfwriteone("default");
337 gcpscad      dxfwriteone("70");
338 gcpscad      dxfwriteone("32");
339 gcpscad      dxfwriteone("10");
340 gcpscad      dxfwriteone(str(bx));
341 gcpscad      dxfwriteone("20");
342 gcpscad      dxfwriteone(str(by));
343 gcpscad      dxfbpl(current_tool(),bx,by);}
344 gcpscad }
345 gcpscad
346 gcpscad module dxfapl(tn,bx,by) {
347 gcpscad      dxfwriteone("0");
348 gcpscad      dxfwrite(tn,"VERTEX");
349 gcpscad      dxfwrite(tn,"8");
350 gcpscad      dxfwrite(tn,"default");
351 gcpscad      dxfwrite(tn,"70");
352 gcpscad      dxfwrite(tn,"32");
353 gcpscad      dxfwrite(tn,"10");
354 gcpscad      dxfwrite(tn,str(bx));
355 gcpscad      dxfwrite(tn,"20");
356 gcpscad      dxfwrite(tn,str(by));
357 gcpscad }
358 gcpscad
359 gcpscad module addpolyline(bx,by,bz) {
360 gcpscad if (generatedxf == true) {
361 gcpscad      dxfwrite(tn,"0");
362 gcpscad      dxfwriteone("VERTEX");
363 gcpscad      dxfwriteone("8");
364 gcpscad      dxfwriteone("default");
365 gcpscad      dxfwriteone("70");
366 gcpscad      dxfwriteone("32");
367 gcpscad      dxfwriteone("10");
368 gcpscad      dxfwriteone(str(bx));
369 gcpscad      dxfwriteone("20");
370 gcpscad      dxfwriteone(str(by));
371 gcpscad      dxfapl(current_tool(),bx,by);
372 gcpscad      }
373 gcpscad }
374 gcpscad
375 gcpscad module dxfcpl(tn) {
376 gcpscad      dxfwrite(tn,"0");
377 gcpscad      dxfwrite(tn,"SEQEND");
378 gcpscad }
379 gcpscad
380 gcpscad module closepolyline() {
381 gcpscad   if (generatedxf == true) {
382 gcpscad      dxfwriteone("0");
383 gcpscad      dxfwriteone("SEQEND");
384 gcpscad      dxfcpl(current_tool());
385 gcpscad   }
386 gcpscad }
387 gcpscad
388 gcpscad module writecomment(comment) {
389 gcpscad   if (generategcode == true) {
390 gcpscad      owritecomment(comment);
391 gcpscad   }
392 gcpscad }
```

pclosegcodefile
pclosedxffile

At the end of the project it will be necessary to close each file. In some instances it will be necessary to write additional information, depending on the file format.

```
205 gcpy def pclosegcodefile():
206 gcpy      f.close()
207 gcpy
208 gcpy def pclosedxffile():
209 gcpy      dxf.close()
210 gcpy
211 gcpy def pclosedxflgblfile():
212 gcpy      dxflgbl.close()
213 gcpy
214 gcpy def pclosedxflgsqfile():
215 gcpy      dxflgsq.close()
```

```
216 gcpy
217 gcpy def pclosedxflgVfile():
218 gcpy     dxflgV.close()
219 gcpy
220 gcpy def pclosedxfsmblfile():
221 gcpy     dxfsmbl.close()
222 gcpy
223 gcpy def pclosedxfsmsqfile():
224 gcpy     dxfsmsq.close()
225 gcpy
226 gcpy def pclosedxfsmVfile():
227 gcpy     dxfsmV.close()
228 gcpy
229 gcpy def pclosedxfDTfile():
230 gcpy     dxfDT.close()
231 gcpy
232 gcpy def pclosedxfKHfile():
233 gcpy     dxfKH.close()
```

oclosegcodefile
oclosedxffile
oclosedxflgblfile

```
267 pyscad module oclosegcodefile() {
268 pyscad     pclosegcodefile();
269 pyscad }
270 pyscad
271 pyscad module oclosedxffile() {
272 pyscad     pclosedxffile();
273 pyscad }
274 pyscad
275 pyscad module oclosedxflgblfile() {
276 pyscad     pclosedxflgblfile();
277 pyscad }
278 pyscad
279 pyscad module oclosedxflgsqfile() {
280 pyscad     pclosedxflgsqfile();
281 pyscad }
282 pyscad
283 pyscad module oclosedxflgVfile() {
284 pyscad     pclosedxflgVfile();
285 pyscad }
286 pyscad
287 pyscad module oclosedxfsmblfile() {
288 pyscad     pclosedxfsmblfile();
289 pyscad }
290 pyscad
291 pyscad module oclosedxfsmsqfile() {
292 pyscad     pclosedxfsmsqfile();
293 pyscad }
294 pyscad
295 pyscad module oclosedxfsmVfile() {
296 pyscad     pclosedxfsmVfile();
297 pyscad }
298 pyscad
299 pyscad module oclosedxfDTfile() {
300 pyscad     pclosedxfDTfile();
301 pyscad }
302 pyscad
303 pyscad module oclosedxfKHfile() {
304 pyscad     pclosedxfKHfile();
305 pyscad }
```

closegcodefile
dxfpostamble
closedxffile

```
394 gcpscad module closegcodefile() {
395 gcpscad   if (generategcode == true) {
396 gcpscad     owriteone("M05");
397 gcpscad     owriteone("M02");
398 gcpscad     oclosegcodefile();
399 gcpscad   }
400 gcpscad }
401 gcpscad
402 gcpscad module dxfpostamble(arg) {
403 gcpscad     dxfwrite(arg,"0");
404 gcpscad     dxfwrite(arg,"ENDSEC");
405 gcpscad     dxfwrite(arg,"0");
406 gcpscad     dxfwrite(arg,"EOF");
407 gcpscad }
```

