The gcodepreview OpenSCAD library*

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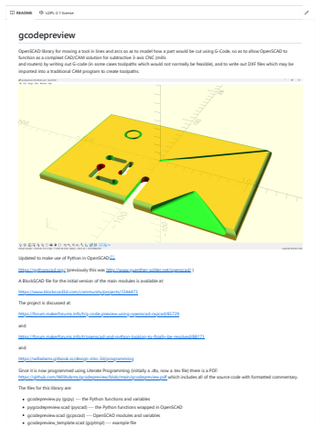
Abstract

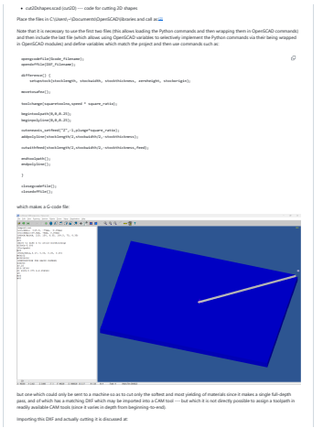
The gcodepreview library allows using OpenPythonSCAD to move a tool in lines and arcs and output dxf and G-code files so as to work as a CAD/CAM program for CNC.

Contents

*This file (gcodepreview) has version number v0.71, last revised 2024/11/29.

1 readme.md





```
1 rdme # gcodepreview
2 rdme
3 rdme OpenPythonSCAD library for moving a tool in lines and arcs so as to
       model how a part would be cut using G-Code, so as to allow
      OpenPythonSCAD to function as a compleat CAD/CAM solution for
      subtractive 3-axis CNC (mills and routers) by writing out G-code
       in addition to 3D modeling (in some cases toolpaths which would
       not normally be feasible), and to write out DXF files which may
       be imported into a traditional CAM program to create toolpaths.
4 rdme
5 rdme ![OpenSCAD Cut Joinery Module](https://raw.githubusercontent.com/
      WillAdams/gcodepreview/main/gcodepreview_unittests.png?raw=true)
6 rdme
7 rdme Updated to make use of Python in OpenSCAD:[^rapcad]
8 rdme
9 rdme [^rapcad]: Previous versions had used RapCAD, so as to take
      advantage of the writeln command, which has since been re-
      written in Python.
10 rdme
11 rdme https://pythonscad.org/ (previously this was http://www.guenther-
      sohler.net/openscad/ )
12 rdme
13 rdme A BlockSCAD file for the initial version of the
14 rdme main modules is available at:
15 rdme
16 rdme https://www.blockscad3d.com/community/projects/1244473
17 rdme
18 rdme The project is discussed at:
19 rdme
20 rdme https://forum.makerforums.info/t/g-code-preview-using-openscad-
      rapcad/85729
21 rdme
22 rdme and
23 rdme
24 rdme https://forum.makerforums.info/t/openscad-and-python-looking-to-
      finally-be-resolved/88171
25 rdme
26 rdme and
27 rdme
28 rdme https://willadams.gitbook.io/design-into-3d/programming
29 rdme
30 rdme Since it is now programmed using Literate Programming (initially a
       .dtx, now a .tex file) there is a PDF: https://github.com/
      WillAdams/gcodepreview/blob/main/gcodepreview.pdf which includes
       all of the source code with formatted commentary.
31 rdme
32 rdme The files for this library are:
33 rdme
34 rdme  - gcodepreview.py (gcpy) --- the Python functions and variables
35 rdme  - pygcodepreview.scad (pyscad) --- the Python functions wrapped in
          OpenSCAD
36 rdme  - gcodepreview.scad (gcpscad) --- OpenSCAD modules and variables
37 rdme  - gcodepreview_template.scad (gcptmpl) --- example file
38 rdme  - cut2Dshapes.scad (cut2D) --- code for cutting 2D shapes
39 rdme
40 rdme If using from OpenPythonSCAD, place the files in C:\Users\\\~\
      Documents\OpenSCAD\libraries and call as:[^libraries]
41 rdme
```

```
42 rdme [^libraries]: C:\Users\\\~\Documents\RapCAD\libraries is deprecated
       since RapCAD is no longer needed since Python is now used for
      writing out files)
43 rdme
44 rdme     use <gcodepreview.py>;
45 rdme     use <pygcodepreview.scad>;
46 rdme     include <gcodepreview.scad>;
47 rdme
48 rdme Note that it is necessary to use the first two files (this allows
      loading the Python commands and then wrapping them in OpenSCAD
      commands) and then include the last file (which allows using
      OpenSCAD variables to selectively implement the Python commands
      via their being wrapped in OpenSCAD modules) and define
      variables which match the project and then use commands such as:
49 rdme
50 rdme     opengcodefile(Gcode_filename);
51 rdme     opendxffile(DXF_filename);
52 rdme
53 rdme     difference() {
54 rdme         setupstock(stockXwidth, stockYheight, stockZthickness,
                 zeroheight, stockzero);
55 rdme
56 rdme     movetosafez();
57 rdme
58 rdme     toolchange(squaretoolnum,speed * square_ratio);
59 rdme
60 rdme     begintoolpath(0,0,0.25);
61 rdme     beginpolyline(0,0,0.25);
62 rdme
63 rdme     cutoneaxis_setfeed("Z",-1,plunge*square_ratio);
64 rdme     addpolyline(stockXwidth/2,stockYheight/2,-stockZthickness);
65 rdme
66 rdme     cutwithfeed(stockXwidth/2,stockYheight/2,-stockZthickness,feed)
             ;
67 rdme
68 rdme     endtoolpath();
69 rdme     endpolyline();
70 rdme
71 rdme     }
72 rdme
73 rdme     closegcodefile();
74 rdme     closedxffile();
75 rdme
76 rdme which makes a G-code file:
77 rdme
78 rdme ![OpenSCAD template G-code file](https://raw.githubusercontent.com/
      WillAdams/gcodepreview/main/gcodepreview_template.png?raw=true)
79 rdme
80 rdme but one which could only be sent to a machine so as to cut only the
       softest and most yielding of materials since it makes a single
      full-depth pass, and of which has a matching DXF which may be
      imported into a CAM tool --- but which it is not directly
      possible to assign a toolpath in readily available CAM tools (
      since it varies in depth from beginning-to-end).
81 rdme
82 rdme Importing this DXF and actually cutting it is discussed at:
83 rdme
84 rdme https://forum.makerforums.info/t/rewriting-gcodepreview-with-python
      /88617/14
85 rdme
86 rdme Alternately, gcodepreview.py may be placed in a Python library
      location and used directly from Python --- note that it may
      become possible to use it from a "normal" Python when generating
       only DXFs.
87 rdme
88 rdme Tool numbers match those of tooling sold by Carbide 3D (ob. discl.,
       I work for them).
89 rdme
90 rdme Comments are included in the G-code to match those expected by
      CutViewer.
91 rdme
92 rdme A complete example file is: gcodepreview_template.scad Note that a
      Python template has since been developed as well, allowing usage
       without OpenSCAD code, and another example is
      openscad_gcodepreview_cutjoinery.tres.scad which is made from an
       OpenSCAD Graph Editor file:
93 rdme
94 rdme ![OpenSCAD Graph Editor Cut Joinery File](https://raw.
```

```
          githubusercontent.com/WillAdams/gcodepreview/main/
          OSGE_cutjoinery.png?raw=true)
 95 rdme
 96 rdme Version 0.1 supports setting up stock, origin, rapid positioning,
          making cuts, and writing out matching G-code, and creating a DXF
           with polylines.
 97 rdme
 98 rdme Added features since initial upload:
 99 rdme
100 rdme  - endpolyline(); --- this command allows ending one polyline so as
             to allow multiple lines in a DXF
101 rdme  - separate dxf files are written out for each tool where tool is
             ball/square/V and small/large (10/31/23)
102 rdme  - re-writing as a Literate Program using the LaTeX package docmfp
             (begun 4/12/24)
103 rdme  - support for additional tooling shapes such as dovetail and
             keyhole tools
104 rdme
105 rdme Version 0.2 adds support for arcs
106 rdme
107 rdme  - DXF: support for arcs (which may be used to make circles)
             (6/1/24)
108 rdme  - Specialty toolpaths such as Keyhole which may be used for
             dovetail as well as keyhole cutters
109 rdme
110 rdme Version 0.3
111 rdme
112 rdme  - Support for curves along the 3rd dimension
113 rdme  - support for roundover tooling
114 rdme
115 rdme Version 0.4
116 rdme
117 rdme  - Rewrite using literati documentclass, suppression of SVG code
118 rdme  - dxfrectangle (without G-code support)
119 rdme
120 rdme Version 0.5
121 rdme
122 rdme  - more shapes
123 rdme  - consolidate rectangles, arcs, and circles in gcodepreview.scad
124 rdme
125 rdme Version 0.6
126 rdme
127 rdme  - notes on modules
128 rdme  - change file for setupstock
129 rdme
130 rdme Version 0.61
131 rdme
132 rdme  - validate all code so that it runs without errors from sample
133 rdme  - NEW: Note that this version is archived as gcodepreview-
             openscad_0_6.tex and the matching PDF is available as well
134 rdme
135 rdme  Version 0.7
136 rdme
137 rdme   - re-write completely in Python --- note that it is possible to
              use from within OpenPythonSCAD and an OpenSCAD wrapper is not
              functional at this time --- note that the OpenSCAD wrapper
              will need to be rewritten
138 rdme
139 rdme Possible future improvements:
140 rdme
141 rdme  - rewrite OpenSCAD wrapper
142 rdme  - support for additional tooling shapes (bowl bits with flat
             bottom, tapered ball nose, lollipop cutters)
143 rdme  - create a single line font for use where text is wanted
144 rdme
145 rdme Note for G-code generation that it is up to the user to implement
          Depth per Pass so as to not take a single full-depth pass.
          Working from a DXF of course allows one to off-load such
          considerations to a specialized CAM tool.
146 rdme
147 rdme Deprecated feature:
148 rdme
149 rdme  - exporting SVGs --- coordinate system differences between
             OpenSCAD/DXFs and SVGs would require managing the inversion of
             the coordinate system (using METAPOST, which shares the same
             orientation and which can write out SVGs may be used for future
              versions)
```

2 gcodepreview

This library for OpenPythonSCAD 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 DXF and/or G-code files (as opposed to the normal technique of rendering to a 3D model and writing out an STL or STEP or other model format). There are multiple modes for this, doing so requires up to three files:

- A Python file: gcodepreview.py (`gcpy`) — this has variables in the traditional sense which may be used for tracking machine position and so forth. Note that where it is placed/loaded from will depend on whether it is imported into a Python file:
  `import gcodepreview_standalone as gcp`
  or used in an OpenSCAD file:
  `use <gcodepreview.py>`
  with additional OpenSCAD modules which allow accessing it
- An OpenSCAD file: pygcodepreview.scad (`pyscad`) — which wraps the Python code in OpenSCAD (note that it too is included by `use <pygcodepreview.scad>`)
- An OpenSCAD file: gcodepreview.scad (`gcpscad`) — which uses the other two files and which is `include`d allowing it to access OpenSCAD variables for branching

Note that this architecture requires that many OpenSCAD modules are essentially "Dispatchers" which pass information from one aspect of the environment to another.

2.1 gcodepreviewtemplate

The various commands are shown all together in templates so as to provide examples of usage, and to ensure that the various files are used/included as necessary, all variables are set up with the correct names, and that files are opened before being written to, and that each is closed at the end.

Note that while the template files seem overly verbose, they specifically incorporate variables for each tool shape, possibly in two different sizes, and a feed rate parameter or ratio for each, which may be used (by setting a tool #) or ignored (by leaving the variable at zero (0).

It should be that this section is all the documentation which some users will need (and arguably is still too much). The balance of the document after this section shows all the code and implementation details.

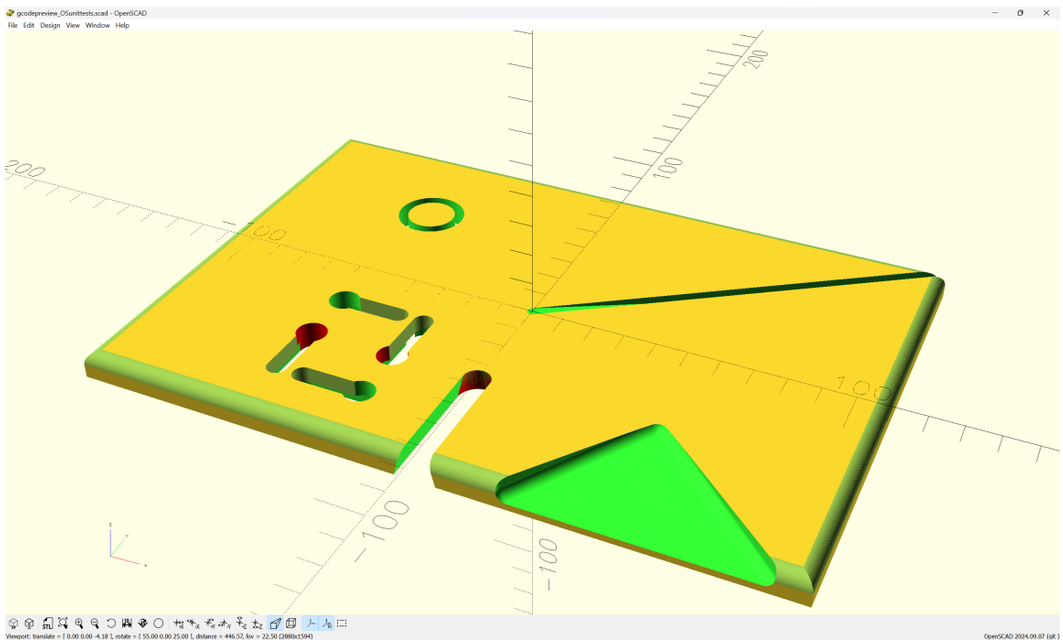
2.1.1 gcodepreviewtemplate.scad

```
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 /* [Stock] */
11 gcptmpl stockXwidth = 219;
12 gcptmpl /* [Stock] */
13 gcptmpl stockYheight = 150;
14 gcptmpl /* [Stock] */
15 gcptmpl stockZthickness = 8.35;
16 gcptmpl /* [Stock] */
17 gcptmpl zeroheight = "Top"; // [Top, Bottom]
18 gcptmpl /* [Stock] */
19 gcptmpl stockzero = "Center"; // [Lower-Left, Center-Left, Top-Left, Center
       ]
20 gcptmpl /* [Stock] */
21 gcptmpl retractheight = 9;
22 gcptmpl
23 gcptmpl /* [Export] */
24 gcptmpl Base_filename = "export";
25 gcptmpl /* [Export] */
26 gcptmpl generatedxf = true;
27 gcptmpl /* [Export] */
28 gcptmpl generategcode = true;
29 gcptmpl ///* [Export] */
30 gcptmpl //generatesvg = false;
31 gcptmpl
32 gcptmpl /* [CAM] */
33 gcptmpl toolradius = 1.5875;
34 gcptmpl /* [CAM] */
```

```
35 gcptmpl large_square_tool_num = 0; // [0:0,112:112,102:102,201:201]
36 gcptmpl /* [CAM] */
37 gcptmpl small_square_tool_num = 102; // [0:0,122:122,112:112,102:102]
38 gcptmpl /* [CAM] */
39 gcptmpl large_ball_tool_num = 0; // [0:0,111:111,101:101,202:202]
40 gcptmpl /* [CAM] */
41 gcptmpl small_ball_tool_num = 0; // [0:0,121:121,111:111,101:101]
42 gcptmpl /* [CAM] */
43 gcptmpl large_V_tool_num = 0; // [0:0,301:301,690:690]
44 gcptmpl /* [CAM] */
45 gcptmpl small_V_tool_num = 0; // [0:0,390:390,301:301]
46 gcptmpl /* [CAM] */
47 gcptmpl DT_tool_num = 0; // [0:0,814:814]
48 gcptmpl /* [CAM] */
49 gcptmpl KH_tool_num = 0; // [0:0,374:374,375:375,376:376,378]
50 gcptmpl /* [CAM] */
51 gcptmpl Roundover_tool_num = 0; // [56142:56142, 56125:56125, 1570:1570]
52 gcptmpl /* [CAM] */
53 gcptmpl MISC_tool_num = 0; //
54 gcptmpl
55 gcptmpl /* [Feeds and Speeds] */
56 gcptmpl plunge = 100;
57 gcptmpl /* [Feeds and Speeds] */
58 gcptmpl feed = 400;
59 gcptmpl /* [Feeds and Speeds] */
60 gcptmpl speed = 16000;
61 gcptmpl /* [Feeds and Speeds] */
62 gcptmpl small_square_ratio = 0.75; // [0.25:2]
63 gcptmpl /* [Feeds and Speeds] */
64 gcptmpl large_ball_ratio = 1.0; // [0.25:2]
65 gcptmpl /* [Feeds and Speeds] */
66 gcptmpl small_ball_ratio = 0.75; // [0.25:2]
67 gcptmpl /* [Feeds and Speeds] */
68 gcptmpl large_V_ratio = 0.875; // [0.25:2]
69 gcptmpl /* [Feeds and Speeds] */
70 gcptmpl small_V_ratio = 0.625; // [0.25:2]
71 gcptmpl /* [Feeds and Speeds] */
72 gcptmpl DT_ratio = 0.75; // [0.25:2]
73 gcptmpl /* [Feeds and Speeds] */
74 gcptmpl KH_ratio = 0.75; // [0.25:2]
75 gcptmpl /* [Feeds and Speeds] */
76 gcptmpl RO_ratio = 0.5; // [0.25:2]
77 gcptmpl /* [Feeds and Speeds] */
78 gcptmpl MISC_ratio = 0.5; // [0.25:2]
79 gcptmpl
80 gcptmpl filename_gcode = str(Base_filename, ".nc");
81 gcptmpl filename_dxf = str(Base_filename);
82 gcptmpl
83 gcptmpl opengcodefile(filename_gcode);
84 gcptmpl opendxffile(filename_dxf);
85 gcptmpl
86 gcptmpl difference() {
87 gcptmpl setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight,
        stockzero);
88 gcptmpl
89 gcptmpl movetosafez();
90 gcptmpl
91 gcptmpl toolchange(small_square_tool_num,speed * small_square_ratio);
92 gcptmpl
93 gcptmpl begintoolpath(0,0,0.25);
94 gcptmpl
95 gcptmpl cutoneaxis_setfeed("Z",0,plunge*small_square_ratio);
96 gcptmpl
97 gcptmpl cutwithfeed(stockXwidth/2,stockYheight/2,-stockZthickness,feed);
98 gcptmpl dxfline(getxpos(),getypos(),stockXwidth/2,stockYheight/2,
        small_square_tool_num);
99 gcptmpl
100 gcptmpl endtoolpath();
101 gcptmpl rapid(-(stockXwidth/4-stockYheight/16),stockYheight/4,0);
102 gcptmpl cutoneaxis_setfeed("Z",-stockZthickness,plunge*small_square_ratio);
103 gcptmpl
104 gcptmpl cutarcNECCdxf(-stockXwidth/4, stockYheight/4+stockYheight/16, -
        stockZthickness, -stockXwidth/4, stockYheight/4, stockYheight
        /16, small_square_tool_num);
105 gcptmpl cutarcNWCCdxf(-(stockXwidth/4+stockYheight/16), stockYheight/4, -
        stockZthickness, -stockXwidth/4, stockYheight/4, stockYheight
        /16, small_square_tool_num);
```

```
gcptmpl cutarcSWCCdxf(-stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYheight/4, stockYheight/16, small_square_tool_num);
gcptmpl cutarcSECCdxf(-(stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stockYheight/4, stockYheight/16, small_square_tool_num);
gcptmpl
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl toolchange(KH_tool_num,speed * KH_ratio);
gcptmpl rapid(-stockXwidth/8,-stockYheight/4,0);
gcptmpl
gcptmpl cutkeyhole_toolpath((stockZthickness), (stockZthickness), "N", stockYheight/8, KH_tool_num);
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl rapid(-stockXwidth/4,-stockYheight/4,0);
gcptmpl cutkeyhole_toolpath((stockZthickness), (stockZthickness), "S", stockYheight/8, KH_tool_num);
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl rapid(-stockXwidth/4,-stockYheight/8,0);
gcptmpl cutkeyhole_toolpath((stockZthickness), (stockZthickness), "E", stockYheight/8, KH_tool_num);
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl rapid(-stockXwidth/8,-stockYheight/8*3,0);
gcptmpl cutkeyhole_toolpath((stockZthickness), (stockZthickness), "W", stockYheight/8, KH_tool_num);
gcptmpl
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl toolchange(DT_tool_num,speed * DT_ratio);
gcptmpl rapid(0,-(stockYheight/2+tool_diameter(DT_tool_num,0)),0);
gcptmpl
gcptmpl cutoneaxis_setfeed("Z",-stockZthickness,plunge*DT_ratio);
gcptmpl cutwithfeed(0,-(stockYheight/4),-stockZthickness,feed*DT_ratio);
gcptmpl rapid(0,-(stockYheight/2+tool_diameter(DT_tool_num,0)),-stockZthickness);
gcptmpl
gcptmpl rapid(getxpos(),getypos(),stockZthickness);
gcptmpl toolchange(Roundover_tool_num, speed * RO_ratio);
gcptmpl rapid(-(stockXwidth/2),-(stockYheight/2),0);
gcptmpl cutoneaxis_setfeed("Z",-4.509,plunge*RO_ratio);
gcptmpl
gcptmpl cutroundovertool(-(stockXwidth/2++0.507/2), -(stockYheight/2+0.507/2), -4.509, stockXwidth/2+0.507/2, -(stockYheight/2+0.507/2), -4.509, 0.507/2, 4.509);
gcptmpl
gcptmpl cutroundover(stockXwidth/2+0.507/2, -(stockYheight/2+0.507/2), -4.509, stockXwidth/2+0.507/2, stockYheight/2+0.507/2, -4.509, 1570);
gcptmpl cutroundover(stockXwidth/2+0.507/2, stockYheight/2+0.507/2, -4.509, -(stockXwidth/2+0.507/2), stockYheight/2+0.507/2, -4.509, 1570);
gcptmpl cutroundover(-(stockXwidth/2+0.507/2), stockYheight/2+0.507/2, -4.509, -(stockXwidth/2+0.507/2), -(stockYheight/2+0.507/2), -4.509, 1570);
gcptmpl
gcptmpl //for (i = [0 : abs(1) : 80]) {
gcptmpl //  cutwithfeed(stockXwidth/4,-stockYheight/4,-stockZthickness/4, feed);
gcptmpl //  cutwithfeed(stockXwidth/8+(stockXwidth/256*i),-stockYheight/2,-stockZthickness*3/4,feed);
gcptmpl //  }
gcptmpl
gcptmpl hull(){
gcptmpl   cutwithfeed(stockXwidth/4,-stockYheight/4,-stockZthickness/4,feed);
gcptmpl   cutwithfeed(stockXwidth/8,-stockYheight/2,-stockZthickness*3/4, feed);
gcptmpl   cutwithfeed(stockXwidth/8+(stockXwidth*0.3125),-stockYheight/2,-stockZthickness*3/4,feed);
gcptmpl   }
gcptmpl }
gcptmpl
gcptmpl closegcodefile();
gcptmpl closedxffile();
```