```
408 gcpscad
409 gcpscad module closedxffile() {
410 gcpscad   if (generatedxf == true) {
411 gcpscad     dxfwriteone("0");
412 gcpscad     dxfwriteone("ENDSEC");
413 gcpscad     dxfwriteone("0");
414 gcpscad     dxfwriteone("EOF");
415 gcpscad     oclosedxffile();
416 gcpscad     echo("CLOSING");
417 gcpscad     if (large_ball_tool_no >  0) {    dxfpostamble(
                    large_ball_tool_no);
418 gcpscad       oclosedxflgblfile();
419 gcpscad     }
420 gcpscad     if (large_square_tool_no >  0) {    dxfpostamble(
                    large_square_tool_no);
421 gcpscad       oclosedxflgsqfile();
422 gcpscad     }
423 gcpscad     if (large_V_tool_no >  0) {    dxfpostamble(large_V_tool_no);
424 gcpscad       oclosedxflgVfile();
425 gcpscad     }
426 gcpscad     if (small_ball_tool_no >  0) {    dxfpostamble(
                    small_ball_tool_no);
427 gcpscad       oclosedxfsmblfile();
428 gcpscad     }
429 gcpscad     if (small_square_tool_no >  0) {    dxfpostamble(
                    small_square_tool_no);
430 gcpscad       oclosedxfsmsqfile();
431 gcpscad     }
432 gcpscad     if (small_V_tool_no >  0) {    dxfpostamble(small_V_tool_no);
433 gcpscad       oclosedxfsmVfile();
434 gcpscad     }
435 gcpscad     if (DT_tool_no >  0) {    dxfpostamble(DT_tool_no);
436 gcpscad       oclosedxfDTfile();
437 gcpscad     }
438 gcpscad     if (KH_tool_no >  0) {    dxfpostamble(KH_tool_no);
439 gcpscad       oclosedxfKHfile();
440 gcpscad     }
441 gcpscad   }
442 gcpscad }
```

2.4 Movement and Cutting

otm ocut orapid

With all the scaffolding in place, it is possible to model tool movement and cutting and to write out files which represent the desired machine motions.

```
444 gcpscad module otm(ex, ey, ez, r,g,b) {
445 gcpscad color([r,g,b]) hull(){
446 gcpscad     translate([xpos(), ypos(), zpos()]){
447 gcpscad       select_tool(current_tool());
448 gcpscad     }
449 gcpscad     translate([ex, ey, ez]){
450 gcpscad       select_tool(current_tool());
451 gcpscad     }
452 gcpscad   }
453 gcpscad oset(ex, ey, ez);
454 gcpscad }
455 gcpscad
456 gcpscad module ocut(ex, ey, ez) {
457 gcpscad   //color([0.2,1,0.2]) hull(){
458 gcpscad   otm(ex, ey, ez, 0.2,1,0.2);
459 gcpscad }
460 gcpscad
461 gcpscad module orapid(ex, ey, ez) {
462 gcpscad   //color([0.93,0,0]) hull(){
463 gcpscad   otm(ex, ey, ez, 0.93,0,0);
464 gcpscad }
465 gcpscad
466 gcpscad module rapidbx(bx, by, bz, ex, ey, ez) {
467 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
468 gcpscad   if (generategcode == true) {
469 gcpscad     writecomment("rapid");
470 gcpscad     owritesix("G0 X",str(ex)," Y", str(ey), " Z", str(ez));
471 gcpscad   }
472 gcpscad     orapid(ex, ey, ez);
473 gcpscad }
474 gcpscad
475 gcpscad module rapid(ex, ey, ez) {
```

```
476 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
477 gcpscad   if (generategcode == true) {
478 gcpscad       writecomment("rapid");
479 gcpscad       owritesix("G0 X",str(ex)," Y", str(ey), " Z", str(ez));
480 gcpscad   }
481 gcpscad   orapid(ex, ey, ez);
482 gcpscad }
483 gcpscad
484 gcpscad module movetosafez() {
485 gcpscad   //this should be move to retract height
486 gcpscad   if (generategcode == true) {
487 gcpscad       writecomment("Move to safe Z to avoid workholding");
488 gcpscad       owriteone("G53G0Z-5.000");
489 gcpscad   }
490 gcpscad   orapid(getxpos(), getypos(), retractheight+55);
491 gcpscad }
492 gcpscad
493 gcpscad module begintoolpath(bx,by,bz) {
494 gcpscad   if (generategcode == true) {
495 gcpscad     writecomment("PREPOSITION FOR RAPID PLUNGE");
496 gcpscad     owritefour("G0X", str(bx), "Y",str(by));
497 gcpscad     owritetwo("Z", str(bz));
498 gcpscad   }
499 gcpscad   orapid(bx,by,bz);
500 gcpscad }
501 gcpscad
502 gcpscad module movetosafeheight() {
503 gcpscad   //this should be move to machine position
504 gcpscad   if (generategcode == true) {
505 gcpscad   //    writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
506 gcpscad   //G1Z24.663F381.0 ,"F",str(plunge)
507 gcpscad     if (zeroheight == "Top") {
508 gcpscad       owritetwo("Z",str(retractheight));
509 gcpscad     }
510 gcpscad   }
511 gcpscad     orapid(getxpos(), getypos(), retractheight+55);
512 gcpscad }
513 gcpscad
514 gcpscad module cutoneaxis_setfeed(axis,depth,feed) {
515 gcpscad   if (generategcode == true) {
516 gcpscad   //    writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
517 gcpscad   //G1Z24.663F381.0 ,"F",str(plunge) G1Z7.612F381.0
518 gcpscad     if (zeroheight == "Top") {
519 gcpscad       owritefive("G1",axis,str(depth),"F",str(feed));
520 gcpscad     }
521 gcpscad   }
522 gcpscad   if (axis == "X") {setxpos(depth);
523 gcpscad     ocut(depth, getypos(), getzpos());}
524 gcpscad     if (axis == "Y") {setypos(depth);
525 gcpscad       ocut(getxpos(), depth, getzpos());
526 gcpscad     }
527 gcpscad       if (axis == "Z") {setzpos(depth);
528 gcpscad         ocut(getxpos(), getypos(), depth);
529 gcpscad       }
530 gcpscad }
531 gcpscad
532 gcpscad module cut(ex, ey, ez) {
533 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
534 gcpscad   if (generategcode == true) {
535 gcpscad      owritesix("G1 X",str(ex)," Y", str(ey), " Z", str(ez));
536 gcpscad   }
537 gcpscad   //if (generatesvg == true) {
538 gcpscad   //    owritesix("G1 X",str(ex)," Y", str(ey), " Z", str(ez));
539 gcpscad   //    orapid(getxpos(), getypos(), retractheight+5);
540 gcpscad   //    writesvgline(getxpos(),getypos(),ex,ey);
541 gcpscad   //}
542 gcpscad   ocut(ex, ey, ez);
543 gcpscad }
544 gcpscad
545 gcpscad module cutwithfeed(ex, ey, ez, feed) {
546 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
547 gcpscad   if (generategcode == true) {
548 gcpscad   //    writecomment("rapid");
549 gcpscad     owriteeight("G1 X",str(ex)," Y", str(ey), " Z", str(ez),"F",str
                (feed));
550 gcpscad   }
551 gcpscad   ocut(ex, ey, ez);
552 gcpscad }
```

```
553 gcpscad
554 gcpscad module endtoolpath() {
555 gcpscad   if (generategcode == true) {
556 gcpscad   //Z31.750
557 gcpscad   //     owriteone("G53G0Z-5.000");
558 gcpscad     owritetwo("Z",str(retractheight));
559 gcpscad   }
560 gcpscad   orapid(getxpos(),getypos(),retractheight);
561 gcpscad }
```

3 cut2Dshapes and expansion

New features may be tried out in a file such as `cut2Dshapes.scad` insofar as the file structures will allow (tool definitions for example will need to consolidated in 2.2.1) which will need to be included in the projects which will make use of said features until such time as they are added into the main `gcodepreview.scad` file.

A basic requirement will be to define two-dimensional regions so as to cut them out. Two different geometric treatments will be necessary: modeling the geometry which defines the region to be cut out (output as a DXF); and modeling the movement of the tool, the toolpath which will be used in creating the 3D model and outputting the G-code.

In the TUG presentation/paper: http://tug.org/TUGboat/tb40-2/tb125adams-3d.pdf a list of 2D shapes was put forward — which of these will need to be created, or if some more general solution will be put forward is uncertain. For the time being, shapes will be implemented on an as-needed basis, as modified by the interaction with the requirements of toolpaths.

The program Carbide Create has toolpath types and options which are as follows:

- Contour — No Offset — the default, this is already supported in the existing code
- Contour — Outside Offset
- Contour — Inside Offset
- (Rectangular) Pocket — such toolpaths/geometry should include the rounding of the tool at the corners
- Drill — note that this is implemented as the plunging of a tool centered on a circle and normally that circle is the same diameter as the tool which is used.
- Keyhole — also beginning from a circle, a nice feature for this would be to include/model the areas which should be cleared for the sake of reducing wear on the tool and ensuring chip clearance

Some further considerations:

- relationship of geometry to toolpath — arguably there should be an option for each toolpath (we will use Carbide Create as a reference implementation) which is to be supported. Note that there are several possibilities: modeling the tool movement, describing the outline which the tool will cut, modeling a reference shape for the toolpath
- tool geometry — it should be possible to include support for specialty tooling such as dove-tail cutters and to get an accurate 3D model, esp. for tooling which undercuts since they cannot be modeled in Carbide Create.
- feeds and speeds — if outputting G-code it would be nice to be able to import feeds and speeds from external files such as the .csv files used for user tool libraries in Carbide Create
- Starting and Max Depth — are there CAD programs which will make use of Z-axis information in a DXF? — would it be possible/necessary to further differentiate the DXF geometry? (currently written out separately for each toolpath in addition to one combined file)

3.1 Arcs for toolpaths and DXFs

A further consideration here is that G-code supports arcs in addition to the lines and polylines already implemented.

Implementing arcs wants at least the following options for quadrant and direction:

- cutarcNWCW — cut the upper-left quadrant of a circle moving clockwise
- cutarcNWCC — upper-left quadrant counter-clockwise
- cutarcNECW
- cutarcNECC
- cutarcSECW

- 0
  - circle
  - ellipse (oval) (requires some sort of non-arc curve)
    - egg-shaped
  - annulus (one circle within another, forming a ring)
  - superellipse (see astroid below)
- 1
  - cone with rounded end (arc)see also "sector" under 3 below
- 2
  - semicircle/circular/half-circle segment (arc and a straight line); see also sector below
  - arch—curve possibly smoothly joining a pair of straight lines with a flat bottom
  - lens/vesica piscis (two convex curves)
  - lune/crescent (one convex, one concave curve)
  - heart (two curves)
  - tomoe (comma shape)—non-arc curves
- 3
  - triangle
    - equilateral
    - isosceles
    - right triangle
    - scalene
  - (circular) sector (two straight edges, one convex arc)
    - quadrant (90°)
    - sextants (60°)
    - octants (45°)
  - deltoid curve (three concave arcs)
  - Reuleaux triangle (three convex arcs)
  - arbelos (one convex, two concave arcs)
  - two straight edges, one concave arc—an example is the hyperbolic sector[1]
  - two convex, one concave arc
- 4
  - rectangle (including square)
  - parallelogram
  - rhombus
  - trapezoid/trapezium
  - kite
  - ring/annulus segment (straight line, concave arc, straight line, convex arc)
  - astroid (four concave arcs)
  - salinon (four semicircles)
  - three straight lines and one concave arc

Is the list of shapes for which there are not widely known names interesting for its lack of notoriety?

- two straight edges, one concave arcoddly, an asymmetric form (hyperbolic sector) has a name, but not the symmetrical—while the colloquial/prosaic arrowhead was considered, it was rejected as being better applied to the shape be low. (Its also the shape used for the spaceship in the game Asteroids (or Hyperspace), but that is potentially confusing with astroid.) At the conference, Prof. Knuth suggested dart as a suitable term.
- two convex, one concave arcwith the above named, the term arrowhead is freed up to use as the name for this shape.
- three straight lines and one concave arc.

The first in particular is sorely needed for this project (its the result of inscribing a circle in a square or other regular geometric shape). Do these shapes have names in any other languages which might be used instead?

- cutarcSECC
- cutarcNECW
- cutarcNECC
- cutcircleCW — while it wont matter for generating a DXF, when G-code is implemented direction of cut will be a consideration for that
- cutcircleCCdxf

It will be necessary to have two separate representations of arcs — the DXF may be easily and directly supported with a single command, but representing the matching tool movement in OpenSCAD will require a series of short line movements which approximate the arc. At this time, the current version of Carbide Create only imports circles in DXF as curves, any other example is converted into polylines — unfortunately, the implementation of this is not such as would allow directly matching that representation. A work-around to import a DXF as curves is to convert the arc into a reasonable number of line segments so as to approximate the arc.

Note that there are the following representations/interfaces for representing an arc:

- G-code — G2 (clockwise) and G3 (counter-clockwise) arcs may be specified, and since the endpoint is the positional requirement, it is most likely best to use the offset to the center (I and J), rather than the radius parameter (K) `G2/3 ...`
- DXF — `dxfarc(tn,xcenter,ycenter,radius,anglebegin,endangle)`
- approximation of arc using lines (OpenSCAD) — note that this may also be used in DXF so as to sidestep the question of how many line segments there would be for a given arc representation

Cutting the quadrant arcs will greatly simplify the calculation and interface for the modules. A full set of 8 will be necessary, then circles may either be stitched together manually or a pair of modules made for them.

At this time, despite what the module names imply (`cutarcNWCWdxf`, &c.), only cutting and DXF generation is supported. Adding support for G-code will be done at a later time. Since these modules will ultimately support G-code, the interface will assume the stored `xpos` and `ypos` as the origin. Parameters which will need to be passed in are:

- `tn`
- `ex`
- `ey`
- `ez` — allowing a different Z position will make possible threading and similar helical toolpaths
- `xcenter` — the center position will be specified as an absolute position which will require calculating the offset when it is used for G-code's `IJ`, for which `xctr/yctr` are suggested
- `ycenter`
- `radius` — while this could be calculated, passing it in as a parameter is both convenient and acts as a check on the other parameters

Adding a simple loop to handle the processing of the `cut()` toolpaths affords a single point of control for adding additional features such as allowing the depth to vary as one cuts along an arc (two when the need to have a version which steps down):