Which cuts as:



Some comments on the template:

- minimal — it is intended as a framework for a minimal working example (MWE) — it should be possible to comment out unused portions and so arrive at code which tests any aspect of this project
- compleat — a quite wide variety of tools are listed (and probably more will be added in the future), but pre-defining them and having these "hooks" seems the easiest (non-object-oriented) mechanism to handle everything
- shortcuts — as the last example shows, while in real life it is necessary to make many passes with a tool, an expedient shortcut is to forgo the `loop` operation and just use a `hull()` operation

Further features will be added to the template, and the main image updated to reflect the capabilities of the system.

2.1.2 gcodepreviewtemplate.py

Note that with the v0.7 re-write, it is possible to directly use the underlying Python code directly.

```
1 gcptmplpy #!/usr/bin/env python
2 gcptmplpy
3 gcptmplpy # getting openscad functions into namespace
4 gcptmplpy #https://github.com/gsohler/openscad/issues/39
5 gcptmplpy from openscad import *
6 gcptmplpy
7 gcptmplpy #import math
8 gcptmplpy
9 gcptmplpy import sys
10 gcptmplpy try:
11 gcptmplpy     if 'gcodepreview' in sys.modules:
12 gcptmplpy         del sys.modules['gcodepreview']
13 gcptmplpy except AttributeError:
14 gcptmplpy     pass
15 gcptmplpy
16 gcptmplpy #Below command only works within OpenPythonSCAD
17 gcptmplpy from gcodepreview import *
18 gcptmplpy
19 gcptmplpy fa = 2
20 gcptmplpy fs = 0.125
21 gcptmplpy
22 gcptmplpy # [Export] */
23 gcptmplpy Base_filename = "aexport"
24 gcptmplpy # [Export] */
25 gcptmplpy generatedxf = True
26 gcptmplpy # [Export] */
27 gcptmplpy generategcode = True
28 gcptmplpy
29 gcptmplpy # [Stock] */
30 gcptmplpy stockXwidth = 220
31 gcptmplpy # [Stock] */
32 gcptmplpy stockYheight = 150
```

```
gcptmplpy # [Stock] */
gcptmplpy stockZthickness = 8.35
gcptmplpy # [Stock] */
gcptmplpy zeroheight = "Top" # [Top, Bottom]
gcptmplpy # [Stock] */
gcptmplpy stockzero = "Center" # [Lower-Left, Center-Left, Top-Left, Center]
gcptmplpy # [Stock] */
gcptmplpy retractheight = 9
gcptmplpy
gcptmplpy # [CAM] */
gcptmplpy toolradius = 1.5875
gcptmplpy # [CAM] */
gcptmplpy large_square_tool_num = 201 # [0:0,112:112,102:102,201:201]
gcptmplpy # [CAM] */
gcptmplpy small_square_tool_num = 102 # [0:0,122:122,112:112,102:102]
gcptmplpy # [CAM] */
gcptmplpy large_ball_tool_num = 202 # [0:0,111:111,101:101,202:202]
gcptmplpy # [CAM] */
gcptmplpy small_ball_tool_num = 101 # [0:0,121:121,111:111,101:101]
gcptmplpy # [CAM] */
gcptmplpy large_V_tool_num = 301 # [0:0,301:301,690:690]
gcptmplpy # [CAM] */
gcptmplpy small_V_tool_num = 390 # [0:0,390:390,301:301]
gcptmplpy # [CAM] */
gcptmplpy DT_tool_num = 814 # [0:0,814:814]
gcptmplpy # [CAM] */
gcptmplpy KH_tool_num = 374 # [0:0,374:374,375:375,376:376,378]
gcptmplpy # [CAM] */
gcptmplpy Roundover_tool_num = 56142 # [56142:56142, 56125:56125, 1570:1570]
gcptmplpy # [CAM] */
gcptmplpy MISC_tool_num = 0 #
gcptmplpy
gcptmplpy # [Feeds and Speeds] */
gcptmplpy plunge = 100
gcptmplpy # [Feeds and Speeds] */
gcptmplpy feed = 400
gcptmplpy # [Feeds and Speeds] */
gcptmplpy speed = 16000
gcptmplpy # [Feeds and Speeds] */
gcptmplpy small_square_ratio = 0.75 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy large_ball_ratio = 1.0 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy small_ball_ratio = 0.75 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy large_V_ratio = 0.875 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy small_V_ratio = 0.625 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy DT_ratio = 0.75 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy KH_ratio = 0.75 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy RO_ratio = 0.5 # [0.25:2]
gcptmplpy # [Feeds and Speeds] */
gcptmplpy MISC_ratio = 0.5 # [0.25:2]
gcptmplpy
gcptmplpy gcp = gcodepreview(Base_filename, #"export", basefilename
gcptmplpy                    True, #generategcode
gcptmplpy                    True, #generatedxf
gcptmplpy                    stockXwidth,
gcptmplpy                    stockYheight,
gcptmplpy                    stockZthickness,
gcptmplpy                    zeroheight,
gcptmplpy                    stockzero,
gcptmplpy                    retractheight,
gcptmplpy                    large_square_tool_num,
gcptmplpy                    toolradius,
gcptmplpy                    plunge,
gcptmplpy                    feed,
gcptmplpy                    speed)
gcptmplpy
gcptmplpy gcp.opengcodefile(Base_filename)
gcptmplpy gcp.opendxffile(Base_filename)
gcptmplpy gcp.opendxffiles(Base_filename,
gcptmplpy                  large_square_tool_num,
gcptmplpy                  small_square_tool_num,
gcptmplpy                  large_ball_tool_num,
```

```
gcptmplpy                   small_ball_tool_num,
gcptmplpy                   large_V_tool_num,
gcptmplpy                   small_V_tool_num,
gcptmplpy                   DT_tool_num,
gcptmplpy                   KH_tool_num,
gcptmplpy                   Roundover_tool_num,
gcptmplpy                   MISC_tool_num)
gcptmplpy
gcptmplpy gcp.setupstock(stockXwidth,stockYheight,stockZthickness,"Top","
    Center",retractheight)
gcptmplpy
gcptmplpy gcp.movetosafeZ()
gcptmplpy
gcptmplpy gcp.toolchange(102,10000)
gcptmplpy
gcptmplpy #gcp.rapidXY(6,12)
gcptmplpy gcp.rapidZ(0)
gcptmplpy
gcptmplpy #print (gcp.xpos())
gcptmplpy #print (gcp.ypos())
gcptmplpy #psetzpos(7)
gcptmplpy #gcp.setzpos(-12)
gcptmplpy #print (gcp.zpos())
gcptmplpy
gcptmplpy #print ("X", str(gcp.xpos()))
gcptmplpy #print ("Y", str(gcp.ypos()))
gcptmplpy #print ("Z", str(gcp.zpos()))
gcptmplpy
gcptmplpy toolpaths = gcp.currenttool()
gcptmplpy
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/2,
    stockYheight/2, -stockZthickness))
gcptmplpy
gcptmplpy gcp.rapidZ(retractheight)
gcptmplpy gcp.toolchange(201,10000)
gcptmplpy gcp.rapidXY(0, stockYheight/16)
gcptmplpy gcp.rapidZ(0)
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*7,
    stockYheight/2, -stockZthickness))
gcptmplpy
gcptmplpy gcp.rapidZ(retractheight)
gcptmplpy gcp.toolchange(202,10000)
gcptmplpy gcp.rapidXY(0, stockYheight/8)
gcptmplpy gcp.rapidZ(0)
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*6,
    stockYheight/2, -stockZthickness))
gcptmplpy
gcptmplpy gcp.rapidZ(retractheight)
gcptmplpy gcp.toolchange(101,10000)
gcptmplpy gcp.rapidXY(0, stockYheight/16*3)
gcptmplpy gcp.rapidZ(0)
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*5,
    stockYheight/2, -stockZthickness))
gcptmplpy
gcptmplpy gcp.setzpos(retractheight)
gcptmplpy gcp.toolchange(390,10000)
gcptmplpy gcp.rapidXY(0, stockYheight/16*4)
gcptmplpy gcp.rapidZ(0)
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*4,
    stockYheight/2, -stockZthickness))
gcptmplpy gcp.rapidZ(retractheight)
gcptmplpy
gcptmplpy gcp.toolchange(301,10000)
gcptmplpy gcp.rapidXY(0, stockYheight/16*6)
gcptmplpy gcp.rapidZ(0)
gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*2,
    stockYheight/2, -stockZthickness))
gcptmplpy
gcptmplpy #gcp.setzpos(retractheight)
gcptmplpy #gcp.toolchange(102,10000)
gcptmplpy #gcp.rapidXY(stockXwidth/4+stockYheight/16, -(stockYheight/4))
gcptmplpy #gcp.rapidZ(0)
gcptmplpy ##arcloop(barc, earc, xcenter, ycenter, radius)
gcptmplpy #gcp.settzpos(stockZthickness/90)
gcptmplpy #toolpaths = toolpaths.union(gcp.arcloop(0, 90, stockXwidth/4, -
    stockYheight/4, stockYheight/16))
gcptmplpy
gcptmplpy gcp.rapidZ(retractheight)
```

```
181 gcptmplpy gcp.toolchange(102,10000)
182 gcptmplpy gcp.rapidXY(stockXwidth/4+stockYheight/8+stockYheight/16, +
                stockYheight/8)
183 gcptmplpy gcp.rapidZ(0)
184 gcptmplpy #gcp.settzpos(stockZthickness/90)
185 gcptmplpy #toolpaths = toolpaths.union(gcp.arcloop(0, 90, stockXwidth/4+
                stockYheight/8, stockYheight/8, stockYheight/16))
186 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcNECCdxfgc(stockXwidth/4+
                stockYheight/8, stockYheight/8+stockYheight/16, -stockZthickness
                , stockXwidth/4+stockYheight/8, stockYheight/8, stockYheight/16)
                )
187 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcNWCCdxfgc(stockXwidth/4+
                stockYheight/8-stockYheight/16, stockYheight/8, -stockZthickness
                , stockXwidth/4+stockYheight/8, stockYheight/8, stockYheight/16)
                )
188 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcSWCCdxfgc(stockXwidth/4+
                stockYheight/8, stockYheight/8-stockYheight/16, -stockZthickness
                , stockXwidth/4+stockYheight/8, stockYheight/8, stockYheight/16)
                )
189 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcSECCdxfgc(stockXwidth/4+
                stockYheight/8+stockYheight/16, stockYheight/8, -stockZthickness
                , stockXwidth/4+stockYheight/8, stockYheight/8, stockYheight/16)
                )
190 gcptmplpy
191 gcptmplpy #a = gcp.currenttool()
192 gcptmplpy #arcbegin = a.translate([64.37357214209116, -37.33638368965047,-
                stockZthickness])
193 gcptmplpy #arcend = a.translate([55.16361631034953, -28.12642785790883,-
                stockZthickness])
194 gcptmplpy #toolpaths = toolpaths.union(arcbegin)
195 gcptmplpy #toolpaths = toolpaths.union(arcend)
196 gcptmplpy
197 gcptmplpy #cu = cube([10,20,30])
198 gcptmplpy #c = cu.translate([0,0,gcp.zpos()])
199 gcptmplpy
200 gcptmplpy #def cutroundovertool(bx, by, bz, ex, ey, ez, tool_radius_tip,
                tool_radius_width):
201 gcptmplpy #    n = 90 + fn*3
202 gcptmplpy #    step = 360/n
203 gcptmplpy #    shaft = cylinder(step,tool_radius_tip,tool_radius_tip)
204 gcptmplpy #    toolpath = hull(shaft.translate([bx,by,bz]), shaft.translate([
                ex,ey,ez]))
205 gcptmplpy #    shaft = cylinder(tool_radius_width*2,tool_radius_tip+
                tool_radius_width,tool_radius_tip+tool_radius_width)
206 gcptmplpy #    toolpath = toolpath.union(hull(shaft.translate([bx,by,bz+
                tool_radius_width]), shaft.translate([ex,ey,ez+tool_radius_width
                ])))
207 gcptmplpy #    for i in range(1, 90, 1):
208 gcptmplpy #        angle = i
209 gcptmplpy #        dx = tool_radius_width*math.cos(math.radians(angle))
210 gcptmplpy #        dxx = tool_radius_width*math.cos(math.radians(angle+1))
211 gcptmplpy #        dzz = tool_radius_width*math.sin(math.radians(angle))
212 gcptmplpy #        dz = tool_radius_width*math.sin(math.radians(angle+1))
213 gcptmplpy #        dh = abs(dzz-dz)+0.0001
214 gcptmplpy #        slice = cylinder(dh,tool_radius_tip+tool_radius_width-dx,
                tool_radius_tip+tool_radius_width-dxx)
215 gcptmplpy #        toolpath = toolpath.union(hull(slice.translate([bx,by,bz+
                dz]), slice.translate([ex,ey,ez+dz])))
216 gcptmplpy #    return toolpath
217 gcptmplpy
218 gcptmplpy gcp.rapidZ(retractheight)
219 gcptmplpy gcp.toolchange(814,10000)
220 gcptmplpy gcp.rapidXY(0, -(stockYheight/2+12.7))
221 gcptmplpy gcp.cutZgcfeed(-stockZthickness,plunge)
222 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgcfeed(0, -(stockYheight
                /16), -stockZthickness, feed))
223 gcptmplpy
224 gcptmplpy
225 gcptmplpy gcp.rapidZ(0)
226 gcptmplpy
227 gcptmplpy #print(gcp.currenttoolnumber())
228 gcptmplpy
229 gcptmplpy gcp.rapidZ(retractheight)
230 gcptmplpy gcp.toolchange(56142,10000)
231 gcptmplpy gcp.rapidXY(-stockXwidth/2, -(stockYheight/2+0.508/2))
232 gcptmplpy gcp.cutZgcfeed(-1.531,plunge)
233 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgcfeed(stockXwidth
                /2+0.508/2, -(stockYheight/2+0.508/2), -1.531, feed))
```

```
234 gcptmplpy
235 gcptmplpy gcp.rapidZ(retractheight)
236 gcptmplpy #gcp.toolchange(56125,10000)
237 gcptmplpy gcp.cutZgcfeed(-1.531,plunge)
238 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgcfeed(stockXwidth
        /2+0.508/2, (stockYheight/2+0.508/2), -1.531, feed))
239 gcptmplpy
240 gcptmplpy gcp.rapidZ(retractheight)
241 gcptmplpy gcp.toolchange(374,10000)
242 gcptmplpy gcp.rapidXY(stockXwidth/4-stockXwidth/16, -(stockYheight/4+
        stockYheight/16))
243 gcptmplpy gcp.rapidZ(0)
244 gcptmplpy #toolpaths = toolpaths.union(gcp.cutlinedxfgcfeed(gcp.xpos(), gcp.
        ypos(), -4, feed))
245 gcptmplpy #toolpaths = toolpaths.union(gcp.cutZgcfeed(-4,plunge))
246 gcptmplpy #toolpaths = toolpaths.union(gcp.cutlinedxfgcfeed(stockXwidth/4, -(
        stockYheight/4)+25.4, -4, feed))
247 gcptmplpy #key = gcp.cutlinedxfgcfeed(stockXwidth/2+0.508/2, (stockYheight
        /2+0.508/2), -1.531, feed)
248 gcptmplpy
249 gcptmplpy #cutkeyholegcdxf(stockZthickness/2, stockZthickness/2, "N",
        stockYheight/8, KH_tool_num)
250 gcptmplpy #rapid(getxpos(),getypos(),stockZthickness);
251 gcptmplpy #rapid(-stockXwidth/4,-stockYheight/4,0);
252 gcptmplpy #cutkeyhole_toolpath((stockZthickness), (stockZthickness), "S",
        stockYheight/8, KH_tool_num);
253 gcptmplpy #rapid(getxpos(),getypos(),stockZthickness);
254 gcptmplpy #rapid(-stockXwidth/4,-stockYheight/8,0);
255 gcptmplpy key = gcp.cutkeyholegcdxf(0, stockZthickness*0.75, "E",
        stockYheight/9, KH_tool_num)
256 gcptmplpy toolpaths = toolpaths.union(key)
257 gcptmplpy #rapid(getxpos(),getypos(),stockZthickness);
258 gcptmplpy #rapid(-stockXwidth/8,-stockYheight/8*3,0);
259 gcptmplpy #cutkeyhole_toolpath((stockZthickness), (stockZthickness), "W",
        stockYheight/8, KH_tool_num);
260 gcptmplpy
261 gcptmplpy gcp.rapidZ(retractheight)
262 gcptmplpy gcp.rapidXY(stockXwidth/4+stockXwidth/16, -(stockYheight/4+
        stockYheight/16))
263 gcptmplpy gcp.rapidZ(0)
264 gcptmplpy toolpaths = toolpaths.union(gcp.cutkeyholegcdxf(0, stockZthickness
        *0.75, "N", stockYheight/9, KH_tool_num))
265 gcptmplpy
266 gcptmplpy gcp.rapidZ(retractheight)
267 gcptmplpy gcp.rapidXY(stockXwidth/4+stockXwidth/16, -(stockYheight/4-
        stockYheight/8))
268 gcptmplpy gcp.rapidZ(0)
269 gcptmplpy toolpaths = toolpaths.union(gcp.cutkeyholegcdxf(0, stockZthickness
        *0.75, "W", stockYheight/9, KH_tool_num))
270 gcptmplpy
271 gcptmplpy gcp.rapidZ(retractheight)
272 gcptmplpy gcp.rapidXY(stockXwidth/4-stockXwidth/16, -(stockYheight/4-
        stockYheight/8))
273 gcptmplpy gcp.rapidZ(0)
274 gcptmplpy toolpaths = toolpaths.union(gcp.cutkeyholegcdxf(0, stockZthickness
        *0.75, "S", stockYheight/9, KH_tool_num))
275 gcptmplpy
276 gcptmplpy gcp.rapidZ(retractheight)
277 gcptmplpy
278 gcptmplpy #Last dxf command not being written...
279 gcptmplpy #empty = gcp.cutlinedxfgcfeed(stockXwidth/2, -(stockYheight
        /2+0.508/2), 1, feed)
280 gcptmplpy
281 gcptmplpy part = gcp.stock.difference(toolpaths)
282 gcptmplpy #part = gcp.stock.union(key)
283 gcptmplpy
284 gcptmplpy output(part)
285 gcptmplpy #output(toolpaths)
286 gcptmplpy #output(key)
287 gcptmplpy
288 gcptmplpy gcp.setzpos(retractheight)
289 gcptmplpy
290 gcptmplpy gcp.closegcodefile()
291 gcptmplpy gcp.closedxffiles()
292 gcptmplpy gcp.closedxffile()
```