```
1 cut2D //!OpenSCAD
2 cut2D
3 cut2D module arcloop(barc,earc, xcenter, ycenter, radius) {
4 cut2D   for (i = [barc : abs(1) : earc]) {
5 cut2D         cut(xcenter + radius * cos(i),
6 cut2D         ycenter + radius * sin(i),
7 cut2D         getzpos()-(gettzpos())
8 cut2D         );
9 cut2D     setxpos(xcenter + radius * cos(i));
10 cut2D    setypos(ycenter + radius * sin(i));
11 cut2D  }
12 cut2D }
13 cut2D
14 cut2D module narcloop(barc,earc, xcenter, ycenter, radius) {
15 cut2D   for (i = [barc : -1 : earc]) {
16 cut2D         cut(xcenter + radius * cos(i),
17 cut2D         ycenter + radius * sin(i),
18 cut2D         getzpos()-(gettzpos())
19 cut2D         );
20 cut2D     setxpos(xcenter + radius * cos(i));
21 cut2D     setypos(ycenter + radius * sin(i));
22 cut2D   }
23 cut2D }
```

The various textual versions are quite obvious:

```
25 cut2D module cutarcNECCdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
26 cut2D   dxfarc(tn,xcenter,ycenter,radius,0,90);
27 cut2D   settzpos((getzpos()-ez)/90);
28 cut2D     arcloop(1,90, xcenter, ycenter, radius);
29 cut2D }
30 cut2D
31 cut2D module cutarcNWCCdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
32 cut2D   dxfarc(tn,xcenter,ycenter,radius,90,180);
33 cut2D   settzpos((getzpos()-ez)/90);
34 cut2D     arcloop(91,180, xcenter, ycenter, radius);
35 cut2D }
36 cut2D
37 cut2D module cutarcSWCCdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
38 cut2D   dxfarc(tn,xcenter,ycenter,radius,180,270);
39 cut2D   settzpos((getzpos()-ez)/90);
40 cut2D     arcloop(181,270, xcenter, ycenter, radius);
41 cut2D }
42 cut2D
43 cut2D module cutarcSECCdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
44 cut2D   dxfarc(tn,xcenter,ycenter,radius,270,360);
45 cut2D   settzpos((getzpos()-ez)/90);
46 cut2D     arcloop(271,360, xcenter, ycenter, radius);
47 cut2D }
48 cut2D
49 cut2D module cutarcNECWdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
50 cut2D   dxfarc(tn,xcenter,ycenter,radius,0,90);
51 cut2D   settzpos((getzpos()-ez)/90);
52 cut2D     narcloop(89,0, xcenter, ycenter, radius);
53 cut2D }
54 cut2D
55 cut2D module cutarcSECWdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
56 cut2D   dxfarc(tn,xcenter,ycenter,radius,270,360);
57 cut2D   settzpos((getzpos()-ez)/90);
58 cut2D     narcloop(359,270, xcenter, ycenter, radius);
59 cut2D }
60 cut2D
61 cut2D module cutarcSWCWdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
62 cut2D   dxfarc(tn,xcenter,ycenter,radius,180,270);
63 cut2D   settzpos((getzpos()-ez)/90);
64 cut2D     narcloop(269,180, xcenter, ycenter, radius);
65 cut2D }
66 cut2D
67 cut2D module cutarcNWCWdxf(tn, ex, ey, ez, xcenter, ycenter, radius) {
68 cut2D   dxfarc(tn,xcenter,ycenter,radius,90,180);
69 cut2D   settzpos((getzpos()-ez)/90);
70 cut2D     narcloop(179,90, xcenter, ycenter, radius);
71 cut2D }
```

3.2 Keyhole toolpath and undercut tooling

The most topologically interesting toolpath is "Keyhole" — where other toolpaths have a direct correspondence between the associated geometry and the area cut, that Keyhole toolpaths may be used with tooling which undercuts will result in the creation of two different physical physical regions: the visible surface matching the union of the tool perimeter at the entry point and the linear movement of the shaft and the larger region of the tool perimeter at the depth which the tool is plunged to and moved along.

Tooling for such toolpaths is defined at paragraph 2.2.1.2

Due to the possibility of rotation, for the in-between positions there are more cases than one would think for each quadrant there are the following possibilities:

- one node on the clockwise side is outside of the quadrant
- two nodes on the clockwise side are outside of the quadrant
- all nodes are w/in the quadrant
- one node on the counter-clockwise side is outside of the quadrant
- two nodes on the counter-clockwise side are outside of the quadrant

Supporting all of these would require trigonometric comparisons in the If else blocks, so only the 4 quadrants, N, W, S, and E will be supported in the initial version. This will be done by wrapping the command with a version which only accepts those options:

```
65 cut2D module keyhole_toolpath(kh_tool_no, kh_start_depth, kh_max_depth,
       kht_angle, kh_length) {
66 cut2D if (kht_angle == "N") {
67 cut2D   keyhole_toolpath_degrees(kh_tool_no, kh_start_depth, kh_max_depth
           , 90, kh_length);
68 cut2D    } else if (kht_angle == "S") {
69 cut2D   keyhole_toolpath_degrees(kh_tool_no, kh_start_depth, kh_max_depth
           , 270, kh_length);
70 cut2D    } else if (kht_angle == "E") {
71 cut2D   keyhole_toolpath_degrees(kh_tool_no, kh_start_depth, kh_max_depth
           , 0, kh_length);
72 cut2D    } else if (kht_angle == "W") {
73 cut2D   keyhole_toolpath_degrees(kh_tool_no, kh_start_depth, kh_max_depth
           , 180, kh_length);
74 cut2D    }
75 cut2D }
```

The original version of the command is renamed and called by that. Note that code is still present for the partial calculation of one quadrant (for the case of all nodes within the quadrant).

The first task is to place a circle at the origin which is invariant of angle:

```
77 cut2D module keyhole_toolpath_degrees(kh_tool_no, kh_start_depth,
       kh_max_depth, kh_angle, kh_length) {
78 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2,0,90);
79 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2,90,180);
80 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2,180,270);
81 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2,270,360);
```

Then it will be necessary to test for each possible case in a series of If Else blocks:

```
83 cut2D   if (kh_angle == 0) {
84 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,180,270);
85 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,90,180);
86 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,asin((tool_diameter(KH_tool_no, (kh_max_depth
       +4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth))/2)),90);
87 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,270,360-asin((tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
       )/2)));
88 cut2D dxfarc(KH_tool_no,getxpos()+kh_length,getypos(),tool_diameter(
       KH_tool_no, (kh_max_depth+4.36))/2,0,90);
89 cut2D dxfarc(KH_tool_no,getxpos()+kh_length,getypos(),tool_diameter(
       KH_tool_no, (kh_max_depth+4.36))/2,270,360);
90 cut2D dxfpolyline(KH_tool_no, getxpos()+sqrt((tool_diameter(KH_tool_no, (
       kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
       +4.36))/2)^2), getypos()+tool_diameter(KH_tool_no, (kh_max_depth
       +4.36))/2, getxpos()+kh_length, getypos()+tool_diameter(
       KH_tool_no, (kh_max_depth+4.36))/2);
91 cut2D dxfpolyline(KH_tool_no, getxpos()+sqrt((tool_diameter(KH_tool_no, (
       kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
       +4.36))/2)^2), getypos()-tool_diameter(KH_tool_no, (kh_max_depth
       +4.36))/2, getxpos()+kh_length, getypos()-tool_diameter(
       KH_tool_no, (kh_max_depth+4.36))/2);
92 cut2D dxfpolyline(KH_tool_no,getxpos(),getypos(),getxpos()+kh_length,
       getypos());
93 cut2D cutwithfeed(getxpos()+kh_length,getypos(),-kh_max_depth,feed);
94 cut2D setxpos(getxpos()-kh_length);
95 cut2D   } else if (kh_angle > 0 && kh_angle < 90) {
96 cut2D echo(kh_angle);
97 cut2D   dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,90+kh_angle,180+kh_angle);
98 cut2D   dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,180+kh_angle,270+kh_angle);
99 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,kh_angle+asin((tool_diameter(KH_tool_no, (
       kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
       )/2)),90+kh_angle);
100 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
       kh_max_depth))/2,270+kh_angle,360+kh_angle-asin((tool_diameter(
```

```
            KH_tool_no, (kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (
            kh_max_depth))/2)));
101 cut2D dxfarc(KH_tool_no,
102 cut2D   getxpos()+(kh_length*cos(kh_angle)),
103 cut2D   getypos()+(kh_length*sin(kh_angle)),tool_diameter(KH_tool_no, (
              kh_max_depth+4.36))/2,0+kh_angle,90+kh_angle);
104 cut2D dxfarc(KH_tool_no,getxpos()+(kh_length*cos(kh_angle)),getypos()+(
            kh_length*sin(kh_angle)),tool_diameter(KH_tool_no, (kh_max_depth
            +4.36))/2,270+kh_angle,360+kh_angle);
105 cut2D dxfpolyline(KH_tool_no,
106 cut2D  getxpos()+tool_diameter(KH_tool_no, (kh_max_depth))/2*cos(kh_angle
             +asin((tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)/(
             tool_diameter(KH_tool_no, (kh_max_depth))/2))),
107 cut2D  getypos()+tool_diameter(KH_tool_no, (kh_max_depth))/2*sin(kh_angle
             +asin((tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)/(
             tool_diameter(KH_tool_no, (kh_max_depth))/2))),
108 cut2D  getxpos()+(kh_length*cos(kh_angle))-((tool_diameter(KH_tool_no, (
             kh_max_depth+4.36))/2)*sin(kh_angle)),
109 cut2D  getypos()+(kh_length*sin(kh_angle))+((tool_diameter(KH_tool_no, (
             kh_max_depth+4.36))/2)*cos(kh_angle)));
110 cut2D echo("a",tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2);
111 cut2D echo("c",tool_diameter(KH_tool_no, (kh_max_depth))/2);
112 cut2D echo("Aangle",asin((tool_diameter(KH_tool_no, (kh_max_depth+4.36))
            /2)/(tool_diameter(KH_tool_no, (kh_max_depth))/2)));
113 cut2D echo(kh_angle);
114 cut2D  cutwithfeed(getxpos()+(kh_length*cos(kh_angle)),getypos()+(
             kh_length*sin(kh_angle)),-kh_max_depth,feed);
115 cut2D  setxpos(getxpos()-(kh_length*cos(kh_angle)));
116 cut2D  setypos(getypos()-(kh_length*sin(kh_angle)));
117 cut2D   } else if (kh_angle == 90) {
118 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,180,270);
119 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,270,360);
120 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,0,90-asin(
121 cut2D     (tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)/(
                tool_diameter(KH_tool_no, (kh_max_depth))/2)));
122 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,90+asin(
123 cut2D     (tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)/(
                tool_diameter(KH_tool_no, (kh_max_depth))/2)),180);
124 cut2D  dxfpolyline(KH_tool_no,getxpos(),getypos(),getxpos(),getypos()+
             kh_length);
125 cut2D dxfarc(KH_tool_no,getxpos(),getypos()+kh_length,tool_diameter(
            KH_tool_no, (kh_max_depth+4.36))/2,0,90);
126 cut2D dxfarc(KH_tool_no,getxpos(),getypos()+kh_length,tool_diameter(
            KH_tool_no, (kh_max_depth+4.36))/2,90,180);
127 cut2D  dxfpolyline(KH_tool_no,getxpos()+tool_diameter(KH_tool_no, (
             kh_max_depth+4.36))/2,getypos()+sqrt((tool_diameter(KH_tool_no,
              (kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
             +4.36))/2)^2),getxpos()+tool_diameter(KH_tool_no, (kh_max_depth
             +4.36))/2,getypos()+kh_length);
128 cut2D  dxfpolyline(KH_tool_no,getxpos()-tool_diameter(KH_tool_no, (
             kh_max_depth+4.36))/2,getypos()+sqrt((tool_diameter(KH_tool_no,
              (kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
             +4.36))/2)^2),getxpos()-tool_diameter(KH_tool_no, (kh_max_depth
             +4.36))/2,getypos()+kh_length);
129 cut2D  cutwithfeed(getxpos(),getypos()+kh_length,-kh_max_depth,feed);
130 cut2D  setypos(getypos()-kh_length);
131 cut2D   } else if (kh_angle == 180) {
132 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,0,90);
133 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,270,360);
134 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,90,180-asin((tool_diameter(KH_tool_no, (
            kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
            )/2)));
135 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
            kh_max_depth))/2,180+asin((tool_diameter(KH_tool_no, (
            kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
            )/2)),270);
136 cut2D dxfarc(KH_tool_no,getxpos()-kh_length,getypos(),tool_diameter(
            KH_tool_no, (kh_max_depth+4.36))/2,90,180);
137 cut2D dxfarc(KH_tool_no,getxpos()-kh_length,getypos(),tool_diameter(
            KH_tool_no, (kh_max_depth+4.36))/2,180,270);
138 cut2D dxfpolyline(KH_tool_no,
```