2.2 Implementation files and gcodepreview class

Each file will begin with a comment indicating the file type and further notes/comments on usage where appropriate:

```
gcpy #!/usr/bin/env python
gcpy #icon "C:\Program Files\PythonSCAD\bin\openscad.exe"  --trust-python
gcpy #Currently tested with 2024.09.23 and Python 3.11
gcpy #gcodepreview 0.7, for use with OpenPythonSCAD,
gcpy #if using from OpenPythonSCAD see gcodepreview.scad
gcpy
gcpy # getting openscad functions into namespace
gcpy #https://github.com/gsohler/openscad/issues/39
gcpy from openscad import *
gcpy
gcpy # add math functions (using radians by default, convert to degrees where necessary)
gcpy import math
```

```
pyscad //!OpenSCAD
pyscad
pyscad //gcodepreview 0.7, see gcodepreview.scad
```

```
gcpscad //!OpenSCAD
gcpscad
gcpscad //gcodepreview 0.7
gcpscad //
gcpscad //used via use <gcodepreview.py>;
gcpscad //          use <pygcodepreview.scad>;
gcpscad //          include <gcodepreview.scad>;
gcpscad //
```

If all functions are to be handled within Python, then they will need to be gathered into a class which contains them and which is initialized so as to define shared variables, and then there will need to be objects/commands for each aspect of the program, each of which will utilise needed variables and will contain appropriate functionality. Note that they will be divided between mandatory and optional functions/variables/objects:

- Mandatory
  - stocksetup:
    - stockXwidth, stockYheight, stockZthickness, zeroheight, stockzero, retractheight
  - gcpfiles:
    - basefilename, generatedxf, generategcode
  - largesquaretool:
    - large_square_tool_num, toolradius, plunge, feed, speed
- Optional
  - smallsquaretool:
    - small_square_tool_num, small_square_ratio
  - largeballtool:
    - large_ball_tool_num, large_ball_ratio
  - largeVtool:
    - large_V_tool_num, large_V_ratio
  - smallballtool:
    - small_ball_tool_num, small_ball_ratio
  - smallVtool:
    - small_V_tool_num, small_V_ratio
  - DTtool:
    - DT_tool_num, DT_ratio
  - KHtool:
    - KH_tool_num, KH_ratio
  - Roundovertool:
    - Roundover_tool_num, RO_ratio
  - misctool:

* MISC_tool_num, MISC_ratio

gcodepreview The first class which is defined is gcodepreview which includes the init method which allows passing in and defining the variables which will be used by the other methods in this class.

```
14 gcpy class gcodepreview:
15 gcpy
16 gcpy     def __init__(self, basefilename = "export",
17 gcpy                  generategcode = False,
18 gcpy                  generatedxf = False,
19 gcpy                  stockXwidth = 25,
20 gcpy                  stockYheight = 25,
21 gcpy                  stockZthickness = 1,
22 gcpy                  zeroheight = "Top",
23 gcpy                  stockzero = "Lower-left" ,
24 gcpy                  retractheight = 6,
25 gcpy                  currenttoolnum = 102,
26 gcpy                  toolradius = 3.175,
27 gcpy                  plunge = 100,
28 gcpy                  feed = 400,
29 gcpy                  speed = 10000):
30 gcpy         self.basefilename = basefilename
31 gcpy         self.generategcode = generategcode
32 gcpy         self.generatedxf = generatedxf
33 gcpy         self.stockXwidth = stockXwidth
34 gcpy         self.stockYheight = stockYheight
35 gcpy         self.stockZthickness = stockZthickness
36 gcpy         self.zeroheight = zeroheight
37 gcpy         self.stockzero = stockzero
38 gcpy         self.retractheight = retractheight
39 gcpy         self.currenttoolnum = currenttoolnum
40 gcpy         self.toolradius = toolradius
41 gcpy         self.plunge = plunge
42 gcpy         self.feed = feed
43 gcpy         self.speed = speed
44 gcpy #         global toolpaths
45 gcpy #         self.toolpaths = cylinder(1.5875, 12.7)
46 gcpy #         global generatedxfs
47 gcpy         self.generatedxfs = False
```

2.2.1 Output files

The gcodepreview class will write out DXF and/or G-code files.

2.2.1.1 G-code and modules and commands The G-code commands and their matching modules may include (but are not limited to):

Command/Module	G-code
opengcodefile(s)(...); setupstock(...)	(export.nc) (stockMin: -109.5, -75mm, -8.35mm) (stockMax:109.5mm, 75mm, 0.00mm) (STOCK/BLOCK, 219, 150, 8.35, 109.5, 75, 8.35) G90 G21
movetosafez()	(Move to safe Z to avoid workholding) G53G0Z-5.000
toolchange(...);	(TOOL/MILL,3.17, 0.00, 0.00, 0.00) M6T102 M03S16000

cutoneaxis_setfeed(...);
 	
cutwithfeed(...);
	(PREPOSITION FOR RAPID PLUNGE)
	G0X0Y0
	Z0.25
	G1Z0F100
	G1 X109.5 Y75 Z-8.35F400
	Z9

closegcodefile();	M05 M02

Conversely, the G-code commands which are supported are generated by the following modules:

G-code	Command/Module
(Design File:) (stockMin:0.00mm, -152.40mm, -34.92mm) (stockMax:109.50mm, -77.40mm, 0.00mm) (STOCK/BLOCK,109.50, 75.00, 34.92,0.00, 152.40, 34.92) G90 G21	opengcodefile(s)(...); setupstock(...
(Move to safe Z to avoid workholding) G53G0Z-5.000	movetosafez()
(Toolpath: Contour Toolpath 1) M05 (TOOL/MILL,3.17, 0.00, 0.00, 0.00) M6T102 M03S10000	toolchange(...);
(PREPOSITION FOR RAPID PLUNGE)	writecomment(...)
G0X0.000Y-152.400 Z0.250	rapid(...) rapid(...)
G1Z-1.000F203.2 X109.500Y-77.400F508.0 X57.918Y16.302Z-0.726 Y22.023Z-1.023 X61.190Z-0.681 Y21.643 X57.681 Z12.700	cutwithfeed(...); cutwithfeed(...);
M05 M02	closegcodefile();

The implication here is that it should be possible to read in a G-code file, and for each line/command instantiate a matching command so as to create a 3D model/preview of the file. One possible option would be to make specialized commands for movement which correspond to the various axis combinations (XYZ, XY, XZ, YZ, X, Y, Z).

2.2.1.2 DXF

Elements in DXFs are represented as lines or arcs. A minimal file showing both:

```
0
SECTION
2
ENTITIES
0
LWPOLYLINE
90
2
70
0
43
0
10
-31.375
20
-34.9152
10
-31.375
20
-18.75
0
ARC
10
-54.75
20
-37.5
40
4
50
0
51
90
0
ENDSEC
0
EOF
```

The class gcodepreview will need additional commands for opening files

```
49 gcpy     def opengcodefile(self, basefilename = "export"):
50 gcpy         if self.generategcode == True:
51 gcpy             self.gcodefilename = basefilename + ".nc"
52 gcpy             self.gc = open(self.gcodefilename, "w")
53 gcpy
54 gcpy     def opendxffile(self, basefilename = "export"):
55 gcpy #         global generatedxfs
56 gcpy #         global dxfclosed
57 gcpy         self.dxfclosed = False
58 gcpy         if self.generatedxf == True:
59 gcpy             self.generatedxfs = False
60 gcpy             self.dxffilename = basefilename + ".dxf"
61 gcpy             self.dxf = open(self.dxffilename, "w")
62 gcpy             self.dxfpreamble(-1)
63 gcpy
64 gcpy     def opendxffiles(self, basefilename = "export",
65 gcpy                      large_square_tool_num = 0,
66 gcpy                      small_square_tool_num = 0,
67 gcpy                      large_ball_tool_num = 0,
68 gcpy                      small_ball_tool_num = 0,
69 gcpy                      large_V_tool_num = 0,
70 gcpy                      small_V_tool_num = 0,
71 gcpy                      DT_tool_num = 0,
72 gcpy                      KH_tool_num = 0,
73 gcpy                      Roundover_tool_num = 0,
74 gcpy                      MISC_tool_num = 0):
75 gcpy #         global generatedxfs
76 gcpy         self.generatedxfs = True
77 gcpy         self.large_square_tool_num = large_square_tool_num
78 gcpy         self.small_square_tool_num = small_square_tool_num
79 gcpy         self.large_ball_tool_num = large_ball_tool_num
80 gcpy         self.small_ball_tool_num = small_ball_tool_num
81 gcpy         self.large_V_tool_num = large_V_tool_num
82 gcpy         self.small_V_tool_num = small_V_tool_num
83 gcpy         self.DT_tool_num = DT_tool_num
84 gcpy         self.KH_tool_num = KH_tool_num
85 gcpy         self.Roundover_tool_num = Roundover_tool_num
86 gcpy         self.MISC_tool_num = MISC_tool_num
87 gcpy         if self.generatedxf == True:
88 gcpy             if (large_square_tool_num > 0):
89 gcpy                 self.dxflgsqfilename = basefilename + str(
                         large_square_tool_num) + ".dxf"
90 gcpy #                print("Opening ", str(self.dxflgsqfilename))
91 gcpy                 self.dxflgsq = open(self.dxflgsqfilename, "w")
92 gcpy             if (small_square_tool_num > 0):
93 gcpy #                print("Opening small square")
94 gcpy                 self.dxfsmsqfilename = basefilename + str(
                         small_square_tool_num) + ".dxf"
95 gcpy                 self.dxfsmsq = open(self.dxfsmsqfilename, "w")
96 gcpy             if (large_ball_tool_num > 0):
97 gcpy #                print("Opening large ball")
98 gcpy                 self.dxflgblfilename = basefilename + str(
                         large_ball_tool_num) + ".dxf"
99 gcpy                 self.dxflgbl = open(self.dxflgblfilename, "w")
100 gcpy             if (small_ball_tool_num > 0):
101 gcpy #                print("Opening small ball")
102 gcpy                 self.dxfsmblfilename = basefilename + str(
                         small_ball_tool_num) + ".dxf"
103 gcpy                 self.dxfsmbl = open(self.dxfsmblfilename, "w")
104 gcpy             if (large_V_tool_num > 0):
105 gcpy #                print("Opening large V")
106 gcpy                 self.dxflgVfilename = basefilename + str(
                         large_V_tool_num) + ".dxf"
107 gcpy                 self.dxflgV = open(self.dxflgVfilename, "w")
108 gcpy             if (small_V_tool_num > 0):
109 gcpy #                print("Opening small V")
110 gcpy                 self.dxfsmVfilename = basefilename + str(
                         small_V_tool_num) + ".dxf"
111 gcpy                 self.dxfsmV = open(self.dxfsmVfilename, "w")
112 gcpy             if (DT_tool_num > 0):
113 gcpy #                print("Opening DT")
114 gcpy                 self.dxfDTfilename = basefilename + str(DT_tool_num
                         ) + ".dxf"
115 gcpy                 self.dxfDT = open(self.dxfDTfilename, "w")
116 gcpy             if (KH_tool_num > 0):
117 gcpy #                print("Opening KH")
```

```
118 gcpy                 self.dxfKHfilename = basefilename + str(KH_tool_num
                             ) + ".dxf"
119 gcpy                 self.dxfKH = open(self.dxfKHfilename, "w")
120 gcpy             if (Roundover_tool_num > 0):
121 gcpy #                 print("Opening Rt")
122 gcpy                 self.dxfRtfilename = basefilename + str(
                             Roundover_tool_num) + ".dxf"
123 gcpy                 self.dxfRt = open(self.dxfRtfilename, "w")
124 gcpy             if (MISC_tool_num > 0):
125 gcpy #                 print("Opening Mt")
126 gcpy                 self.dxfMtfilename = basefilename + str(
                             MISC_tool_num) + ".dxf"
127 gcpy                 self.dxfMt = open(self.dxfMtfilename, "w")
```

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

```
128 gcpy             if (large_square_tool_num > 0):
129 gcpy                 self.dxfpreamble(large_square_tool_num)
130 gcpy             if (small_square_tool_num > 0):
131 gcpy                 self.dxfpreamble(small_square_tool_num)
132 gcpy             if (large_ball_tool_num > 0):
133 gcpy                 self.dxfpreamble(large_ball_tool_num)
134 gcpy             if (small_ball_tool_num > 0):
135 gcpy                 self.dxfpreamble(small_ball_tool_num)
136 gcpy             if (large_V_tool_num > 0):
137 gcpy                 self.dxfpreamble(large_V_tool_num)
138 gcpy             if (small_V_tool_num > 0):
139 gcpy                 self.dxfpreamble(small_V_tool_num)
140 gcpy             if (DT_tool_num > 0):
141 gcpy                 self.dxfpreamble(DT_tool_num)
142 gcpy             if (KH_tool_num > 0):
143 gcpy                 self.dxfpreamble(KH_tool_num)
144 gcpy             if (Roundover_tool_num > 0):
145 gcpy                 self.dxfpreamble(Roundover_tool_num)
146 gcpy             if (MISC_tool_num > 0):
147 gcpy                 self.dxfpreamble(MISC_tool_num)
```

Note that the commands which interact with files include checks to see if said files are being generated.

writeln The original implementation in RapSCAD used a command `writeln` — fortunately, this command is easily re-created in Python. Note that the dxf commands will be wrapped up with `if/elif` blocks which will write to additional file(s) based on tool number as set up above.

```
149 gcpy     def writegc(self, *arguments):
150 gcpy         line_to_write = ""
151 gcpy         for element in arguments:
152 gcpy             line_to_write += element
153 gcpy         self.gc.write(line_to_write)
154 gcpy         self.gc.write("\n")
155 gcpy
156 gcpy     def writedxf(self, toolnumber, *arguments):
157 gcpy #         global dxfclosed
158 gcpy         line_to_write = ""
159 gcpy         for element in arguments:
160 gcpy             line_to_write += element
161 gcpy         if self.generatedxf == True:
162 gcpy             if self.dxfclosed == False:
163 gcpy                 self.dxf.write(line_to_write)
164 gcpy                 self.dxf.write("\n")
165 gcpy         if self.generatedxfs == True:
166 gcpy             self.writedxfs(toolnumber, line_to_write)
167 gcpy
168 gcpy     def writedxfs(self, toolnumber, line_to_write):
169 gcpy #         print("Processing writing toolnumber", toolnumber)
170 gcpy #         line_to_write = ""
171 gcpy #         for element in arguments:
172 gcpy #             line_to_write += element
173 gcpy         if (toolnumber == 0):
174 gcpy             return
175 gcpy         elif self.generatedxfs == True:
176 gcpy             if (self.large_square_tool_num == toolnumber):
177 gcpy                 self.dxflgsq.write(line_to_write)
178 gcpy                 self.dxflgsq.write("\n")
179 gcpy             if (self.small_square_tool_num == toolnumber):
180 gcpy                 self.dxfsmsq.write(line_to_write)
181 gcpy                 self.dxfsmsq.write("\n")
```

```
182 gcpy             if (self.large_ball_tool_num == toolnumber):
183 gcpy                 self.dxflgbl.write(line_to_write)
184 gcpy                 self.dxflgbl.write("\n")
185 gcpy             if (self.small_ball_tool_num == toolnumber):
186 gcpy                 self.dxfsmbl.write(line_to_write)
187 gcpy                 self.dxfsmbl.write("\n")
188 gcpy             if (self.large_V_tool_num == toolnumber):
189 gcpy                 self.dxflgV.write(line_to_write)
190 gcpy                 self.dxflgV.write("\n")
191 gcpy             if (self.small_V_tool_num == toolnumber):
192 gcpy                 self.dxfsmV.write(line_to_write)
193 gcpy                 self.dxfsmV.write("\n")
194 gcpy             if (self.DT_tool_num == toolnumber):
195 gcpy                 self.dxfDT.write(line_to_write)
196 gcpy                 self.dxfDT.write("\n")
197 gcpy             if (self.KH_tool_num == toolnumber):
198 gcpy                 self.dxfKH.write(line_to_write)
199 gcpy                 self.dxfKH.write("\n")
200 gcpy             if (self.Roundover_tool_num == toolnumber):
201 gcpy                 self.dxfRt.write(line_to_write)
202 gcpy                 self.dxfRt.write("\n")
203 gcpy             if (self.MISC_tool_num == toolnumber):
204 gcpy                 self.dxfMt.write(line_to_write)
205 gcpy                 self.dxfMt.write("\n")
```

which commands will accept a series of arguments and then write them out to a file object for the appropriate file. Note that the DXF files for specific tools will expect that the tool numbers be set in the matching variables from the template. Further note that while it is possible to use tools which are not so defined, the toolpaths will not be written into DXF files for any tool numbers which do not match the variables from the template (but will appear in the main `.dxf`).

2.3 Module Naming Convention

Note that as a convention, where it is necessary for a module to coordinate between Python and OpenSCAD, in certain cases it will be necessary for there to be three separate versions: a Python definition for the manipulation of Python variables and any file routines, originally these were identified as `p`<foo>, but with the use of an object-oriented programming style and dot notation, since v0.7 they will be identified as `gcp.foo` (where `gcp` is the identifier used to import the class); while 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.

Number will be abbreviated as `num` rather than `no`, and the short form will be used internally for variable names, while the compleat word will be used in commands.

In natural languages such as English, there is an order to various parts of speech such as adjectives — since various prefixes and suffixes will be used for module names, having a consistent ordering/usage will help in consistency and make expression clearer. The ordering should be: sequence (if necessary), action, function, parameter, filetype, and where possible a hierarchy of large/general to small/specific should be maintained.

- Both prefix and suffix
  - `dxf` (action (write out dxf file), filetype)
- Prefixes
  - `write` (action) — used to write to files
  - `begin` (sequence) — note that sequencing may not be necessary, not having been used in the 0.7 re-write
  - `continue` (sequence)
  - `end` (sequence)
  - `cut` (action — create 3D object)
  - `rapid` (action — create 3D object so as to show a collision)
  - `open` (action)
  - `close` (action)
  - `set` (action/function) — note that the matching `get` is implicit in functions which return variables, e.g., `xpos()`
  - `current`
- Nouns
  - `arc`
  - `line`

  - `Bézier` — a possible future addition, will likely be rendered `bezier`

- Suffixes
  - `feed` (parameter)
  - `gcode/gc` (filetype)
  - `pos` — position
  - `tool`
  - `number/num` — note that `num` is used internally for variable names, making it straightforward to ensure that functions and variables have different names for purposes of scope

Further note that commands which are implicitly for the generation of G-code, such as `toolchange()` will omit `gc` for the sake of conciseness.

In particular, this means that the basic `cut...` and associated commands exist (or potentially exist) in the following forms and have matching versions which may be used when programming in Python or OpenSCAD:

	line			arc		
	cut	dxf	gcode	cut	dxf	gcode
cut	cutline		cutlinegc	cutarc		cutarcgc
dxf	cutlinedxf	dxfline		cutarcdxf	dxfarc	
gcode		dxflinegc	linegc		dxfarcgc	arcgc
	cutlinedxfgc			cutarcdxfgc		

Note that certain commands (`dxflinegc`, `dxfarcgc`, `linegc`, `arcgc`) are unlikely to be needed, and may not be implemented. Note that there may be additional versions as required for the convenience of notation or cutting, in particular, a set of `cutarc`<quadrant><direction>`dxf` commands was warranted during the initial development of `arc`-related commands.

OpenPythonSCAD requires that the current toolpath be returned and stored in a variable (which can then be subtracted from the stock) using OpenSCAD will instead have the toolpaths output in a structure which is differenced from the declared stock.

Principles for naming modules (and variables):

- minimize use of underscores (for convenience sake, underscores are not used for index entries)
- identify which aspect of the project structure is being worked with (`cut`(ting), `dxf`, `gcode`, `tool`, etc.) and esp. note the use of `o`(penscad) and `p`(ython) as prefixes, though the latter is not necessary for definitions within the `gcodepreview` class which will normally be imported as `gcp` so that module `<foo>` will be called as `gcp.<foo>`

Structurally, when developing OpenSCAD commands which make use of Python this will typically look like:

```
The user-facing module is \DescribeRoutine{FOOBAR}

\lstset{firstnumber=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module FOOBAR(...) {
    oFOOBAR(...);
}

\end{writecode}
\addtocounter{gcpscad}{4}

which calls the internal OpenSCAD Module \DescribeSubroutine{FOOBAR}{oFOOBAR}

\begin{writecode}{a}{pygcodepreview.scad}{scad}
module oFOOBAR(...) {
    pFOOBAR(...);
 }

\end{writecode}
\addtocounter{pyscad}{4}

which in turn calls the internal Python definitioon \DescribeSubroutine{FOOBAR}{pFOOBAR}

\lstset{firstnumber=\thegcpy}
\begin{writecode}{a}{gcodepreview.py}{python}
def pFOOBAR (...)
    ...

\end{writecode}
\addtocounter{gcpy}{3}
```

Further note that this definition will not be necessary for some later modules since they are in turn calling internal modules which already use this structure.

Another consideration is that all commands which write files will check to see if a given filetype is enabled or no.

2.3.1 Initial Modules

setupstock
gcodepreview

The first such routine, (actually a subroutine, see `setupstock`) `gcodepreview` will be appropriately enough, to set up the stock, and perform other initializations — initially, the only thing done in Python was to set the value of the persistent (Python) variables, but the rewritten standalone Python version does everything.

gcp.setupstock

The Python code, `gcp.setupstock` requires that the user set parameters for stock dimensions and so forth, and will create comments in the G-code which incorporate the stock dimensions and its position relative to the zero as set relative to the stock.

```
207 gcpy     def setupstock(self, stockXwidth,
208 gcpy                    stockYheight,
209 gcpy                    stockZthickness,
210 gcpy                    zeroheight,
211 gcpy                    stockzero,
212 gcpy                    retractheight):
213 gcpy #         global mpx
214 gcpy          self.mpx = float(0)
215 gcpy #         global mpy
216 gcpy          self.mpy = float(0)
217 gcpy #         global mpz
218 gcpy          self.mpz = float(0)
219 gcpy #         global tpz
220 gcpy          self.tpz = float(0)
221 gcpy #         global currenttoolnum
222 gcpy          self.currenttoolnum = 102
223 gcpy #         global currenttoolshape
224 gcpy          self.currenttoolshape = cylinder(12.7, 1.5875)
225 gcpy #         global stock
226 gcpy          self.stock = cube([stockXwidth, stockYheight,
                      stockZthickness])
227 gcpy          if self.generategcode == True:
228 gcpy              self.writegc("(Design␣File:␣" + self.basefilename + ")"
                          )
```

Note that since Python in OpenPythonSCAD defers output of the 3D model, it is possible to define it once, then set up all the specifics for each possible positioning of the stock in terms of origin:

The internal variable `stockzero` is used in an `<if then else>` structure to position the 3D model of the stock and write out the G-code comment which defines it.

```
229 gcpy          if self.zeroheight == "Top":
230 gcpy              if self.stockzero == "Lower-Left":
231 gcpy                  self.stock = stock.translate([0,0,-self.
                              stockZthickness])
232 gcpy                  if self.generategcode == True:
233 gcpy                      self.writegc("(stockMin:0.00mm,␣0.00mm,␣-",str(
                                  self.stockZthickness),"mm)")
234 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth)
                                  ,"mm,␣",str(stockYheight),"mm,␣0.00mm)")
235 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                                  stockXwidth),",␣",str(self.stockYheight),",␣
                                  ",str(self.stockZthickness),",␣0.00,␣0.00,␣"
                                  ,str(self.stockZthickness),")")
236 gcpy              if self.stockzero == "Center-Left":
237 gcpy                  self.stock = self.stock.translate([0,-stockYheight
                              / 2,-stockZthickness])
238 gcpy                  if self.generategcode == True:
239 gcpy                      self.writegc("(stockMin:0.00mm,␣-",str(self.
                                  stockYheight/2),"mm,␣-",str(self.
                                  stockZthickness),"mm)")
240 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth)
                                  ,"mm,␣",str(self.stockYheight/2),"mm,␣0.00mm
                                  )")
241 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                                  stockXwidth),",␣",str(self.stockYheight),",␣
                                  ",str(self.stockZthickness),",␣0.00,␣",str(
                                  self.stockYheight/2),",␣",str(self.
                                  stockZthickness),")");
242 gcpy              if self.stockzero == "Top-Left":
243 gcpy                  self.stock = self.stock.translate([0,-self.
```

```
                        stockYheight,-self.stockZthickness])
244 gcpy                if self.generategcode == True:
245 gcpy                    self.writegc("(stockMin:0.00mm, -",str(self.
                            stockYheight),"mm, -",str(self.
                            stockZthickness),"mm)")
246 gcpy                    self.writegc("(stockMax:",str(self.stockXwidth)
                            ,"mm, 0.00mm, 0.00mm)")
247 gcpy                    self.writegc("(STOCK/BLOCK, ",str(self.
                            stockXwidth),", ",str(self.stockYheight),", 
                            ",str(self.stockZthickness),", 0.00, ",str(
                            self.stockYheight),", ",str(self.
                            stockZthickness),")")
248 gcpy            if self.stockzero == "Center":
249 gcpy                self.stock = self.stock.translate([-self.
                        stockXwidth / 2,-self.stockYheight / 2,-self.
                        stockZthickness])
250 gcpy                if self.generategcode == True:
251 gcpy                    self.writegc("(stockMin: -",str(self.
                            stockXwidth/2),", -",str(self.stockYheight
                            /2),"mm, -",str(self.stockZthickness),"mm)")
252 gcpy                    self.writegc("(stockMax:",str(self.stockXwidth
                            /2),"mm, ",str(self.stockYheight/2),"mm, 
                            0.00mm)")
253 gcpy                    self.writegc("(STOCK/BLOCK, ",str(self.
                            stockXwidth),", ",str(self.stockYheight),", 
                            ",str(self.stockZthickness),", ",str(self.
                            stockXwidth/2),", ", str(self.stockYheight
                            /2),", ",str(self.stockZthickness),")")
254 gcpy        if self.zeroheight == "Bottom":
255 gcpy            if self.stockzero == "Lower-Left":
256 gcpy                 self.stock = self.stock.translate([0,0,0])
257 gcpy                 if self.generategcode == True:
258 gcpy                     self.writegc("(stockMin:0.00mm, 0.00mm, 0.00mm
                             )")
259 gcpy                     self.writegc("(stockMax:",str(self.stockXwidth
                             ),"mm, ",str(self.stockYheight),"mm, ",str
                             (self.stockZthickness),"mm)")
260 gcpy                     self.writegc("(STOCK/BLOCK, ",str(self.
                             stockXwidth),", ",str(self.stockYheight),", 
                             ",str(self.stockZthickness),", 0.00, 0.00, 
                             0.00)")
261 gcpy            if self.stockzero == "Center-Left":
262 gcpy                self.stock = self.stock.translate([0,-self.
                        stockYheight / 2,0])
263 gcpy                if self.generategcode == True:
264 gcpy                    self.writegc("(stockMin:0.00mm, -",str(self.
                            stockYheight/2),"mm, 0.00mm)")
265 gcpy                    self.writegc("(stockMax:",str(self.stockXwidth)
                            ,"mm, ",str(self.stockYheight/2),"mm, -",str
                            (self.stockZthickness),"mm)")
266 gcpy                    self.writegc("(STOCK/BLOCK, ",str(self.
                            stockXwidth),", ",str(self.stockYheight),", 
                            ",str(self.stockZthickness),", 0.00, ",str(
                            self.stockYheight/2),", 0.00mm)");
267 gcpy            if self.stockzero == "Top-Left":
268 gcpy                self.stock = self.stock.translate([0,-self.
                        stockYheight,0])
269 gcpy                if self.generategcode == True:
270 gcpy                    self.writegc("(stockMin:0.00mm, -",str(self.
                            stockYheight),"mm, 0.00mm)")
271 gcpy                    self.writegc("(stockMax:",str(self.stockXwidth)
                            ,"mm, 0.00mm, ",str(self.stockZthickness),"
                            mm)")
272 gcpy                    self.writegc("(STOCK/BLOCK, ",str(self.
                            stockXwidth),", ",str(self.stockYheight),", 
                            ",str(self.stockZthickness),", 0.00, ",str(
                            self.stockYheight),", 0.00)")
273 gcpy            if self.stockzero == "Center":
274 gcpy                self.stock = self.stock.translate([-self.
                        stockXwidth / 2,-self.stockYheight / 2,0])
275 gcpy                if self.generategcode == True:
276 gcpy                    self.writegc("(stockMin: -",str(self.
                            stockXwidth/2),", -",str(self.stockYheight
                            /2),"mm, 0.00mm)")
277 gcpy                    self.writegc("(stockMax:",str(self.stockXwidth
                            /2),"mm, ",str(self.stockYheight/2),"mm, ",
                            str(self.stockZthickness),"mm)")
278 gcpy                    self.writegc("(STOCK/BLOCK, ",str(self.
```

```
                                    stockXwidth),",␣",str(self.stockYheight),",␣
                                    ",str(self.stockZthickness),",␣",str(self.
                                    stockXwidth/2),",␣", str(self.stockYheight
                                    /2),",␣0.00)")
 279 gcpy          if self.generategcode == True:
 280 gcpy              self.writegc("G90");
 281 gcpy              self.writegc("G21");
```

Note that while the #102 is declared as a default tool, while it was originally necessary to call a tool change after invoking `setupstock` in the 2024.09.03 version of PythonSCAD this requirement went away when an update which interfered with persistently setting a variable directly was fixed.

osetupstock The intermediary OpenSCAD code, `osetupstock` simply calls the Python version. Note that the parameters are passed all the way down, which was initially for consistency (they were not used) in 0.8 and later, everything happens in the Python file, and the OpenSCAD code is simply a series of descriptors which simply call the Python file.

```
 4 pyscad  module osetupstock(stockXwidth, stockYheight, stockZthickness,
               zeroheight, stockzero) {
 5 pyscad      psetupstock(stockXwidth, stockYheight, stockZthickness,
                   zeroheight, stockzero);
 6 pyscad  }
```

```
 9 gcpscad module setupstock(stockXwidth, stockYheight, stockZthickness,
               zeroheight, stockzero) {
10 gcpscad   osetupstock(stockXwidth, stockYheight, stockZthickness,
                zeroheight, stockzero);
11 gcpscad }
```

An example usage in OpenSCAD would be:

```
difference() {
setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight, stockzero);
... // Cutting commands go here
}
```

For Python, the initial 3D model is stored in the variable `stock`:

```
setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight, stockzero)

cy = cube([1,2,stockZthickness*2])

diff = stock.difference(cy)
#output(diff)
diff.show()
```

2.3.2 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, and depth in toolpath. This will be done using paired functions (which will set and return the matching variable) and a matching 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:

currenttoolnum
- `currenttoolnum`

Note that the `currenttoolnum` variable should always be used for any specification of a tool, being read in whenever a tool is to be made use of, or a parameter or aspect of the tool needs to be used in a calculation.

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`).

xpos
ypos
zpos

It will be necessary to have Python functions (`xpos`, `ypos`, and `zpos`) which return the current values of the machine position in Cartesian coordinates:

```
283 gcpy     def xpos(self):
284 gcpy #         global mpx
285 gcpy         return self.mpx
286 gcpy
287 gcpy     def ypos(self):
288 gcpy #         global mpy
289 gcpy         return self.mpy
290 gcpy
291 gcpy     def zpos(self):
292 gcpy #         global mpz
293 gcpy         return self.mpz
294 gcpy
295 gcpy     def tzpos(self):
296 gcpy #         global tpz
297 gcpy         return self.tpz
```

psetxpos psetypos psetzpos psettzpos and in turn, functions which set the positions: psetxpos, psetypos, psetzpos, and psettzpos

```
299 gcpy     def setxpos(self, newxpos):
300 gcpy #         global mpx
301 gcpy         self.mpx = newxpos
302 gcpy
303 gcpy     def setypos(self, newypos):
304 gcpy #         global mpy
305 gcpy         self.mpy = newypos
306 gcpy
307 gcpy     def setzpos(self, newzpos):
308 gcpy #         global mpz
309 gcpy         self.mpz = newzpos
310 gcpy
311 gcpy     def settzpos(self, newtzpos):
312 gcpy #         global tpz
313 gcpy         self.tpz = newtzpos
```

setxpos setypos setzpos settzpos getxpos getypos getzpos gettzpos and as noted above, there will need to be matching OpenSCAD versions which will set: setxpos, setypos, setzpos, and settzpos; as well as return the value: getxpos, getypos, getzpos, and 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 needto use an intermediary OpenSCAD module.

```
 8 pyscad //function getxpos() = xpos();
 9 pyscad //function getypos() = ypos();
10 pyscad //function getzpos() = zpos();
11 pyscad //function gettzpos() = tzpos();
12 pyscad //
13 pyscad //module setxpos(newxpos) {
14 pyscad //    psetxpos(newxpos);
15 pyscad //}
16 pyscad //
17 pyscad //module setypos(newypos) {
18 pyscad //    psetypos(newypos);
19 pyscad //}
20 pyscad //
21 pyscad //module setzpos(newzpos) {
22 pyscad //    psetzpos(newzpos);
23 pyscad //}
24 pyscad //
25 pyscad //module settzpos(newtzpos) {
26 pyscad //    psettzpos(newtzpos);
27 pyscad //}
28 pyscad //
```

oset oset while for setting all three of the variables, there is an internal OpenSCAD module:

```
102 gcpscad //module oset(ex, ey, ez) {
103 gcpscad //    setxpos(ex);
104 gcpscad //    setypos(ey);
105 gcpscad //    setzpos(ez);
106 gcpscad //}
107 gcpscad //
```

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

```
108 gcpscad //module osettz(tz) {
```

```
109 gcpscad //     settzpos(tz);
110 gcpscad //}
111 gcpscad //
```

2.4 Tools and Changes

currenttoolnumber
settool

Similarly Python functions and variables will be used in: `currenttoolnumber` (note that it is important to use a different name than the variable `currenttoolnum` and `settool` (it may be that the latter will be removed) to track and set and return the current tool:

```
315 gcpy      def settool(self,tn):
316 gcpy #         global currenttoolnum
317 gcpy          self.currenttoolnum = tn
318 gcpy
319 gcpy      def currenttoolnumber(self):
320 gcpy #         global currenttoolnum
321 gcpy          return self.currenttoolnum
322 gcpy
323 gcpy      def currentroundovertoolnumber(self):
324 gcpy #         global Roundover_tool_num
325 gcpy          return self.Roundover_tool_num
```

osettool
current tool

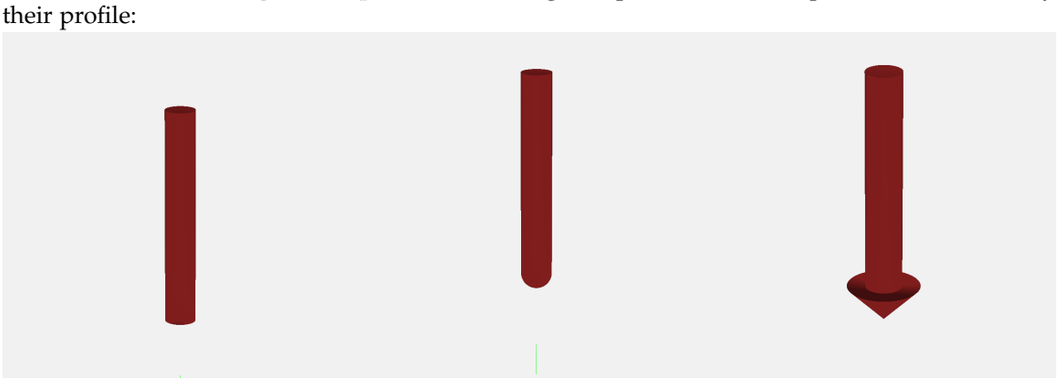
and matching OpenSCAD modules: `osettool` and `current tool` set and return the current tool:

```
29 pyscad module osettool(tn){
30 pyscad     psettool(tn);
31 pyscad }
32 pyscad
33 pyscad function current_tool() = pcurrent_tool();
```

2.4.1 3D Shapes for Tools

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

2.4.1.1 Normal Tooling/toolshapes 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 of 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)

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

endmill square

The `endmill square` is a simple cylinder:

```
327 gcpy      def endmill_square(self, es_diameter, es_flute_length):
328 gcpy          return cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2),
                      h=es_flute_length, center = False)
```

gcp endmill ball

The `gcp endmill ball` is modeled as a hemisphere joined with a cylinder:

```
330 gcpy     def gcp_endmill_ball(self, es_diameter, es_flute_length):
331 gcpy         b = sphere(r=(es_diameter / 2))
332 gcpy         s = cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=
                     es_flute_length, center=False)
333 gcpy         p = union(b,s)
334 gcpy         return p.translate([0, 0, (es_diameter / 2)])
```

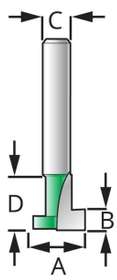
gcp endmill v

The `gcp endmill v` is modeled as a cylinder with a zero width base and a second cylinder for the shaft (note that Python's `math` defaults to radians, hence the need to convert from degrees):

```
336 gcpy     def gcp_endmill_v(self, es_v_angle, es_diameter):
337 gcpy         es_v_angle = math.radians(es_v_angle)
338 gcpy         v = cylinder(r1=0, r2=(es_diameter / 2), h=((es_diameter /
                     2) / math.tan((es_v_angle / 2))), center=False)
339 gcpy         s = cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h
                     =((es_diameter * 8) ), center=False)
340 gcpy         sh = s.translate([0, 0, ((es_diameter / 2) / math.tan((
                     es_v_angle / 2)))])
341 gcpy         return union(v,sh)
```

2.4.1.2 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 Router Bits

#	A	B	C	D
374	3/8″	1/8″	1/4″	3/8″
375	9.525mm	3.175mm	8mm	9.525mm
376	1/2″	3/16″	1/4″	1/2″
378	12.7mm	4.7625mm	8mm	12.7mm

- Keyhole tools — intended to cut slots for retaining hardware used for picture hanging, they may be used to create slots for other purposes Note that it will be necessary to model these twice, once for the shaft, the second time for the actual keyhole cutting https://assetssc.leevalley.com/en-gb/shop/tools/power-tool-accessories/router-bits/30113-keyhole-router-bits
- 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
- Threadmill — used for cutting threads, normally a single form geometry is used on a CNC.

2.4.1.3 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

gcp keyhole

2.4.1.4 Keyhole The `gcp keyhole` is modeled in two parts, first the cutting base:

```
343 gcpy     def gcp_keyhole(self, es_diameter, es_flute_length):
344 gcpy         return cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2),
                     h=es_flute_length, center=False)
```

and a second call for an additional cylinder for the shaft will be necessary:

```
346 gcpy     def gcp_keyhole_shaft(self, es_diameter, es_flute_length):
347 gcpy         return cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2),
                     h=es_flute_length, center=False)
```

gcp dovetail The gcp dovetail is modeled as a cylinder with the differing bottom and top diameters determining the angle (though dt_angle is still required as a parameter)

```
349 gcpy     def gcp_dovetail(self, dt_bottomdiameter, dt_topdiameter,
                 dt_height, dt_angle):
350 gcpy         return cylinder(r1=(dt_bottomdiameter / 2), r2=(
                     dt_topdiameter / 2), h= dt_height, center=False)
```

2.4.1.5 Concave toolshapes While normal tooling may be represented with a single hull operation betwixt two 3D toolshapes (or four in the instance of keyhole tools), concave tooling such as roundover/radius tooling require multiple slices of the tool shape which are then hulled 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-43723.

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
cutroundover different modules, the public-facing version which includes the tool number:cutroundover

2.4.1.6 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 2.4.1.5.

```
112 gcpscad module cutroundover(bx, by, bz, ex, ey, ez, radiustn) {
113 gcpscad     if (radiustn == 56125) {
114 gcpscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.508/2, 1.531);
115 gcpscad     } else if (radiustn == 56142) {
116 gcpscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.508/2, 2.921);
117 gcpscad //     } else if (radiustn == 312) {
118 gcpscad //         cutroundovertool(bx, by, bz, ex, ey, ez, 1.524/2, 3.175);
119 gcpscad     } else if (radiustn == 1570) {
120 gcpscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.507/2, 4.509);
121 gcpscad     }
122 gcpscad }
```

which then calls the actual cutroundovertool 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.