```
139 cut2D  getxpos()-sqrt((tool_diameter(KH_tool_no, (kh_max_depth))/2)^2-(
               tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)^2),
140 cut2D  getypos()+tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2,
141 cut2D  getxpos()-kh_length,
142 cut2D  getypos()+tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2);
143 cut2D dxfpolyline(KH_tool_no,
144 cut2D  getxpos()-sqrt((tool_diameter(KH_tool_no, (kh_max_depth))/2)^2-(
               tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2)^2),
145 cut2D  getypos()-tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2,
146 cut2D  getxpos()-kh_length,
147 cut2D  getypos()-tool_diameter(KH_tool_no, (kh_max_depth+4.36))/2);
148 cut2D  dxfpolyline(KH_tool_no,getxpos(),getypos(),getxpos()-kh_length,
               getypos());
149 cut2D  cutwithfeed(getxpos()-kh_length,getypos(),-kh_max_depth,feed);
150 cut2D  setxpos(getxpos()+kh_length);
151 cut2D   } else if (kh_angle == 270) {
152 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,0,90);
153 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,90,180);
154 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,270+asin((tool_diameter(KH_tool_no, (
           kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
           )/2)),360);
155 cut2D dxfarc(KH_tool_no,getxpos(),getypos(),tool_diameter(KH_tool_no, (
           kh_max_depth))/2,180, 270-asin((tool_diameter(KH_tool_no, (
           kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_no, (kh_max_depth)
           )/2)));
156 cut2D dxfarc(KH_tool_no,getxpos(),getypos()-kh_length,tool_diameter(
           KH_tool_no, (kh_max_depth+4.36))/2,180,270);
157 cut2D dxfarc(KH_tool_no,getxpos(),getypos()-kh_length,tool_diameter(
           KH_tool_no, (kh_max_depth+4.36))/2,270,360);
158 cut2D  dxfpolyline(KH_tool_no,getxpos()+tool_diameter(KH_tool_no, (
            kh_max_depth+4.36))/2,getypos()-sqrt((tool_diameter(KH_tool_no,
             (kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
            +4.36))/2)^2),getxpos()+tool_diameter(KH_tool_no, (kh_max_depth
            +4.36))/2,getypos()-kh_length);
159 cut2D  dxfpolyline(KH_tool_no,getxpos()-tool_diameter(KH_tool_no, (
            kh_max_depth+4.36))/2,getypos()-sqrt((tool_diameter(KH_tool_no,
             (kh_max_depth))/2)^2-(tool_diameter(KH_tool_no, (kh_max_depth
            +4.36))/2)^2),getxpos()-tool_diameter(KH_tool_no, (kh_max_depth
            +4.36))/2,getypos()-kh_length);
160 cut2D  dxfpolyline(KH_tool_no,getxpos(),getypos(),getxpos(),getypos()-
           kh_length);
161 cut2D  cutwithfeed(getxpos(),getypos()-kh_length,-kh_max_depth,feed);
162 cut2D  setypos(getypos()+kh_length);
163 cut2D   }
164 cut2D }
```

3.3 Shapes and tool movement

The majority of commands will be more general, focusing on tooling which is generally supported by this library, moving in lines and arcs so as to describe shapes which lend themselves to representation with those tool and which match up with both toolpaths and supported geometry in Carbide Create, and the usage requirements of the typical user.

3.3.1 Generalized commands and cuts

The first consideration is a naming convention which will allow a generalized set of associated commands to be defined. The initial version will only create OpenSCAD commands for 3D modeling and write out matching DXF files. At a later time this will be extended with G-code support.

3.3.1.1 begincutdxf The first command will need to allow the machine to rapid to the beginning point of the cut and then rapid down to the surface of the stock, and then plunge down to the depth of the cut. The implementation will need to allow for a hook where the Depth per Pass is applied to the plunge operation so that multiple passes are made.

begincutdxf The first module will ensure that the tool is safely up above the stock and will rapid to the position specified at the retract height (moving to that position as an initial step, then will `cutwithfeed` to the specified position at the specified feed rate. Despite `dxf` being included in the filename no change is made to the dxf file at this time, this simply indicates that this file is preparatory to `continuecutdxf`.

```
174 cut2D module begincutdxf(rh, ex, ey, ez, fr) {
175 cut2D   rapid(getxpos(),getypos(),rh);
176 cut2D   cutwithfeed(ex,ey,ez,fr);
```

```
177 cut2D }
```

```
179 cut2D module continuecutdxf(ex, ey, ez, fr) {
180 cut2D   cutwithfeed(ex,ey,ez,fr);
181 cut2D }
```

3.3.1.2 Rectangles Cutting rectangles while writing out their perimeter in the DXF files (so that they may be assigned a matching toolpath in a traditional CAM program upon import) will require the origin coordinates, height and width and depth of the pocket, and the tool # so that the corners may have a radius equal to the tool which is used.

A further consideration is that cut orientation as an option should be accounted for if writing out G-code, as well as stepover, and the nature of initial entry (whether ramping in would be implemented, and if so at what angle). Advanced toolpath strategies such as trochoidal milling could also be implemented.

cutrectangledxf The initial version would work as a beginning point for vertical cutting if the `hull()` operation was removed and the loop was uncommented:

```
183 cut2D module cutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn)
        {//passes
184 cut2D   movetosafez();
185 cut2D   hull(){
186 cut2D     //  for (i = [0 : abs(1) : passes]) {
187 cut2D     //      rapid(bx+tool_radius(rtn)+i*(rwidth-tool_diameter(
            current_tool()))/passes,bx+tool_radius(rtn),1);
188 cut2D     //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter
            (current_tool()))/passes,by+tool_radius(rtn),bz-rdepth,feed)
            ;
189 cut2D     //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter
            (current_tool()))/passes,by+rheight-tool_radius(rtn),bz-
            rdepth,feed);
190 cut2D
191 cut2D     cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,
            feed);
192 cut2D     cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-
            rdepth,feed);
193 cut2D     cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(
            rtn),bz-rdepth,feed);
194 cut2D     cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-
            rdepth,feed);
195 cut2D   }
196 cut2D   //dxfarc(tn,xcenter,ycenter,radius,anglebegin,endangle)
197 cut2D   dxfarc(rtn,bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(
            rtn),180,270);
198 cut2D   //dxfpolyline(tn,xbegin,ybegin,xend,yend)
199 cut2D   dxfpolyline(rtn,bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(
            rtn));
200 cut2D   dxfarc(rtn,bx+tool_radius(rtn),by+rheight-tool_radius(rtn),
            tool_radius(rtn),90,180);
201 cut2D   dxfpolyline(rtn,bx+tool_radius(rtn),by+rheight,bx+rwidth-
            tool_radius(rtn),by+rheight);
202 cut2D   dxfarc(rtn,bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn)
            ,tool_radius(rtn),0,90);
203 cut2D   dxfpolyline(rtn,bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,
            by+tool_radius(rtn));
204 cut2D   dxfarc(rtn,bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),
            tool_radius(rtn),270,360);
205 cut2D   dxfpolyline(rtn,bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn)
            ,by);
206 cut2D }
```

cutrectangleoutlinedxf Cutting the outline of a rounded rectangle is a simplification of the above:

```
208 cut2D module cutrectangleoutlinedxf(bx, by, bz, rwidth, rheight, rdepth,
        rtn) {//passes
209 cut2D   movetosafez();
210 cut2D   cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,
            feed);
211 cut2D   cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-
            rdepth,feed);
212 cut2D   cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn
            ),bz-rdepth,feed);
213 cut2D   cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-
            rdepth,feed);
```

```
214 cut2D   dxfarc(rtn,bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(
                rtn),180,270);
215 cut2D   dxfpolyline(rtn,bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(
                rtn));
216 cut2D   dxfarc(rtn,bx+tool_radius(rtn),by+rheight-tool_radius(rtn),
                tool_radius(rtn),90,180);
217 cut2D   dxfpolyline(rtn,bx+tool_radius(rtn),by+rheight,bx+rwidth-
                tool_radius(rtn),by+rheight);
218 cut2D   dxfarc(rtn,bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn)
                ,tool_radius(rtn),0,90);
219 cut2D   dxfpolyline(rtn,bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,
                by+tool_radius(rtn));
220 cut2D   dxfarc(rtn,bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),
                tool_radius(rtn),270,360);
221 cut2D   dxfpolyline(rtn,bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn)
                ,by);
222 cut2D }
```

the initial section performs the cutting operation for the 3D preview while the latter section writes out the outline to the DXF files.

rectangleoutlinedxf Which suggests a further command for simply adding a rectangle which could be used in Job Setup to add the stock outline to DXFs to assist in registration of jobs with multiple tools:

```
224 cut2D module rectangleoutlinedxf(bx, by, bz, rwidth, rheight, rtn) {
225 cut2D   dxfpolyline(rtn,bx,by,bx,by+rheight);
226 cut2D   dxfpolyline(rtn,bx,by+rheight,bx+rwidth,by+rheight);
227 cut2D   dxfpolyline(rtn,bx+rwidth,by+rheight,bx+rwidth,by);
228 cut2D   dxfpolyline(rtn,bx+rwidth,by,bx,by);
229 cut2D }
```

cutoutrectangledxf For a cutting version of that file it would make sense to cut to the outside:

```
231 cut2D module cutoutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn)
        {
232 cut2D   movetosafez();
233 cut2D   cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,
                feed);
234 cut2D   cutwithfeed(bx+rwidth+tool_radius(rtn),by-tool_radius(rtn),bz-
                rdepth,feed);
235 cut2D   cutwithfeed(bx+rwidth+tool_radius(rtn),by+rheight+tool_radius(rtn
                ),bz-rdepth,feed);
236 cut2D   cutwithfeed(bx-tool_radius(rtn),by+rheight+tool_radius(rtn),bz-
                rdepth,feed);
237 cut2D   cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,
                feed);
238 cut2D   dxfpolyline(rtn,bx,by,bx,by+rheight);
239 cut2D   dxfpolyline(rtn,bx,by+rheight,bx+rwidth,by+rheight);
240 cut2D   dxfpolyline(rtn,bx+rwidth,by+rheight,bx+rwidth,by);
241 cut2D   dxfpolyline(rtn,bx+rwidth,by,bx,by);
242 cut2D }
```

4 gcodepreviewtemplate.scad

The commands may then be put together using a template which will ensure that the various files are used/included as necessary, that files are opened before being written to, and that they are closed at the end.

```
1 gcptmpl //!OpenSCAD
2 gcptmpl
3 gcptmpl use <gcodepreview.py>;
4 gcptmpl use <pygcodepreview.scad>;
5 gcptmpl include <gcodepreview.scad>;
6 gcptmpl
7 gcptmpl $fa = 2;
8 gcptmpl $fs = 0.125;
9 gcptmpl
10 gcptmpl /* [Export] */
11 gcptmpl Base_filename = "export";
12 gcptmpl
13 gcptmpl /* [Export] */
14 gcptmpl generatedxf = true;
15 gcptmpl
16 gcptmpl /* [Export] */
17 gcptmpl generategcode = true;
```

```
18 gcptmpl
19 gcptmpl ///* [Export] */
20 gcptmpl //generatesvg = false;
21 gcptmpl
22 gcptmpl /* [CAM] */
23 gcptmpl toolradius = 1.5875;
24 gcptmpl
25 gcptmpl /* [CAM] */
26 gcptmpl large_ball_tool_no = 0; // [0:0,111:111,101:101,202:202]
27 gcptmpl
28 gcptmpl /* [CAM] */
29 gcptmpl large_square_tool_no = 0; // [0:0,112:112,102:102,201:201]
30 gcptmpl
31 gcptmpl /* [CAM] */
32 gcptmpl large_V_tool_no = 0; // [0:0,301:301,690:690]
33 gcptmpl
34 gcptmpl /* [CAM] */
35 gcptmpl small_ball_tool_no = 0; // [0:0,121:121,111:111,101:101]
36 gcptmpl
37 gcptmpl /* [CAM] */
38 gcptmpl small_square_tool_no = 102; // [0:0,122:122,112:112,102:102]
39 gcptmpl
40 gcptmpl /* [CAM] */
41 gcptmpl small_V_tool_no = 0; // [0:0,390:390,301:301]
42 gcptmpl
43 gcptmpl /* [CAM] */
44 gcptmpl KH_tool_no = 0; // [0:0,375:375]
45 gcptmpl
46 gcptmpl /* [CAM] */
47 gcptmpl DT_tool_no = 0; // [0:0,814:814]
48 gcptmpl
49 gcptmpl /* [Feeds and Speeds] */
50 gcptmpl plunge = 100;
51 gcptmpl
52 gcptmpl /* [Feeds and Speeds] */
53 gcptmpl feed = 400;
54 gcptmpl
55 gcptmpl /* [Feeds and Speeds] */
56 gcptmpl speed = 16000;
57 gcptmpl
58 gcptmpl /* [Feeds and Speeds] */
59 gcptmpl square_ratio = 1.0; // [0.25:2]
60 gcptmpl
61 gcptmpl /* [Feeds and Speeds] */
62 gcptmpl small_V_ratio = 0.75; // [0.25:2]
63 gcptmpl
64 gcptmpl /* [Feeds and Speeds] */
65 gcptmpl large_V_ratio = 0.875; // [0.25:2]
66 gcptmpl
67 gcptmpl /* [Stock] */
68 gcptmpl stocklength = 219;
69 gcptmpl
70 gcptmpl /* [Stock] */
71 gcptmpl stockwidth = 150;
72 gcptmpl
73 gcptmpl /* [Stock] */
74 gcptmpl stockthickness = 8.35;
75 gcptmpl
76 gcptmpl /* [Stock] */
77 gcptmpl zeroheight = "Top"; // [Top, Bottom]
78 gcptmpl
79 gcptmpl /* [Stock] */
80 gcptmpl stockorigin = "Center"; // [Lower-Left, Center-Left, Top-Left,
          Center]
81 gcptmpl
82 gcptmpl /* [Stock] */
83 gcptmpl retractheight = 9;
84 gcptmpl
85 gcptmpl filename_gcode = str(Base_filename, ".nc");
86 gcptmpl filename_dxf = str(Base_filename);
87 gcptmpl //filename_svg = str(Base_filename, ".svg");
88 gcptmpl
89 gcptmpl opengcodefile(filename_gcode);
90 gcptmpl opendxffile(filename_dxf);
91 gcptmpl
92 gcptmpl difference() {
93 gcptmpl setupstock(stocklength, stockwidth, stockthickness, zeroheight,
          stockorigin);
```