2.4.2 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).

A further concern is that early versions often passed the tool into a module using a parameter. That ceased to be necessary in the 2024.09.03 version of PythonSCAD, and all modules should read the tool # from currenttoolnumber(). Note that this variable has changed names from the original currenttool which is now used to store the current tool *shape* (or 3D model).

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 early versions of this project

2.4.2.1 Selecting Tools The original implementation created the model for the tool at the current position, wrapping the twain for each end of a given movement in a hull() command. This approach will not work within Python, so it will be necessary to instead assign and select the tool
currenttoolshape as part of the cutting command indirectly by first storing it in the variable currenttoolshape (if the toolshape will work with the hull command) which may be done in this module, or it will be necessary to check for the specific toolnumber in the cutline module and handle the tooling in a separate module as is currently done for roundover tooling.

```
352 gcpy     def currenttool(self):
353 gcpy #         global currenttoolshape
354 gcpy         return self.currenttoolshape
```

Note that it will also be necessary to write out a tool description compatible with the program CutViewer as a G-code comment so that it may be used as a 3D previewer for the G-code for tool changes in G-code. Several forms are available:

2.4.2.2 Square and ball nose (including tapered ball nose)

`TOOL/MILL, Diameter, Corner radius, Height, Taper Angle`

2.4.2.3 Roundover (corner rounding)

`TOOL/CRMILL, Diameter1, Diameter2,Radius, Height, Length`

Unfortunately, tools which support undercuts such as dovetails are not supported (CAMotics will work for such tooling).

```
356 gcpy     def toolchange(self,tool_number,speed):
357 gcpy #         global currenttoolshape
358 gcpy         self.currenttoolshape = self.endmill_square(0.001, 0.001)
359 gcpy
360 gcpy         self.settool(tool_number)
361 gcpy         if (self.generategcode == True):
362 gcpy             self.writegc("(Toolpath)")
363 gcpy             self.writegc("M05")
364 gcpy         if (tool_number == 201):
365 gcpy             self.writegc("(TOOL/MILL,6.35,␣0.00,␣0.00,␣0.00)")
366 gcpy             self.currenttoolshape = self.endmill_square(6.35,
                         19.05)
367 gcpy         elif (tool_number == 102):
368 gcpy             self.writegc("(TOOL/MILL,3.175,␣0.00,␣0.00,␣0.00)")
369 gcpy             self.currenttoolshape = self.endmill_square(3.175,
                         12.7)
370 gcpy         elif (tool_number == 112):
371 gcpy             self.writegc("(TOOL/MILL,1.5875,␣0.00,␣0.00,␣0.00)")
372 gcpy             self.currenttoolshape = self.endmill_square(1.5875,
                         6.35)
373 gcpy         elif (tool_number == 122):
374 gcpy             self.writegc("(TOOL/MILL,0.79375,␣0.00,␣0.00,␣0.00)")
375 gcpy             self.currenttoolshape = self.endmill_square(0.79375,
                         1.5875)
376 gcpy         elif (tool_number == 202):
377 gcpy             self.writegc("(TOOL/MILL,6.35,␣3.175,␣0.00,␣0.00)")
378 gcpy             self.currenttoolshape = self.gcp_endmill_ball(6.35,
                         19.05)
379 gcpy         elif (tool_number == 101):
380 gcpy             self.writegc("(TOOL/MILL,3.175,␣1.5875,␣0.00,␣0.00)")
381 gcpy             self.currenttoolshape = self.gcp_endmill_ball(3.175,
                         12.7)
382 gcpy         elif (tool_number == 111):
383 gcpy             self.writegc("(TOOL/MILL,1.5875,␣0.79375,␣0.00,␣0.00)")
384 gcpy             self.currenttoolshape = self.gcp_endmill_ball(1.5875,
                         6.35)
385 gcpy         elif (tool_number == 121):
386 gcpy             self.writegc("(TOOL/MILL,3.175,␣0.79375,␣0.00,␣0.00)")
387 gcpy             self.currenttoolshape = self.gcp_endmill_ball(0.79375,
                         1.5875)
388 gcpy         elif (tool_number == 327):
389 gcpy             self.writegc("(TOOL/MILL,0.03,␣0.00,␣13.4874,␣30.00)")
390 gcpy             self.currenttoolshape = self.gcp_endmill_v(60, 26.9748)
391 gcpy         elif (tool_number == 301):
392 gcpy             self.writegc("(TOOL/MILL,0.03,␣0.00,␣6.35,␣45.00)")
393 gcpy             self.currenttoolshape = self.gcp_endmill_v(90, 12.7)
394 gcpy         elif (tool_number == 302):
395 gcpy             self.writegc("(TOOL/MILL,0.03,␣0.00,␣10.998,␣30.00)")
396 gcpy             self.currenttoolshape = self.gcp_endmill_v(60, 12.7)
397 gcpy         elif (tool_number == 390):
398 gcpy             self.writegc("(TOOL/MILL,0.03,␣0.00,␣1.5875,␣45.00)")
399 gcpy             self.currenttoolshape = self.gcp_endmill_v(90, 3.175)
400 gcpy         elif (tool_number == 374):
401 gcpy             self.writegc("(TOOL/MILL,9.53,␣0.00,␣3.17,␣0.00)")
402 gcpy         elif (tool_number == 375):
403 gcpy             self.writegc("(TOOL/MILL,9.53,␣0.00,␣3.17,␣0.00)")
404 gcpy         elif (tool_number == 376):
405 gcpy             self.writegc("(TOOL/MILL,12.7,␣0.00,␣4.77,␣0.00)")
406 gcpy         elif (tool_number == 378):
407 gcpy             self.writegc("(TOOL/MILL,12.7,␣0.00,␣4.77,␣0.00)")
408 gcpy         elif (tool_number == 814):
409 gcpy             self.writegc("(TOOL/MILL,12.7,␣6.367,␣12.7,␣0.00)")
410 gcpy             #dt_bottomdiameter, dt_topdiameter, dt_height, dt_angle
                         )
411 gcpy             #https://www.leevalley.com/en-us/shop/tools/power-tool-
                         accessories/router-bits/30172-dovetail-bits?item=18
                         J1607
```

```
412 gcpy             self.currenttoolshape = self.gcp_dovetail(12.7, 6.367,
                         12.7, 14)
413 gcpy         elif (tool_number == 56125):#0.508/2, 1.531
414 gcpy             self.writegc("(TOOL/CRMILL,␣0.508,␣6.35,␣3.175,␣7.9375,
                         ␣3.175)")
415 gcpy         elif (tool_number == 56142):#0.508/2, 2.921
416 gcpy             self.writegc("(TOOL/CRMILL,␣0.508,␣3.571875,␣1.5875,␣
                         5.55625,␣1.5875)")
417 gcpy #         elif (tool_number == 312):#1.524/2, 3.175
418 gcpy #             self.writegc("(TOOL/CRMILL, Diameter1, Diameter2,
        Radius, Height, Length)")
419 gcpy         elif (tool_number == 1570):#0.507/2, 4.509
420 gcpy             self.writegc("(TOOL/CRMILL,␣0.17018,␣9.525,␣4.7625,␣
                         12.7,␣4.7625)")
```

With the tools delineated, the module is closed out and the toolchange information written into the G-code as well as the command to start the spindle at the specified speed.

```
421 gcpy         self.writegc("M6T",str(tool_number))
422 gcpy         self.writegc("M03S",str(speed))
```

For example:

```
toolchange(small_square_tool_num,speed);
```

(the assumption is that all speed rates in a file will be the same, so as to account for the most frequent use case of a trim router with speed controlled by a dial setting)

2.4.3 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, `tool diameter` simply calls the matching OpenSCAD module which wraps the Python code:

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

`otool diameter` the matching OpenSCAD function, `otool diameter` calls the Python function:

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

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

```
424 gcpy     def tool_diameter(self, ptd_tool, ptd_depth):
425 gcpy # Square 122,112,102,201
426 gcpy         if ptd_tool == 122:
427 gcpy             return 0.79375
428 gcpy         if ptd_tool == 112:
429 gcpy             return 1.5875
430 gcpy         if ptd_tool == 102:
431 gcpy             return 3.175
432 gcpy         if ptd_tool == 201:
433 gcpy             return 6.35
434 gcpy # Ball 121,111,101,202
435 gcpy         if ptd_tool == 122:
436 gcpy             if ptd_depth > 0.396875:
437 gcpy                 return 0.79375
438 gcpy             else:
439 gcpy                 return ptd_tool
440 gcpy         if ptd_tool == 112:
441 gcpy             if ptd_depth > 0.79375:
442 gcpy                 return 1.5875
443 gcpy             else:
444 gcpy                 return ptd_tool
445 gcpy         if ptd_tool == 101:
446 gcpy             if ptd_depth > 1.5875:
447 gcpy                 return 3.175
```

```
448 gcpy                 else:
449 gcpy                     return ptd_tool
450 gcpy             if ptd_tool == 202:
451 gcpy                 if ptd_depth > 3.175:
452 gcpy                     return 6.35
453 gcpy                 else:
454 gcpy                     return ptd_tool
455 gcpy # V 301, 302, 390
456 gcpy             if ptd_tool == 301:
457 gcpy                 return ptd_tool
458 gcpy             if ptd_tool == 302:
459 gcpy                 return ptd_tool
460 gcpy             if ptd_tool == 390:
461 gcpy                 return ptd_tool
462 gcpy # Keyhole
463 gcpy             if ptd_tool == 374:
464 gcpy                 if ptd_depth < 3.175:
465 gcpy                     return 9.525
466 gcpy                 else:
467 gcpy                     return 6.35
468 gcpy             if ptd_tool == 375:
469 gcpy                 if ptd_depth < 3.175:
470 gcpy                     return 9.525
471 gcpy                 else:
472 gcpy                     return 8
473 gcpy             if ptd_tool == 376:
474 gcpy                 if ptd_depth < 4.7625:
475 gcpy                     return 12.7
476 gcpy                 else:
477 gcpy                     return 6.35
478 gcpy             if ptd_tool == 378:
479 gcpy                 if ptd_depth < 4.7625:
480 gcpy                     return 12.7
481 gcpy                 else:
482 gcpy                     return 8
483 gcpy # Dovetail
484 gcpy             if ptd_tool == 814:
485 gcpy                 if ptd_depth > 12.7:
486 gcpy                     return 6.35
487 gcpy                 else:
488 gcpy                     return 12.7
```

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

```
490 gcpy     def tool_radius(self, ptd_tool, ptd_depth):
491 gcpy         tr = self.tool_diameter(ptd_tool, ptd_depth)/2
492 gcpy         return tr
```

(Note that where values are not fully calculated values currently the passed in tool number is returned which will need to be replaced with code which calculates the appropriate values.)

2.4.4 Feeds and Speeds

`feed` `plunge` `speed` There are several possibilities for handling feeds and speeds. Currently, base values for `feed`, `plunge`, and `speed` are used, which may then be adjusted using various `<tooldescriptor>_ratio` values, as an acknowledgement of the likelihood of a trim router being used as a spindle, the assumption is that the `speed` will remain unchanged.

One notable possibility for the future would be to load it from the .csv files used for User tool libraries in Carbide Create. Ideally, any use of such values in modules would be such that some other scheme could replace that usage with minimal editing and updating.

The tools which need to be calculated thus are those in addition to the `large_square` tool:

- `small_square_ratio`
- `small_ball_ratio`
- `large_ball_ratio`
- `small_V_ratio`
- `large_V_ratio`
- `KH_ratio`
- `DT_ratio`

2.5 OpenSCAD File Handling

popengcodefile
popendxffile
popendxflgsqfile
popendxfsmsqfile
popendxflgblfile
popendxfsmblfile
popendxflgVfile
popendxfsmVfile

For writing to files it will be necessary to have commands: popengcodefile, popendxffile, popendxflgsqfile, popendxfsmsqfile, popendxflgblfile, popendxfsmblfile, popendxflgVfile, and popendxfsmVfile. There is a separate function for each type of file, and for DXFs, there are multiple file 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.

Integrating G-code and DXF generation with everything else would be ideal, but will require ensuring that each command which moves the tool creates a matching command for both files.

```
494 gcpy #def popengcodefile(fn):
495 gcpy #     global f
496 gcpy #     f = open(fn, "w")
497 gcpy #
498 gcpy #def popendxffile(fn):
499 gcpy #     global dxf
500 gcpy #     dxf = open(fn, "w")
501 gcpy #
502 gcpy #def popendxflgblfile(fn):
503 gcpy #     global dxflgbl
504 gcpy #     dxflgbl = open(fn, "w")
505 gcpy #
506 gcpy #def popendxflgsqfile(fn):
507 gcpy #     global dxflgsq
508 gcpy #     dxflgsq = open(fn, "w")
509 gcpy #
510 gcpy #def popendxflgVfile(fn):
511 gcpy #     global dxflgV
512 gcpy #     dxflgV = open(fn, "w")
513 gcpy #
514 gcpy #def popendxfsmblfile(fn):
515 gcpy #     global dxfsmbl
516 gcpy #     dxfsmbl = open(fn, "w")
517 gcpy #
518 gcpy #def popendxfsmsqfile(fn):
519 gcpy #     global dxfsmsq
520 gcpy #     dxfsmsq = open(fn, "w")
521 gcpy #
522 gcpy #def popendxfsmVfile(fn):
523 gcpy #     global dxfsmV
524 gcpy #     dxfsmV = open(fn, "w")
525 gcpy #
526 gcpy #def popendxfKHfile(fn):
527 gcpy #     global dxfKH
528 gcpy #     dxfKH = open(fn, "w")
529 gcpy #
530 gcpy #def popendxfDTfile(fn):
531 gcpy #     global dxfDT
532 gcpy #     dxfDT = open(fn, "w")
533 gcpy #
```

oopengcodefile
oopendxffile

There will need to be matching OpenSCAD modules oopengcodefile, and oopendxffile, for the Python functions.

```
37 pyscad module oopengcodefile(fn) {
38 pyscad     popengcodefile(fn);
39 pyscad }
40 pyscad
41 pyscad module oopendxffile(fn) {
42 pyscad //     echo(fn);
43 pyscad     popendxffile(fn);
44 pyscad }
45 pyscad
46 pyscad module oopendxflgblfile(fn) {
47 pyscad     popendxflgblfile(fn);
48 pyscad }
49 pyscad
50 pyscad module oopendxflgsqfile(fn) {
51 pyscad     popendxflgsqfile(fn);
52 pyscad }
53 pyscad
54 pyscad module oopendxflgVfile(fn) {
55 pyscad     popendxflgVfile(fn);
56 pyscad }
57 pyscad
58 pyscad module oopendxfsmblfile(fn) {
59 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 }
pyscad
pyscad module oopendxfKHfile(fn) {
pyscad     popendxfKHfile(fn);
pyscad }
pyscad
pyscad module oopendxfDTfile(fn) {
pyscad     popendxfDTfile(fn);
pyscad }
```

opengcodefile With matching OpenSCAD commands: `opengcodefile`

```
gcpscad module opengcodefile(fn) {
gcpscad if (generategcode == true) {
gcpscad     oopengcodefile(fn);
gcpscad //    echo(fn);
gcpscad     owritecomment(fn);
gcpscad     }
gcpscad }
```

2.5.1 Writing to files

When the command to open `.dxf` files is called it is passed all of the variables for the various tool types/sizes, and based on a value being greater than zero, the matching file is opened, and in addition, the main DXF which is always written to is opened as well. On the gripping hand, 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. It will be necessary for the dxfwrite `dxfwrite` command to evaluate the tool number which is passed in, and to use an appropriate command or set of commands to then write out to the appropriate file for a given tool (if positive) or not do anything (if zero), and to write to the master file if a negative value is passed in (this allows the various DXF template commands to be written only once and then called at need).
has a matching command each tool/size combination:

writedxflgbl • Ball nose, large (lgbl) `writedxflgbl`

writedxfsmbl • Ball nose, small (smbl) `writedxfsmbl`

writedxflgsq • Square, large (lgsq) `writedxflgsq`

writedxfsmsq • Square, small (smsq) `writedxfsmsq`

writedxflgV • V, large (lgV) `writedxflgV`

writedxfsmV • V, small (smV) `writedxfsmV`

writedxfKH • Keyhole (KH) `writedxfKH`

writedxfDT • Dovetail (DT) `writedxfDT`

```
gcpy #def writedxflgbl(*arguments):
gcpy #    line_to_write = ""
gcpy #    for element in arguments:
gcpy #        line_to_write += element
gcpy #    dxflgbl.write(line_to_write)
gcpy #    print(line_to_write)
gcpy #    dxflgbl.write("\n")
gcpy #
gcpy #def writedxflgsq(*arguments):
gcpy #    line_to_write = ""
gcpy #    for element in arguments:
gcpy #        line_to_write += element
gcpy #    dxflgsq.write(line_to_write)
gcpy #    print(line_to_write)
gcpy #    dxflgsq.write("\n")
gcpy #
gcpy #def writedxflgV(*arguments):
gcpy #    line_to_write = ""
```

```
552 gcpy #     for element in arguments:
553 gcpy #         line_to_write += element
554 gcpy #     dxflgV.write(line_to_write)
555 gcpy #     print(line_to_write)
556 gcpy #     dxflgV.write("\n")
557 gcpy #
558 gcpy #def writedxfsmbl(*arguments):
559 gcpy #     line_to_write = ""
560 gcpy #     for element in arguments:
561 gcpy #         line_to_write += element
562 gcpy #     dxfsmbl.write(line_to_write)
563 gcpy #     print(line_to_write)
564 gcpy #     dxfsmbl.write("\n")
565 gcpy #
566 gcpy #def writedxfsmsq(*arguments):
567 gcpy #     line_to_write = ""
568 gcpy #     for element in arguments:
569 gcpy #         line_to_write += element
570 gcpy #     dxfsmsq.write(line_to_write)
571 gcpy #     print(line_to_write)
572 gcpy #     dxfsmsq.write("\n")
573 gcpy #
574 gcpy #def writedxfsmV(*arguments):
575 gcpy #     line_to_write = ""
576 gcpy #     for element in arguments:
577 gcpy #         line_to_write += element
578 gcpy #     dxfsmV.write(line_to_write)
579 gcpy #     print(line_to_write)
580 gcpy #     dxfsmV.write("\n")
581 gcpy #
582 gcpy #def writedxfKH(*arguments):
583 gcpy #     line_to_write = ""
584 gcpy #     for element in arguments:
585 gcpy #         line_to_write += element
586 gcpy #     dxfKH.write(line_to_write)
587 gcpy #     print(line_to_write)
588 gcpy #     dxfKH.write("\n")
589 gcpy #
590 gcpy #def writedxfDT(*arguments):
591 gcpy #     line_to_write = ""
592 gcpy #     for element in arguments:
593 gcpy #         line_to_write += element
594 gcpy #     dxfDT.write(line_to_write)
595 gcpy #     print(line_to_write)
596 gcpy #     dxfDT.write("\n")
597 gcpy #
```

owritecomment
dxfwriteone
dxfwritelgbl
dxfwritelgsq
dxfwritelgV
dxfwritesmbl
dxfwritesmsq
dxfwritesmV

Separate OpenSCAD modules, `owritecomment`, `dxfwriteone`, `dxfwritelgbl`, `dxfwritelgsq`, `dxfwritelgV`, `dxfwritesmbl`, `dxfwritesmsq`, and `dxfwritesmV` 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.

```
 79 pyscad module owritecomment(comment) {
 80 pyscad     writeln("(",comment,")");
 81 pyscad }
 82 pyscad
 83 pyscad module dxfwriteone(first) {
 84 pyscad     writedxf(first);
 85 pyscad //    writeln(first);
 86 pyscad //    echo(first);
 87 pyscad }
 88 pyscad
 89 pyscad module dxfwritelgbl(first) {
 90 pyscad     writedxflgbl(first);
 91 pyscad }
 92 pyscad
 93 pyscad module dxfwritelgsq(first) {
 94 pyscad     writedxflgsq(first);
 95 pyscad }
 96 pyscad
 97 pyscad module dxfwritelgV(first) {
 98 pyscad     writedxflgV(first);
 99 pyscad }
100 pyscad
101 pyscad module dxfwritesmbl(first) {
102 pyscad     writedxfsmbl(first);
103 pyscad }
104 pyscad
```

```
105 pyscad module dxfwritesmsq(first) {
106 pyscad     writedxfsmsq(first);
107 pyscad }
108 pyscad
109 pyscad module dxfwritesmV(first) {
110 pyscad     writedxfsmV(first);
111 pyscad }
112 pyscad
113 pyscad module dxfwriteKH(first) {
114 pyscad     writedxfKH(first);
115 pyscad }
116 pyscad
117 pyscad module dxfwriteDT(first) {
118 pyscad     writedxfDT(first);
119 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, `owrite...`

owrite...

```
121 pyscad module owriteone(first) {
122 pyscad     writeln(first);
123 pyscad }
124 pyscad
125 pyscad module owritetwo(first, second) {
126 pyscad     writeln(first, second);
127 pyscad }
128 pyscad
129 pyscad module owritethree(first, second, third) {
130 pyscad     writeln(first, second, third);
131 pyscad }
132 pyscad
133 pyscad module owritefour(first, second, third, fourth) {
134 pyscad     writeln(first, second, third, fourth);
135 pyscad }
136 pyscad
137 pyscad module owritefive(first, second, third, fourth, fifth) {
138 pyscad     writeln(first, second, third, fourth, fifth);
139 pyscad }
140 pyscad
141 pyscad module owritesix(first, second, third, fourth, fifth, sixth) {
142 pyscad     writeln(first, second, third, fourth, fifth, sixth);
143 pyscad }
144 pyscad
145 pyscad module owriteseven(first, second, third, fourth, fifth, sixth,
            seventh) {
146 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh);
147 pyscad }
148 pyscad
149 pyscad module owriteeight(first, second, third, fourth, fifth, sixth,
            seventh,eighth) {
150 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
                eighth);
151 pyscad }
152 pyscad
153 pyscad module owritenine(first, second, third, fourth, fifth, sixth,
            seventh, eighth, ninth) {
154 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
                eighth, ninth);
155 pyscad }
156 pyscad
157 pyscad module owriteten(first, second, third, fourth, fifth, sixth,
            seventh, eighth, ninth, tenth) {
158 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
                eighth, ninth, tenth);
159 pyscad }
160 pyscad
161 pyscad module owriteeleven(first, second, third, fourth, fifth, sixth,
            seventh, eighth, ninth, tenth, eleventh) {
162 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
                eighth, ninth, tenth, eleventh);
163 pyscad }
164 pyscad
165 pyscad module owritetwelve(first, second, third, fourth, fifth, sixth,
            seventh, eighth, ninth, tenth, eleventh, twelfth) {
166 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
                eighth, ninth, tenth, eleventh, twelfth);
167 pyscad }
```

```
168 pyscad
169 pyscad module owritethirteen(first, second, third, fourth, fifth, sixth,
        seventh, eighth, ninth, tenth, eleventh, twelfth, thirteenth) {
170 pyscad     writeln(first, second, third, fourth, fifth, sixth, seventh,
            eighth, ninth, tenth, eleventh, twelfth, thirteenth);
171 pyscad }
```

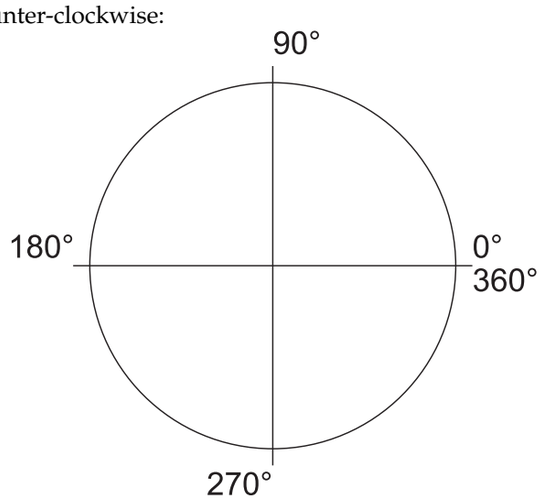
2.5.1.1 Writing to DXFs This module requires that the tool number be passed in, and after writing out `dxfpreamble`, that value will be used to write out to the appropriate file with a series of `if` statements.

```
598 gcpy     def dxfpreamble(self, tn):
599 gcpy #         self.writedxf(tn,str(tn))
600 gcpy         self.writedxf(tn,"0")
601 gcpy         self.writedxf(tn,"SECTION")
602 gcpy         self.writedxf(tn,"2")
603 gcpy         self.writedxf(tn,"ENTITIES")
```

2.5.1.2 DXF Lines and Arcs There are two notable elements which may be written to a DXF:

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

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

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.

When writing out to a DXF file there is a pair of commands, a public facing command which takes in a tool number in addition to the coordinates which then writes out to the main DXF file and then calls an internal command to which repeats the call with the tool number so as to write it out to the matching file.

```
605 gcpy     def dxfline(self, tn, xbegin,ybegin,xend,yend):
606 gcpy         self.writedxf(tn,"0")
607 gcpy         self.writedxf(tn,"LWPOLYLINE")
608 gcpy         self.writedxf(tn,"90")
609 gcpy         self.writedxf(tn,"2")
610 gcpy         self.writedxf(tn,"70")
611 gcpy         self.writedxf(tn,"0")
```

```
612 gcpy          self.writedxf(tn,"43")
613 gcpy          self.writedxf(tn,"0")
614 gcpy          self.writedxf(tn,"10")
615 gcpy          self.writedxf(tn,str(xbegin))
616 gcpy          self.writedxf(tn,"20")
617 gcpy          self.writedxf(tn,str(ybegin))
618 gcpy          self.writedxf(tn,"10")
619 gcpy          self.writedxf(tn,str(xend))
620 gcpy          self.writedxf(tn,"20")
621 gcpy          self.writedxf(tn,str(yend))
```

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

```
134 gcpscad module dxfbpl(tn,bx,by) {
135 gcpscad     dxfwrite(tn,"0");
136 gcpscad     dxfwrite(tn,"POLYLINE");
137 gcpscad     dxfwrite(tn,"8");
138 gcpscad     dxfwrite(tn,"default");
139 gcpscad     dxfwrite(tn,"66");
140 gcpscad     dxfwrite(tn,"1");
141 gcpscad     dxfwrite(tn,"70");
142 gcpscad     dxfwrite(tn,"0");
143 gcpscad     dxfwrite(tn,"0");
144 gcpscad     dxfwrite(tn,"VERTEX");
145 gcpscad     dxfwrite(tn,"8");
146 gcpscad     dxfwrite(tn,"default");
147 gcpscad     dxfwrite(tn,"70");
148 gcpscad     dxfwrite(tn,"32");
149 gcpscad     dxfwrite(tn,"10");
150 gcpscad     dxfwrite(tn,str(bx));
151 gcpscad     dxfwrite(tn,"20");
152 gcpscad     dxfwrite(tn,str(by));
153 gcpscad }
154 gcpscad
155 gcpscad module beginpolyline(bx,by,bz) {
156 gcpscad if (generatedxf == true) {
157 gcpscad     dxfwriteone("0");
158 gcpscad     dxfwriteone("POLYLINE");
159 gcpscad     dxfwriteone("8");
160 gcpscad     dxfwriteone("default");
161 gcpscad     dxfwriteone("66");
162 gcpscad     dxfwriteone("1");
163 gcpscad     dxfwriteone("70");
164 gcpscad     dxfwriteone("0");
165 gcpscad     dxfwriteone("0");
166 gcpscad     dxfwriteone("VERTEX");
167 gcpscad     dxfwriteone("8");
168 gcpscad     dxfwriteone("default");
169 gcpscad     dxfwriteone("70");
170 gcpscad     dxfwriteone("32");
171 gcpscad     dxfwriteone("10");
172 gcpscad     dxfwriteone(str(bx));
173 gcpscad     dxfwriteone("20");
174 gcpscad     dxfwriteone(str(by));
175 gcpscad     dxfbpl(current_tool(),bx,by);}
176 gcpscad }
177 gcpscad
178 gcpscad module dxfapl(tn,bx,by) {
179 gcpscad     dxfwrite(tn,"0");
180 gcpscad     dxfwrite(tn,"VERTEX");
181 gcpscad     dxfwrite(tn,"8");
182 gcpscad     dxfwrite(tn,"default");
183 gcpscad     dxfwrite(tn,"70");
184 gcpscad     dxfwrite(tn,"32");
185 gcpscad     dxfwrite(tn,"10");
186 gcpscad     dxfwrite(tn,str(bx));
187 gcpscad     dxfwrite(tn,"20");
188 gcpscad     dxfwrite(tn,str(by));
189 gcpscad }
190 gcpscad
191 gcpscad module addpolyline(bx,by,bz) {
192 gcpscad if (generatedxf == true) {
193 gcpscad     dxfwriteone("0");
194 gcpscad     dxfwriteone("VERTEX");
195 gcpscad     dxfwriteone("8");
196 gcpscad     dxfwriteone("default");
197 gcpscad     dxfwriteone("70");
198 gcpscad     dxfwriteone("32");
```

```
199 gcpscad      dxfwriteone("10");
200 gcpscad      dxfwriteone(str(bx));
201 gcpscad      dxfwriteone("20");
202 gcpscad      dxfwriteone(str(by));
203 gcpscad      dxfapl(current_tool(),bx,by);
204 gcpscad      }
205 gcpscad }
206 gcpscad
207 gcpscad module dxfcpl(tn) {
208 gcpscad      dxfwrite(tn,"0");
209 gcpscad      dxfwrite(tn,"SEQEND");
210 gcpscad }
211 gcpscad
212 gcpscad module closepolyline() {
213 gcpscad    if (generatedxf == true) {
214 gcpscad      dxfwriteone("0");
215 gcpscad      dxfwriteone("SEQEND");
216 gcpscad      dxfcpl(current_tool());
217 gcpscad    }
218 gcpscad }
219 gcpscad
220 gcpscad module writecomment(comment) {
221 gcpscad    if (generategcode == true) {
222 gcpscad      owritecomment(comment);
223 gcpscad    }
224 gcpscad }
```

At the end of the project it will be necessary to close each file using the commands: pclosegcodefile pclosegcodefile, and closedxffile. In some instances it may be necessary to write additional closedxffile information, depending on the file format. Note that these commands will need to be within the gcodepreview class.

```
623 gcpy      def dxfpostamble(self,tn):
624 gcpy #         self.writedxf(tn,str(tn))
625 gcpy          self.writedxf(tn,"0")
626 gcpy          self.writedxf(tn,"ENDSEC")
627 gcpy          self.writedxf(tn,"0")
628 gcpy          self.writedxf(tn,"EOF")
```

```
630 gcpy      def gcodepostamble(self):
631 gcpy          self.writegc("Z12.700")
632 gcpy          self.writegc("M05")
633 gcpy          self.writegc("M02")
```

It will be necessary to call the dxfpostamble (with appropriate checks and trappings so as to ensure that each dxf file is ended and closed so as to be valid.

```
635 gcpy      def closegcodefile(self):
636 gcpy          self.gcodepostamble()
637 gcpy          self.gc.close()
638 gcpy
639 gcpy      def closedxffile(self):
640 gcpy          if self.generatedxf == True:
641 gcpy #             global dxfclosed
642 gcpy              self.dxfclosed = True
643 gcpy              self.dxfpostamble(-1)
644 gcpy              self.dxf.close()
645 gcpy
646 gcpy      def closedxffiles(self):
647 gcpy          if self.generatedxfs == True:
648 gcpy              if (self.large_square_tool_num > 0):
649 gcpy                  self.dxfpostamble(self.large_square_tool_num)
650 gcpy              if (self.small_square_tool_num > 0):
651 gcpy                  self.dxfpostamble(self.small_square_tool_num)
652 gcpy              if (self.large_ball_tool_num > 0):
653 gcpy                  self.dxfpostamble(self.large_ball_tool_num)
654 gcpy              if (self.small_ball_tool_num > 0):
655 gcpy                  self.dxfpostamble(self.small_ball_tool_num)
656 gcpy              if (self.large_V_tool_num > 0):
657 gcpy                  self.dxfpostamble(self.large_V_tool_num)
658 gcpy              if (self.small_V_tool_num > 0):
659 gcpy                  self.dxfpostamble(self.small_V_tool_num)
660 gcpy              if (self.DT_tool_num > 0):
661 gcpy                  self.dxfpostamble(self.DT_tool_num)
662 gcpy              if (self.KH_tool_num > 0):
```

```
663 gcpy                 self.dxfpostamble(self.KH_tool_num)
664 gcpy             if (self.Roundover_tool_num > 0):
665 gcpy                 self.dxfpostamble(self.Roundover_tool_num)
666 gcpy             if (self.MISC_tool_num > 0):
667 gcpy                 self.dxfpostamble(self.MISC_tool_num)
668 gcpy
669 gcpy             if (self.large_square_tool_num > 0):
670 gcpy                 self.dxflgsq.close()
671 gcpy             if (self.small_square_tool_num > 0):
672 gcpy                 self.dxfsmsq.close()
673 gcpy             if (self.large_ball_tool_num > 0):
674 gcpy                 self.dxflgbl.close()
675 gcpy             if (self.small_ball_tool_num > 0):
676 gcpy                 self.dxfsmbl.close()
677 gcpy             if (self.large_V_tool_num > 0):
678 gcpy                 self.dxflgV.close()
679 gcpy             if (self.small_V_tool_num > 0):
680 gcpy                 self.dxfsmV.close()
681 gcpy             if (self.DT_tool_num > 0):
682 gcpy                 self.dxfDT.close()
683 gcpy             if (self.KH_tool_num > 0):
684 gcpy                 self.dxfKH.close()
685 gcpy             if (self.Roundover_tool_num > 0):
686 gcpy                 self.dxfRt.close()
687 gcpy             if (self.MISC_tool_num > 0):
688 gcpy                 self.dxfMt.close()
```

In addition to the Python forms, there will need to be matching OpenSCAD commands to call them: `oclosegcodefile`, and `oclosedxffile`.

oclosegcodefile
oclosedxffile

```
173 pyscad module oclosegcodefile() {
174 pyscad     pclosegcodefile();
175 pyscad }
176 pyscad
177 pyscad module oclosedxffile() {
178 pyscad     pclosedxffile();
179 pyscad }
180 pyscad
181 pyscad module oclosedxflgblfile() {
182 pyscad     pclosedxflgblfile();
183 pyscad }
184 pyscad
185 pyscad module oclosedxflgsqfile() {
186 pyscad     pclosedxflgsqfile();
187 pyscad }
188 pyscad
189 pyscad module oclosedxflgVfile() {
190 pyscad     pclosedxflgVfile();
191 pyscad }
192 pyscad
193 pyscad module oclosedxfsmblfile() {
194 pyscad     pclosedxfsmblfile();
195 pyscad }
196 pyscad
197 pyscad module oclosedxfsmsqfile() {
198 pyscad     pclosedxfsmsqfile();
199 pyscad }
200 pyscad
201 pyscad module oclosedxfsmVfile() {
202 pyscad     pclosedxfsmVfile();
203 pyscad }
204 pyscad
205 pyscad module oclosedxfDTfile() {
206 pyscad     pclosedxfDTfile();
207 pyscad }
208 pyscad
209 pyscad module oclosedxfKHfile() {
210 pyscad     pclosedxfKHfile();
211 pyscad }
```

closegcodefile
closedxffile
dxfpostamble

The commands: `closegcodefile`, and `closedxffile` are used to close the files at the end of a program. For efficiency, each references the command: `dxfpostamble` which when called provides the boilerplate needed at the end of their respective files.

```
226 gcpscad module closegcodefile() {
227 gcpscad   if (generategcode == true) {
228 gcpscad     owriteone("M05");
```

```
229 gcpscad      owriteone("M02");
230 gcpscad      oclosegcodefile();
231 gcpscad    }
232 gcpscad }
233 gcpscad
234 gcpscad module dxfpostamble(arg) {
235 gcpscad      dxfwrite(arg,"0");
236 gcpscad      dxfwrite(arg,"ENDSEC");
237 gcpscad      dxfwrite(arg,"0");
238 gcpscad      dxfwrite(arg,"EOF");
239 gcpscad }
240 gcpscad
241 gcpscad module closedxffile() {
242 gcpscad    if (generatedxf == true) {
243 gcpscad      dxfwriteone("0");
244 gcpscad      dxfwriteone("ENDSEC");
245 gcpscad      dxfwriteone("0");
246 gcpscad      dxfwriteone("EOF");
247 gcpscad      oclosedxffile();
248 gcpscad //     echo("CLOSING");
249 gcpscad      if (large_ball_tool_num >  0) {    dxfpostamble(
                     large_ball_tool_num);
250 gcpscad        oclosedxflgblfile();
251 gcpscad      }
252 gcpscad      if (large_square_tool_num >  0) {    dxfpostamble(
                     large_square_tool_num);
253 gcpscad        oclosedxflgsqfile();
254 gcpscad      }
255 gcpscad      if (large_V_tool_num >  0) {    dxfpostamble(large_V_tool_num);
256 gcpscad        oclosedxflgVfile();
257 gcpscad      }
258 gcpscad      if (small_ball_tool_num >  0) {    dxfpostamble(
                     small_ball_tool_num);
259 gcpscad        oclosedxfsmblfile();
260 gcpscad      }
261 gcpscad      if (small_square_tool_num >  0) {    dxfpostamble(
                     small_square_tool_num);
262 gcpscad        oclosedxfsmsqfile();
263 gcpscad      }
264 gcpscad      if (small_V_tool_num >  0) {    dxfpostamble(small_V_tool_num);
265 gcpscad        oclosedxfsmVfile();
266 gcpscad      }
267 gcpscad      if (DT_tool_num >  0) {    dxfpostamble(DT_tool_num);
268 gcpscad        oclosedxfDTfile();
269 gcpscad      }
270 gcpscad      if (KH_tool_num >  0) {    dxfpostamble(KH_tool_num);
271 gcpscad        oclosedxfKHfile();
272 gcpscad      }
273 gcpscad    }
274 gcpscad }
```

2.6 Movement and Cutting

otm ocut orapid rapid rapidbx

With all the scaffolding in place, it is possible to model the tool: `otm`, (colors the tool model so as to differentiate cut areas) and cutting: `ocut`, as well as Rapid movements to position the tool to begin a cut: `orapid`, `rapid`, and `rapidbx` which will also need to write out files which represent the desired machine motions.

The first command needs to be a move to/from the safe Z height. In G-code this would be:

```
(Move to safe Z to avoid workholding)
G53G0Z-5.000
```

but in the 3D model, since we do not know how tall the Z-axis is, we simply move to safe height and use that as a starting point:

```
690 gcpy      def movetosafeZ(self):
691 gcpy #         global toolpaths
692 gcpy          self.writegc("(Move␣to␣safe␣Z␣to␣avoid␣workholding)")
693 gcpy          self.writegc("G53G0Z-5.000")
694 gcpy          self.setzpos(self.retractheight)
695 gcpy          toolpath = cylinder(1.5875,12.7)
696 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                      .zpos()])
697 gcpy #         self.toolpaths = union([self.toolpaths, toolpath])
698 gcpy          return toolpath
```

Note that a hard-coded cylinder is used since the command will be used prior to a toolchange. toolpaths In the future there may be a command for initializing the toolpaths so that later cut commands may add to it.

There are three different movements in G-code which will need to be handled. Rapid commands will be used for G0 movements and will not appear in DXFs but will appear in G-code files, while straight line cut (G1) and arc (G2/G3) commands will appear in both G-code and DXF files.

```
700 gcpy     def rapid(self, ex, ey, ez):
701 gcpy #         global toolpath
702 gcpy #         global toolpaths
703 gcpy         self.writegc("G00 X", str(ex), " Y", str(ey), " Z", str(ez)
                    )
704 gcpy         start = self.currenttool()
705 gcpy         start = start.translate([self.xpos(), self.ypos(), self.
                    zpos()])
706 gcpy         toolpath = hull(start, start.translate([ex,ey,ez]))
707 gcpy         self.setxpos(ex)
708 gcpy         self.setypos(ey)
709 gcpy         self.setzpos(ez)
710 gcpy #         self.toolpaths = union([self.toolpaths, toolpath])
711 gcpy         return toolpath
```

```
713 gcpy     def rapidXY(self, ex, ey):
714 gcpy #         global toolpath
715 gcpy #         global toolpaths
716 gcpy         self.writegc("G00 X", str(ex), " Y", str(ey))
717 gcpy         start = self.currenttool()
718 gcpy         start = start.translate([self.xpos(), self.ypos(), self.
                    zpos()])
719 gcpy         toolpath = hull(start, start.translate([ex,ey,self.zpos()])
                    )
720 gcpy         self.setxpos(ex)
721 gcpy         self.setypos(ey)
722 gcpy #         self.toolpaths = union([self.toolpaths, toolpath])
723 gcpy         return toolpath
```

```
725 gcpy     def rapidZ(self, ez):
726 gcpy #         global toolpath
727 gcpy #         global toolpaths
728 gcpy         self.writegc("G00 Z", str(ez))
729 gcpy         start = self.currenttool()
730 gcpy         start = start.translate([self.xpos(), self.ypos(), self.
                    zpos()])
731 gcpy         toolpath = hull(start, start.translate([self.xpos(),self.
                    ypos(),ez]))
732 gcpy         self.setzpos(ez)
733 gcpy #         self.toolpaths = union([self.toolpaths, toolpath])
734 gcpy         return toolpath
```

cut... The Python commands cut... add the currenttool to the toolpath hulled together at the current position and the end position of the move.