```
94 gcptmpl
95 gcptmpl movetosafez();
96 gcptmpl
97 gcptmpl toolchange(small_square_tool_no,speed * square_ratio);
98 gcptmpl
99 gcptmpl begintoolpath(0,0,0.25);
100 gcptmpl beginpolyline(0,0,0.25);
101 gcptmpl
102 gcptmpl cutoneaxis_setfeed("Z",0,plunge*square_ratio);
103 gcptmpl
104 gcptmpl cutwithfeed(stocklength/2,stockwidth/2,-stockthickness,feed);
105 gcptmpl addpolyline(stocklength/2,stockwidth/2,-stockthickness);
106 gcptmpl
107 gcptmpl endtoolpath();
108 gcptmpl closepolyline();
109 gcptmpl }
110 gcptmpl
111 gcptmpl closegcodefile();
112 gcptmpl closedxffile();
```

4.1 Future

4.1.1 Images

Would it be helpful to re-create code algorithms/sections using OpenSCAD Graph Editor so as to represent/illustrate the program?

4.1.2 Generalized DXF creation

Generalize the creation of DXFs based on the projection() of a toolpath? (Note that openpython-scad has a specific feature to export a given 3D object as a DXF.)

4.1.3 Import G-code

Use a tool to read in a G-code file, then create a 3D model which would serve as a preview of the cut?

- https://stackoverflow.com/questions/34638372/simple-python-program-to-read-gcode-file
- https://pypi.org/project/gcodeparser/
- https://github.com/fragmuffin/pygcode/wiki

4.1.4 Bézier curves in 2 dimensions

Take a Bézier curve definition and approximate it as arcs and write them into a DXF?
https://pomax.github.io/bezierinfo/
c.f., https://linuxcnc.org/docs/html/gcode/g-code.html#gcode:g5

4.1.5 Bézier curves in 3 dimensions

One question is how many Bézier curves would it be necessary to have to define a surface in 3 dimensions. Attributes for this which are desirable/necessary:

- concise — a given Bézier curve should be represented by just the point coordinates, so two on-curve points, two off-curve points, each with a pair of coordinates
- For a given shape/region it will need to be possible to have a matching definition exactly match up with it so that one could piece together a larger more complex shape from smaller/simpler regions
- similarly it will be necessary for it to be possible to sub-divide a defined region — for example it should be possible if one had 4 adjacent regions, then the four quadrants at the intersection of the four regions could be used to construct a new region — is it possible to derive a new Bézier curve from half of two other curves?

For the three planes:

- XY
- XZ
- ZY

it should be possible to have three Bézier curves (left-most/right-most or front-back or top/bottom for two, and a mid-line for the third), so a region which can be so represented would be definable by:

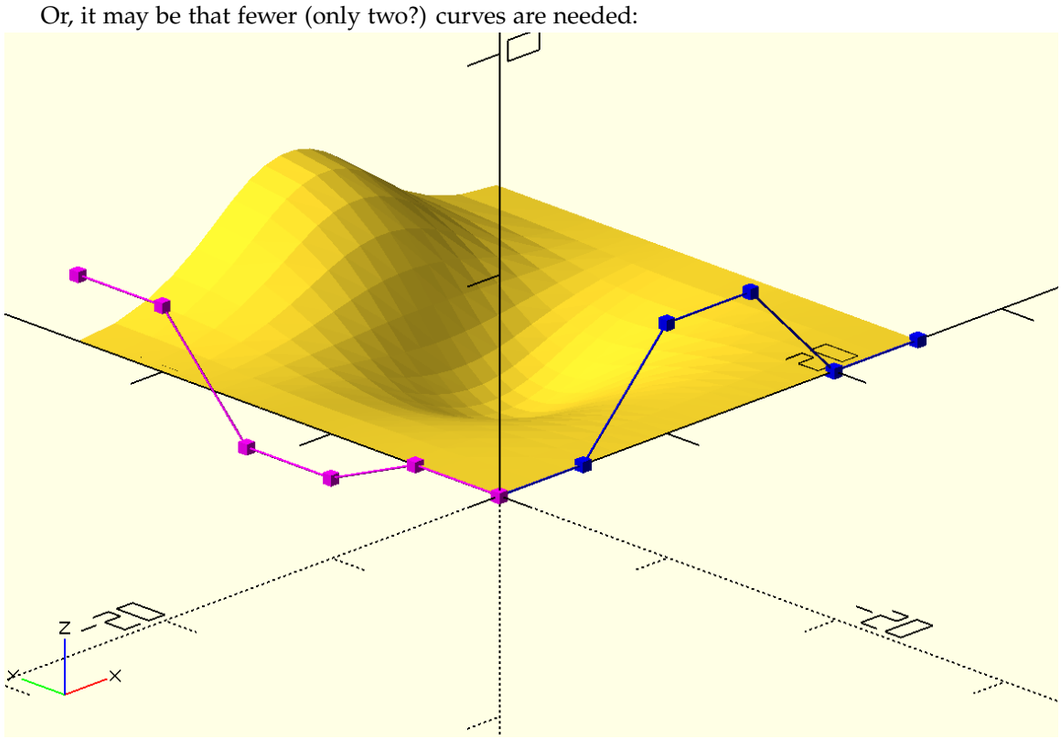
```
3 planes * 3 Béziers * (2 on-curve + 2 off-curve points) == 36 coordinate pairs
```

which is a marked contrast to representations such as:

https://github.com/DavidPhillipOster/Teapot

and regions which could not be so represented could be sub-divided until the representation is workable.

Or, it may be that fewer (only two?) curves are needed:



https://pages.mtu.edu/~shene/COURSES/cs3621/NOTES/notes.html

5 Other Resources

Holidays are from https://nationaltoday.com/

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