```
736 gcpy     def cutline(self,ex, ey, ez):
737 gcpy #         global toolpath
738 gcpy #         global toolpaths
739 gcpy #         print("cutline tool #", self.currenttoolnumber())
740 gcpy         if (self.currenttoolnumber() == 56142):
741 gcpy #                 print("cutline tool internal #", self.
        currenttoolnumber())
742 gcpy             toolpath = self.cutroundovertool(self.xpos(), self.ypos
                        (), self.zpos(), ex, ey, ez, 0.508/2, 1.531)
743 gcpy         elif (self.currenttoolnumber() == 56125):
744 gcpy             toolpath = self.cutroundovertool(self.xpos(), self.ypos
                        (), self.zpos(), ex, ey, ez, 0.508/2, 2.921)
745 gcpy #         elif (self.currenttoolnumber() == 312):
746 gcpy #             toolpath = self.cutroundovertool(self.xpos(), self.
        ypos(), self.zpos(), ex, ey, ez, 1.524/2, 3.175)
747 gcpy         elif (self.currenttoolnumber() == 1570):
748 gcpy             toolpath = self.cutroundovertool(self.xpos(), self.ypos
                        (), self.zpos(), ex, ey, ez, 0.507/2, 4.509)
749 gcpy         elif (self.currenttoolnumber() == 374):
750 gcpy #             self.writegc("(TOOL/MILL,9.53, 0.00, 3.17, 0.00)")
751 gcpy             shaft = cylinder(9.525, 6.35/2, 6.35/2)
```

```
752 gcpy             shaftend = shaft
753 gcpy             shaftbegin = shaft.translate([self.xpos(), self.ypos(),
                         self.zpos()])
754 gcpy             shaftpath = hull(shaftbegin, shaftend.translate([ex,ey,
                        ez]))
755 gcpy             start = cylinder(3.175, 9.525/2, 9.525/2)
756 gcpy             end = start
757 gcpy             start = start.translate([self.xpos(), self.ypos(), self
                        .zpos()])
758 gcpy             cutpath = hull(start, end.translate([ex,ey,ez]))
759 gcpy             toolpath = union(shaftpath, cutpath)
760 gcpy         elif (self.currenttoolnumber() == 375):
761 gcpy #            self.writegc("(TOOL/MILL,9.53, 0.00, 3.17, 0.00)")
762 gcpy             shaft = cylinder(9.525, 8/2, 8/2)
763 gcpy             shaftend = shaft
764 gcpy             shaftbegin = shaft.translate([self.xpos(), self.ypos(),
                         self.zpos()])
765 gcpy             shaftpath = hull(shaftbegin, shaftend.translate([ex,ey,
                        ez]))
766 gcpy             start = cylinder(3.175, 9.525/2, 9.525/2)
767 gcpy             end = start
768 gcpy             start = start.translate([self.xpos(), self.ypos(), self
                        .zpos()])
769 gcpy             cutpath = hull(start, end.translate([ex,ey,ez]))
770 gcpy             toolpath = union(shaftpath, cutpath)
771 gcpy         elif (self.currenttoolnumber() == 376):
772 gcpy #            self.writegc("(TOOL/MILL,12.7, 0.00, 4.77, 0.00)")
773 gcpy             shaft = cylinder(9.525, 6.35/2, 6.35/2)
774 gcpy             shaftend = shaft
775 gcpy             shaftbegin = shaft.translate([self.xpos(), self.ypos(),
                         self.zpos()])
776 gcpy             shaftpath = hull(shaftbegin, shaftend.translate([ex,ey,
                        ez]))
777 gcpy             start = cylinder(3.175, 12.7/2, 12.7/2)
778 gcpy             end = start
779 gcpy             start = start.translate([self.xpos(), self.ypos(), self
                        .zpos()])
780 gcpy             cutpath = hull(start, end.translate([ex,ey,ez]))
781 gcpy             toolpath = union(shaftpath, cutpath)
782 gcpy         elif (self.currenttoolnumber() == 378):
783 gcpy #            self.writegc("(TOOL/MILL,12.7, 0.00, 4.77, 0.00)")
784 gcpy             shaft = cylinder(9.525, 8/2, 8/2)
785 gcpy             shaftend = shaft
786 gcpy             shaftbegin = shaft.translate([self.xpos(), self.ypos(),
                         self.zpos()])
787 gcpy             shaftpath = hull(shaftbegin, shaftend.translate([ex,ey,
                        ez]))
788 gcpy             start = cylinder(3.175, 12.7/2, 12.7/2)
789 gcpy             end = start
790 gcpy             start = start.translate([self.xpos(), self.ypos(), self
                        .zpos()])
791 gcpy             cutpath = hull(start, end.translate([ex,ey,ez]))
792 gcpy             toolpath = union(shaftpath, cutpath)
793 gcpy         else:
794 gcpy             start = self.currenttool()
795 gcpy             start = start.translate([self.xpos(), self.ypos(), self
                        .zpos()])
796 gcpy             end = self.currenttool()
797 gcpy             toolpath = hull(start, end.translate([ex,ey,ez]))
798 gcpy         self.setxpos(ex)
799 gcpy         self.setypos(ey)
800 gcpy         self.setzpos(ez)
801 gcpy #        self.toolpaths = union([self.toolpaths, toolpath])
802 gcpy         return toolpath
803 gcpy
804 gcpy     def cutZgcfeed(self, ez, feed):
805 gcpy         self.writegc("G01␣Z", str(ez), "F",str(feed))
806 gcpy         return self.cutline(self.xpos(),self.ypos(),ez)
807 gcpy
808 gcpy     def cutlinedxfgc(self,ex, ey, ez):
809 gcpy         self.dxfline(self.currenttoolnumber(), self.xpos(), self.
                    ypos(), ex, ey)
810 gcpy         self.writegc("G01␣X", str(ex), "␣Y", str(ey), "␣Z", str(ez)
                    )
811 gcpy         return self.cutline(ex, ey, ez)
812 gcpy
813 gcpy     def cutlinedxfgcfeed(self,ex, ey, ez, feed):
814 gcpy         self.dxfline(self.currenttoolnumber(), self.xpos(), self.
```

```
                ypos(), ex, ey)
815 gcpy          self.writegc("G01␣X", str(ex), "␣Y", str(ey), "␣Z", str(ez)
                    , "␣F", str(feed))
816 gcpy          return self.cutline(ex, ey, ez)
817 gcpy
818 gcpy      def cutroundovertool(self, bx, by, bz, ex, ey, ez,
                  tool_radius_tip, tool_radius_width):
819 gcpy #         n = 90 + fn*3
820 gcpy #         print("Tool dimensions", tool_radius_tip,
          tool_radius_width, "begin ",bx, by, bz,"end ", ex, ey, ez)
821 gcpy          step = 4 #360/n
822 gcpy          shaft = cylinder(step,tool_radius_tip,tool_radius_tip)
823 gcpy          toolpath = hull(shaft.translate([bx,by,bz]), shaft.
                    translate([ex,ey,ez]))
824 gcpy          shaft = cylinder(tool_radius_width*2,tool_radius_tip+
                    tool_radius_width,tool_radius_tip+tool_radius_width)
825 gcpy          toolpath = toolpath.union(hull(shaft.translate([bx,by,bz+
                    tool_radius_width]), shaft.translate([ex,ey,ez+
                    tool_radius_width])))
826 gcpy          for i in range(1, 90, 1):
827 gcpy              angle = i
828 gcpy              dx = tool_radius_width*math.cos(math.radians(angle))
829 gcpy              dxx = tool_radius_width*math.cos(math.radians(angle+1))
830 gcpy              dzz = tool_radius_width*math.sin(math.radians(angle))
831 gcpy              dz = tool_radius_width*math.sin(math.radians(angle+1))
832 gcpy              dh = abs(dzz-dz)+0.0001
833 gcpy              slice = cylinder(dh,tool_radius_tip+tool_radius_width-
                        dx,tool_radius_tip+tool_radius_width-dxx)
834 gcpy              toolpath = toolpath.union(hull(slice.translate([bx,by,
                        bz+dz]), slice.translate([ex,ey,ez+dz])))
835 gcpy          return toolpath
```

```
276 gcpscad module otm(ex, ey, ez, r,g,b) {
277 gcpscad color([r,g,b]) hull(){
278 gcpscad     translate([xpos(), ypos(), zpos()]){
279 gcpscad       select_tool(current_tool());
280 gcpscad     }
281 gcpscad     translate([ex, ey, ez]){
282 gcpscad       select_tool(current_tool());
283 gcpscad     }
284 gcpscad   }
285 gcpscad oset(ex, ey, ez);
286 gcpscad }
287 gcpscad
288 gcpscad module ocut(ex, ey, ez) {
289 gcpscad   //color([0.2,1,0.2]) hull(){
290 gcpscad   otm(ex, ey, ez, 0.2,1,0.2);
291 gcpscad }
292 gcpscad
293 gcpscad module orapid(ex, ey, ez) {
294 gcpscad   //color([0.93,0,0]) hull(){
295 gcpscad   otm(ex, ey, ez, 0.93,0,0);
296 gcpscad }
297 gcpscad
298 gcpscad module rapidbx(bx, by, bz, ex, ey, ez) {
299 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
300 gcpscad   if (generategcode == true) {
301 gcpscad     writecomment("rapid");
302 gcpscad     owritesix("G0 X",str(ex)," Y", str(ey), " Z", str(ez));
303 gcpscad   }
304 gcpscad     orapid(ex, ey, ez);
305 gcpscad }
306 gcpscad
307 gcpscad module rapid(ex, ey, ez) {
308 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
309 gcpscad   if (generategcode == true) {
310 gcpscad       writecomment("rapid");
311 gcpscad       owritesix("G0 X",str(ex)," Y", str(ey), " Z", str(ez));
312 gcpscad   }
313 gcpscad   orapid(ex, ey, ez);
314 gcpscad }
315 gcpscad
316 gcpscad module movetosafez() {
317 gcpscad   //this should be move to retract height
318 gcpscad   if (generategcode == true) {
319 gcpscad       writecomment("Move to safe Z to avoid workholding");
320 gcpscad       owriteone("G53G0Z-5.000");
```

```
321 gcpscad   }
322 gcpscad   orapid(getxpos(), getypos(), retractheight+55);
323 gcpscad }
324 gcpscad
325 gcpscad module begintoolpath(bx,by,bz) {
326 gcpscad   if (generategcode == true) {
327 gcpscad     writecomment("PREPOSITION FOR RAPID PLUNGE");
328 gcpscad     owritefour("G0X", str(bx), "Y",str(by));
329 gcpscad     owritetwo("Z", str(bz));
330 gcpscad   }
331 gcpscad   orapid(bx,by,bz);
332 gcpscad }
333 gcpscad
334 gcpscad module movetosafeheight() {
335 gcpscad   //this should be move to machine position
336 gcpscad   if (generategcode == true) {
337 gcpscad   //    writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
338 gcpscad   //G1Z24.663F381.0 ,"F",str(plunge)
339 gcpscad     if (zeroheight == "Top") {
340 gcpscad       owritetwo("Z",str(retractheight));
341 gcpscad     }
342 gcpscad   }
343 gcpscad     orapid(getxpos(), getypos(), retractheight+55);
344 gcpscad }
345 gcpscad
346 gcpscad module cutoneaxis_setfeed(axis,depth,feed) {
347 gcpscad   if (generategcode == true) {
348 gcpscad   //    writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
349 gcpscad   //G1Z24.663F381.0 ,"F",str(plunge) G1Z7.612F381.0
350 gcpscad     if (zeroheight == "Top") {
351 gcpscad       owritefive("G1",axis,str(depth),"F",str(feed));
352 gcpscad     }
353 gcpscad   }
354 gcpscad   if (axis == "X") {setxpos(depth);
355 gcpscad     ocut(depth, getypos(), getzpos());}
356 gcpscad     if (axis == "Y") {setypos(depth);
357 gcpscad       ocut(getxpos(), depth, getzpos());
358 gcpscad     }
359 gcpscad       if (axis == "Z") {setzpos(depth);
360 gcpscad         ocut(getxpos(), getypos(), depth);
361 gcpscad       }
362 gcpscad }
363 gcpscad
364 gcpscad module cut(ex, ey, ez) {
365 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
366 gcpscad   if (generategcode == true) {
367 gcpscad      owritesix("G1 X",str(ex)," Y", str(ey), " Z", str(ez));
368 gcpscad   }
369 gcpscad   //if (generatesvg == true) {
370 gcpscad   //    owritesix("G1 X",str(ex)," Y", str(ey), " Z", str(ez));
371 gcpscad   //    orapid(getxpos(), getypos(), retractheight+5);
372 gcpscad   //    writesvgline(getxpos(),getypos(),ex,ey);
373 gcpscad   //}
374 gcpscad   ocut(ex, ey, ez);
375 gcpscad }
376 gcpscad
377 gcpscad module cutwithfeed(ex, ey, ez, feed) {
378 gcpscad   //    writeln("G0 X",bx," Y", by, "Z", bz);
379 gcpscad   if (generategcode == true) {
380 gcpscad   //    writecomment("rapid");
381 gcpscad     owriteeight("G1 X",str(ex)," Y", str(ey), " Z", str(ez),"F",str
                (feed));
382 gcpscad   }
383 gcpscad   ocut(ex, ey, ez);
384 gcpscad }
385 gcpscad
386 gcpscad module endtoolpath() {
387 gcpscad   if (generategcode == true) {
388 gcpscad   //Z31.750
389 gcpscad   //    owriteone("G53G0Z-5.000");
390 gcpscad     owritetwo("Z",str(retractheight));
391 gcpscad   }
392 gcpscad   orapid(getxpos(),getypos(),retractheight);
393 gcpscad }
```

3 Cutting shapes, cut2Dshapes, and expansion

Certain basic shapes (arcs, circles, rectangles), will be incorporated in the main code. Other shapes will be added to the additional/optional file, `cut2Dshapes.scad` as they are developed, and of course the user is free to develop their own systems.

It is most expedient to test out new features in a new/separate file insofar as the file structures will allow (tool definitions for example will need to consolidated in 2.4.2) 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 for two-dimensional regions will be to define them 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
- Pocket — such toolpaths/geometry should include the rounding of the tool at the corners, c.f., cutrectangledxf
- 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 dovetail 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
- 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

- 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) — cutrectangledxf, cutoutrectangledxf, rectangleoutlinedxf
  - 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 below. (Its also the shape used for the spaceship in the game Asteroids (or Hyperspace), but that is potentially confusing with astroid.) At the conference, Dr. 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?

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(xcenter, ycenter, radius, anglebegin, endangle, tn)`
- 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

`arcloop` `narcloop`

Since OpenSCAD does not have an arc movement command it is necessary to iterate through a loop: `arcloop` (clockwise), `narcloop` (counterclockwise) to handle the drawing and processing of the `cut()` toolpaths as short line segments which additionally affords a single point of control for adding additional features such as allowing the depth to vary as one cuts along an arc. Note that the definition matches the `DXF` definition of defining the center position with a matching radius, but it will be necessary to move the tool to the actual origin, and to calculate the end position when writing out a `G2/G3` arc.

```
837 gcpy     def arcloop(self, barc, earc, xcenter, ycenter, radius):
838 gcpy #         global toolpath
839 gcpy         toolpath = self.currenttool()
840 gcpy         toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
841 gcpy         i = barc
842 gcpy         while i < earc:
843 gcpy             toolpath = toolpath.union(self.cutline(xcenter + radius
                          * math.cos(math.radians(i)), ycenter + radius *
                         math.sin(math.radians(i)), self.zpos()-(self.tzpos()
                         )))
844 gcpy             self.setxpos(xcenter + radius * math.cos(math.radians(i
                         )))
845 gcpy             self.setypos(ycenter + radius * math.sin(math.radians(i
                         )))
846 gcpy             i += 1
847 gcpy #         self.dxfarc(xcenter, ycenter, radius, barc, earc, self.
            currenttoolnumber())
848 gcpy         return toolpath
849 gcpy
850 gcpy     def narcloop(barc,earc, xcenter, ycenter, radius):
851 gcpy #         global toolpath
852 gcpy         toolpath = self.currenttool()
853 gcpy         toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
854 gcpy         i = barc
```

```
855 gcpy          while i > earc:
856 gcpy              toolpath = toolpath.union(self.cutline(xcenter + radius
                          * math.cos(math.radians(i)), ycenter + radius *
                         math.sin(math.radians(i)), self.zpos()-(self.tzpos()
                         )))
857 gcpy              self.setxpos(xcenter + radius * math.cos(math.radians(i
                         )))
858 gcpy              self.setypos(ycenter + radius * math.sin(math.radians(i
                         )))
859 gcpy #             print(str(self.xpos()), str(self.ypos()))
860 gcpy              i += -1
861 gcpy #          self.dxfarc(xcenter, ycenter, radius, barc, earc, self.
        currenttoolnumber())
862 gcpy          return toolpath
```

There are specific commands for writing out the DXF and G-code files. Note that for the G-code version it will be necessary to calculate the end-position.

```
864 gcpy      def dxfarc(self, xcenter, ycenter, radius, anglebegin, endangle
                 , tn):
865 gcpy          if (self.generatedxf == True):
866 gcpy              self.writedxf(tn, "0")
867 gcpy              self.writedxf(tn, "ARC")
868 gcpy              self.writedxf(tn, "10")
869 gcpy              self.writedxf(tn, str(xcenter))
870 gcpy              self.writedxf(tn, "20")
871 gcpy              self.writedxf(tn, str(ycenter))
872 gcpy              self.writedxf(tn, "40")
873 gcpy              self.writedxf(tn, str(radius))
874 gcpy              self.writedxf(tn, "50")
875 gcpy              self.writedxf(tn, str(anglebegin))
876 gcpy              self.writedxf(tn, "51")
877 gcpy              self.writedxf(tn, str(endangle))
878 gcpy
879 gcpy      def gcodearc(self, xcenter, ycenter, radius, anglebegin,
                 endangle, tn):
880 gcpy          if (self.generategcode == True):
881 gcpy              self.writegc(tn, "(0)")
```

The various textual versions are quite obvious, and due to the requirements of G-code, it is easiest to include the G-code in them if it is wanted.

```
883 gcpy      def cutarcNECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
884 gcpy #         global toolpath
885 gcpy          toolpath = self.currenttool()
886 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
887 gcpy          self.dxfarc(xcenter,ycenter,radius,0,90, self.
                     currenttoolnumber())
888 gcpy          if (self.zpos == ez):
889 gcpy              self.settzpos(0)
890 gcpy          else:
891 gcpy              self.settzpos((self.zpos()-ez)/90)
892 gcpy          toolpath = self.arcloop(1,90, xcenter, ycenter, radius)
893 gcpy          self.setxpos(ex)
894 gcpy          self.setypos(ey)
895 gcpy          self.setzpos(ez)
896 gcpy          return toolpath
897 gcpy
898 gcpy      def cutarcNWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
899 gcpy #         global toolpath
900 gcpy          toolpath = self.currenttool()
901 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
902 gcpy          self.dxfarc(xcenter,ycenter,radius,90,180, self.
                     currenttoolnumber())
903 gcpy          if (self.zpos == ez):
904 gcpy              self.settzpos(0)
905 gcpy          else:
906 gcpy              self.settzpos((self.zpos()-ez)/90)
907 gcpy          toolpath = self.arcloop(91,180, xcenter, ycenter, radius)
908 gcpy          self.setxpos(ex)
909 gcpy          self.setypos(ey)
910 gcpy          self.setzpos(ez)
911 gcpy          return toolpath
912 gcpy
913 gcpy      def cutarcSWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
```

```
914 gcpy #         global toolpath
915 gcpy          toolpath = self.currenttool()
916 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
917 gcpy          self.dxfarc(xcenter,ycenter,radius,180,270, self.
                     currenttoolnumber())
918 gcpy          if (self.zpos == ez):
919 gcpy              self.settzpos(0)
920 gcpy          else:
921 gcpy              self.settzpos((self.zpos()-ez)/90)
922 gcpy          toolpath = self.arcloop(181,270, xcenter, ycenter, radius)
923 gcpy          self.setxpos(ex)
924 gcpy          self.setypos(ey)
925 gcpy          self.setzpos(ez)
926 gcpy          return toolpath
927 gcpy
928 gcpy      def cutarcSECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
929 gcpy #         global toolpath
930 gcpy          toolpath = self.currenttool()
931 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
932 gcpy          self.dxfarc(xcenter,ycenter,radius,270,360, self.
                     currenttoolnumber())
933 gcpy          if (self.zpos == ez):
934 gcpy              self.settzpos(0)
935 gcpy          else:
936 gcpy              self.settzpos((self.zpos()-ez)/90)
937 gcpy          toolpath = self.arcloop(271,360, xcenter, ycenter, radius)
938 gcpy          self.setxpos(ex)
939 gcpy          self.setypos(ey)
940 gcpy          self.setzpos(ez)
941 gcpy          return toolpath
942 gcpy
943 gcpy      def cutarcNECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
944 gcpy #         global toolpath
945 gcpy          toolpath = self.currenttool()
946 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
947 gcpy          self.dxfarc(xcenter,ycenter,radius,0,90, self.
                     currenttoolnumber())
948 gcpy          if (self.zpos == ez):
949 gcpy              self.settzpos(0)
950 gcpy          else:
951 gcpy              self.settzpos((self.zpos()-ez)/90)
952 gcpy          toolpath = self.narcloop(89,0, xcenter, ycenter, radius)
953 gcpy          self.setxpos(ex)
954 gcpy          self.setypos(ey)
955 gcpy          self.setzpos(ez)
956 gcpy          return toolpath
957 gcpy
958 gcpy      def cutarcSECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
959 gcpy #         global toolpath
960 gcpy          toolpath = self.currenttool()
961 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
962 gcpy          self.dxfarc(xcenter,ycenter,radius,270,360, self.
                     currenttoolnumber())
963 gcpy          if (self.zpos == ez):
964 gcpy              self.settzpos(0)
965 gcpy          else:
966 gcpy              self.settzpos((self.zpos()-ez)/90)
967 gcpy          toolpath = self.narcloop(359,270, xcenter, ycenter, radius)
968 gcpy          self.setxpos(ex)
969 gcpy          self.setypos(ey)
970 gcpy          self.setzpos(ez)
971 gcpy          return toolpath
972 gcpy
973 gcpy      def cutarcSWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
974 gcpy #         global toolpath
975 gcpy          toolpath = self.currenttool()
976 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                     .zpos()])
977 gcpy          self.dxfarc(xcenter,ycenter,radius,180,270, self.
                     currenttoolnumber())
978 gcpy          if (self.zpos == ez):
979 gcpy              self.settzpos(0)
980 gcpy          else:
981 gcpy              self.settzpos((self.zpos()-ez)/90)
```

```
 982 gcpy          toolpath = self.narcloop(269,180, xcenter, ycenter, radius)
 983 gcpy          self.setxpos(ex)
 984 gcpy          self.setypos(ey)
 985 gcpy          self.setzpos(ez)
 986 gcpy          return toolpath
 987 gcpy
 988 gcpy      def cutarcNWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
 989 gcpy #          global toolpath
 990 gcpy          toolpath = self.currenttool()
 991 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                       .zpos()])
 992 gcpy          self.dxfarc(xcenter,ycenter,radius,90,180, self.
                       currenttoolnumber())
 993 gcpy          if (self.zpos == ez):
 994 gcpy              self.settzpos(0)
 995 gcpy          else:
 996 gcpy              self.settzpos((self.zpos()-ez)/90)
 997 gcpy          toolpath = self.narcloop(179,90, xcenter, ycenter, radius)
 998 gcpy          self.setxpos(ex)
 999 gcpy          self.setypos(ey)
1000 gcpy          self.setzpos(ez)
1001 gcpy          return toolpath
```

Using such commands to create a circle is quite straight-forward:

```
cutarcNECCdxf(-stockXwidth/4, stockYheight/4+stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcNWCCdxf(-(stockXwidth/4+stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock
cutarcSWCCdxf(-stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcSECCdxf(-(stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock
```

```
1003 gcpy      def arcCCgc(self, ex, ey, ez, xcenter, ycenter, radius):
1004 gcpy          self.writegc("G03␣X", str(ex), "␣Y", str(ey), "␣Z", str(ez)
                       , "␣R", str(radius))
1005 gcpy
1006 gcpy      def arcCWgc(self, ex, ey, ez, xcenter, ycenter, radius):
1007 gcpy          self.writegc("G02␣X", str(ex), "␣Y", str(ey), "␣Z", str(ez)
                       , "␣R", str(radius))
```

The above commands may be called if G-code is also wanted with writing out G-code added:

```
1009 gcpy      def cutarcNECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1010 gcpy          self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1011 gcpy          return self.cutarcNECCdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1012 gcpy
1013 gcpy      def cutarcNWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1014 gcpy          self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1015 gcpy          return self.cutarcNWCCdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1016 gcpy
1017 gcpy      def cutarcSWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1018 gcpy          self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1019 gcpy          return self.cutarcSWCCdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1020 gcpy
1021 gcpy      def cutarcSECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1022 gcpy          self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1023 gcpy          return self.cutarcSECCdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1024 gcpy
1025 gcpy      def cutarcNECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1026 gcpy          self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1027 gcpy          return self.cutarcNECWdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1028 gcpy
1029 gcpy      def cutarcSECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                   :
1030 gcpy          self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1031 gcpy          return self.cutarcSECWdxf(ex, ey, ez, xcenter, ycenter,
                       radius)
1032 gcpy
```

```
1033 gcpy     def cutarcSWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                  :
1034 gcpy         self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1035 gcpy         return self.cutarcSWCWdxf(ex, ey, ez, xcenter, ycenter,
                      radius)
1036 gcpy
1037 gcpy     def cutarcNWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
                  :
1038 gcpy         self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1039 gcpy         return self.cutarcNWCWdxf(ex, ey, ez, xcenter, ycenter,
                      radius)
```

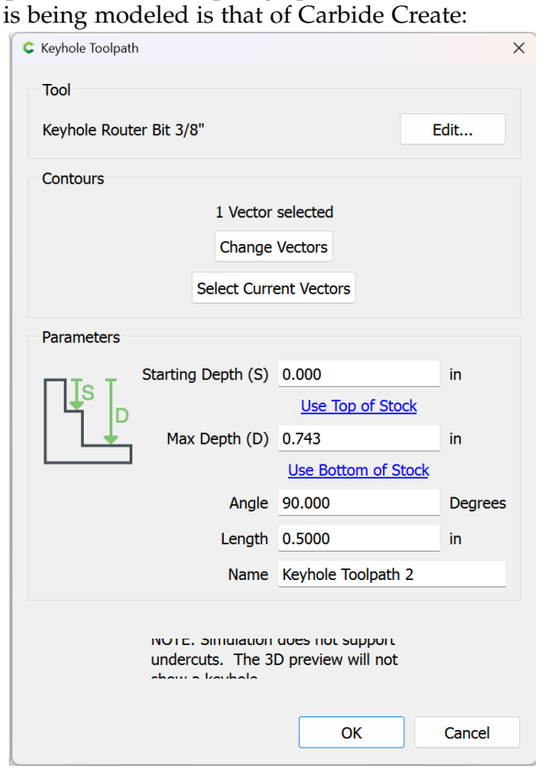
3.2 Keyhole toolpath and undercut tooling

cutkeyhole toolpath

The first topologically unusual toolpath is `cutkeyhole toolpath` — 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 2.4.1.2

The interface which is being modeled is that of Carbide Create:



Hence the parameters:

- Starting Depth == `kh_start_depth`
- Max Depth == `kh_max_depth`
- Angle == `kht_direction`
- Length == `kh_distance`
- Tool == `kh_tool_num`

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, S, E, and W will be supported in the initial version. This will be done by wrapping the command with a version which only accepts those options:

```
1041 gcpy      def cutkeyholegcdxf(self, kh_start_depth, kh_max_depth,
                   kht_direction, kh_distance, kh_tool_num):
1042 gcpy          if (kht_direction == "N"):
1043 gcpy              toolpath = self.cutKHgcdxf(kh_start_depth, kh_max_depth
                           , 90, kh_distance, kh_tool_num)
1044 gcpy              return toolpath
1045 gcpy          elif (kht_direction == "S"):
1046 gcpy              toolpath = self.cutKHgcdxf(kh_start_depth, kh_max_depth
                           , 270, kh_distance, kh_tool_num)
1047 gcpy              return toolpath
1048 gcpy          elif (kht_direction == "E"):
1049 gcpy              toolpath = self.cutKHgcdxf(kh_start_depth, kh_max_depth
                           , 0, kh_distance, kh_tool_num)
1050 gcpy              return toolpath
1051 gcpy          elif (kht_direction == "W"):
1052 gcpy              toolpath = self.cutKHgcdxf(kh_start_depth, kh_max_depth
                           , 180, kh_distance, kh_tool_num)
1053 gcpy              return toolpath
```

cutKHgcdxf The original version of the command, `cutKHgcdxf` retains an interface which allows calling it for arbitrary beginning and ending points of an arc. 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:

```
1055 gcpy      def cutKHgcdxf(self, kh_start_depth, kh_max_depth, kh_angle,
                   kh_distance, kh_tool_num):
1056 gcpy          oXpos = self.xpos()
1057 gcpy          oYpos = self.ypos()
1058 gcpy #Circle at entry hole
1059 gcpy #    def dxfarc(self, xcenter, ycenter, radius, anglebegin,
               endangle, tn):
1060 gcpy #         print(self.tool_radius(kh_tool_num, 7))
1061 gcpy          self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                       kh_tool_num, 7),  0, 90, kh_tool_num)
1062 gcpy          self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                       kh_tool_num, 7), 90,180, kh_tool_num)
1063 gcpy          self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                       kh_tool_num, 7),180,270, kh_tool_num)
1064 gcpy          self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                       kh_tool_num, 7),270,360, kh_tool_num)
1065 gcpy          toolpath = self.cutline(self.xpos(), self.ypos(), -
                       kh_max_depth)
```

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

```
1067 gcpy #pre-calculate needed values
1068 gcpy          r = self.tool_radius(kh_tool_num, 7)
1069 gcpy #         print(r)
1070 gcpy          rt = self.tool_radius(kh_tool_num, 1)
1071 gcpy #         print(rt)
1072 gcpy          ro = math.sqrt((self.tool_radius(kh_tool_num, 1))**2-(self.
                       tool_radius(kh_tool_num, 7))**2)
1073 gcpy #         print(ro)
1074 gcpy          angle = math.degrees(math.acos(ro/rt))
1075 gcpy #Outlines of entry hole and slot
1076 gcpy          if (kh_angle == 0):
1077 gcpy #Lower left of entry hole
1078 gcpy              self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                           kh_tool_num, 1),180,270, kh_tool_num)
1079 gcpy #Upper left of entry hole
1080 gcpy              self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                           kh_tool_num, 1),90,180, kh_tool_num)
1081 gcpy #Upper right of entry hole
1082 gcpy #             self.dxfarc(self.xpos(), self.ypos(), rt, 41.810, 90,
               kh_tool_num)
1083 gcpy              self.dxfarc(self.xpos(), self.ypos(), rt, angle, 90,
                           kh_tool_num)
1084 gcpy #Lower right of entry hole
1085 gcpy              self.dxfarc(self.xpos(), self.ypos(), rt, 270, 360-
                           angle, kh_tool_num)
1086 gcpy #             self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
               kh_tool_num, 1),270, 270+math.acos(math.radians(self.
               tool_diameter(kh_tool_num, 5)/self.tool_diameter(kh_tool_num, 1)
               )), kh_tool_num)
1087 gcpy #Actual line of cut
1088 gcpy #             self.dxfline(kh_tool_num, self.xpos(),self.ypos(),self
```

```
            .xpos()+kh_distance,self.ypos())
1089 gcpy #upper right of end of slot (kh_max_depth+4.36))/2
1090 gcpy             self.dxfarc(self.xpos()+kh_distance,self.ypos(),self.
                          tool_diameter(kh_tool_num, (kh_max_depth+4.36))
                          /2,0,90, kh_tool_num)
1091 gcpy #lower right of end of slot
1092 gcpy             self.dxfarc(self.xpos()+kh_distance,self.ypos(),self.
                          tool_diameter(kh_tool_num, (kh_max_depth+4.36))
                          /2,270,360, kh_tool_num)
1093 gcpy #upper right slot
1094 gcpy             self.dxfline(kh_tool_num, self.xpos()+ro, self.ypos()-(
                          self.tool_diameter(kh_tool_num,7)/2), self.xpos()+
                          kh_distance, self.ypos()-(self.tool_diameter(
                          kh_tool_num,7)/2))
1095 gcpy #             self.dxfline(kh_tool_num, self.xpos()+(sqrt((self.
            tool_diameter(kh_tool_num,1)^2)-(self.tool_diameter(kh_tool_num
            ,5)^2))/2), self.ypos()+self.tool_diameter(kh_tool_num, (
            kh_max_depth))/2, ( (kh_max_depth-6.34))/2)^2-(self.
            tool_diameter(kh_tool_num, (kh_max_depth-6.34))/2)^2, self.xpos
            ()+kh_distance, self.ypos()+self.tool_diameter(kh_tool_num, (
            kh_max_depth))/2, kh_tool_num)
1096 gcpy #end position at top of slot
1097 gcpy #lower right slot
1098 gcpy             self.dxfline(kh_tool_num, self.xpos()+ro, self.ypos()+(
                          self.tool_diameter(kh_tool_num,7)/2), self.xpos()+
                          kh_distance, self.ypos()+(self.tool_diameter(
                          kh_tool_num,7)/2))
1099 gcpy #         dxfline(kh_tool_num, self.xpos()+(sqrt((self.tool_diameter
            (kh_tool_num,1)^2)-(self.tool_diameter(kh_tool_num,5)^2))/2),
            self.ypos()-self.tool_diameter(kh_tool_num, (kh_max_depth))/2, (
             (kh_max_depth-6.34))/2)^2-(self.tool_diameter(kh_tool_num, (
            kh_max_depth-6.34))/2)^2, self.xpos()+kh_distance, self.ypos()-
            self.tool_diameter(kh_tool_num, (kh_max_depth))/2, KH_tool_num)
1100 gcpy #end position at top of slot
1101 gcpy #    hull(){
1102 gcpy #      translate([xpos(), ypos(), zpos()]){
1103 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1104 gcpy #      }
1105 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1106 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1107 gcpy #      }
1108 gcpy #    }
1109 gcpy #    hull(){
1110 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1111 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1112 gcpy #      }
1113 gcpy #      translate([xpos()+kh_distance, ypos(), zpos()-kh_max_depth])
            {
1114 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1115 gcpy #      }
1116 gcpy #    }
1117 gcpy #    cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
1118 gcpy #    cutwithfeed(getxpos()+kh_distance,getypos(),-kh_max_depth,feed
            );
1119 gcpy #    setxpos(getxpos()-kh_distance);
1120 gcpy #  } else if (kh_angle > 0 && kh_angle < 90) {
1121 gcpy #//echo(kh_angle);
1122 gcpy #  dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
            kh_max_depth))/2,90+kh_angle,180+kh_angle, KH_tool_num);
1123 gcpy #  dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
            kh_max_depth))/2,180+kh_angle,270+kh_angle, KH_tool_num);
1124 gcpy #dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
            kh_max_depth))/2,kh_angle+asin((tool_diameter(KH_tool_num, (
            kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth
            ))/2)),90+kh_angle, KH_tool_num);
1125 gcpy #dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
            kh_max_depth))/2,270+kh_angle,360+kh_angle-asin((tool_diameter(
            KH_tool_num, (kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num,
             (kh_max_depth))/2)), KH_tool_num);
1126 gcpy #dxfarc(getxpos()+(kh_distance*cos(kh_angle)),
1127 gcpy #  getypos()+(kh_distance*sin(kh_angle)),tool_diameter(KH_tool_num,
             (kh_max_depth+4.36))/2,0+kh_angle,90+kh_angle, KH_tool_num);
1128 gcpy #dxfarc(getxpos()+(kh_distance*cos(kh_angle)),getypos()+(
            kh_distance*sin(kh_angle)),tool_diameter(KH_tool_num, (
            kh_max_depth+4.36))/2,270+kh_angle,360+kh_angle, KH_tool_num);
1129 gcpy #dxfline( getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2*
            cos(kh_angle+asin((tool_diameter(KH_tool_num, (kh_max_depth
            +4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2))),
```

```
1130 gcpy # getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2*sin(
         kh_angle+asin((tool_diameter(KH_tool_num, (kh_max_depth+4.36))
         /2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2))),
1131 gcpy # getxpos()+(kh_distance*cos(kh_angle))-((tool_diameter(KH_tool_num
         , (kh_max_depth+4.36))/2)*sin(kh_angle)),
1132 gcpy # getypos()+(kh_distance*sin(kh_angle))+((tool_diameter(KH_tool_num
         , (kh_max_depth+4.36))/2)*cos(kh_angle)), KH_tool_num);
1133 gcpy #//echo("a",tool_diameter(KH_tool_num, (kh_max_depth+4.36))/2);
1134 gcpy #//echo("c",tool_diameter(KH_tool_num, (kh_max_depth))/2);
1135 gcpy #echo("Aangle",asin((tool_diameter(KH_tool_num, (kh_max_depth+4.36)
         )/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2)));
1136 gcpy #//echo(kh_angle);
1137 gcpy # cutwithfeed(getxpos()+(kh_distance*cos(kh_angle)),getypos()+(
         kh_distance*sin(kh_angle)),-kh_max_depth,feed);
1138 gcpy                 toolpath = toolpath.union(self.cutline(self.xpos()+
                         kh_distance, self.ypos(), -kh_max_depth))
1139 gcpy             elif (kh_angle == 90):
1140 gcpy #Lower left of entry hole
1141 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),180,270, kh_tool_num)
1142 gcpy #Lower right of entry hole
1143 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),270,360, kh_tool_num)
1144 gcpy #left slot
1145 gcpy                 self.dxfline(kh_tool_num, self.xpos()-r, self.ypos()+ro
                         , self.xpos()-r, self.ypos()+kh_distance)
1146 gcpy #right slot
1147 gcpy                 self.dxfline(kh_tool_num, self.xpos()+r, self.ypos()+ro
                         , self.xpos()+r, self.ypos()+kh_distance)
1148 gcpy #upper left of end of slot
1149 gcpy                 self.dxfarc(self.xpos(),self.ypos()+kh_distance,r
                         ,90,180, kh_tool_num)
1150 gcpy #upper right of end of slot
1151 gcpy                 self.dxfarc(self.xpos(),self.ypos()+kh_distance,r,0,90,
                          kh_tool_num)
1152 gcpy #Upper right of entry hole
1153 gcpy                 self.dxfarc(self.xpos(), self.ypos(), rt, 0, 90-angle,
                         kh_tool_num)
1154 gcpy #Upper left of entry hole
1155 gcpy                 self.dxfarc(self.xpos(), self.ypos(), rt, 90+angle,
                         180, kh_tool_num)
1156 gcpy                 toolpath = toolpath.union(self.cutline(self.xpos(),
                         self.ypos()+kh_distance, -kh_max_depth))
1157 gcpy             elif (kh_angle == 180):
1158 gcpy #Lower right of entry hole
1159 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),270,360, kh_tool_num)
1160 gcpy #Upper right of entry hole
1161 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),0,90, kh_tool_num)
1162 gcpy #Upper left of entry hole
1163 gcpy                 self.dxfarc(self.xpos(), self.ypos(), rt, 90, 180-angle
                         , kh_tool_num)
1164 gcpy #Lower left of entry hole
1165 gcpy                 self.dxfarc(self.xpos(), self.ypos(), rt, 180+angle,
                         270, kh_tool_num)
1166 gcpy #upper slot
1167 gcpy                 self.dxfline(kh_tool_num, self.xpos()-ro, self.ypos()-r
                         , self.xpos()-kh_distance, self.ypos()-r)
1168 gcpy #lower slot
1169 gcpy                 self.dxfline(kh_tool_num, self.xpos()-ro, self.ypos()+r
                         , self.xpos()-kh_distance, self.ypos()+r)
1170 gcpy #upper left of end of slot
1171 gcpy                 self.dxfarc(self.xpos()-kh_distance,self.ypos(),r
                         ,90,180, kh_tool_num)
1172 gcpy #lower left of end of slot
1173 gcpy                 self.dxfarc(self.xpos()-kh_distance,self.ypos(),r
                         ,180,270, kh_tool_num)
1174 gcpy                 toolpath = toolpath.union(self.cutline(self.xpos()-
                         kh_distance, self.ypos(), -kh_max_depth))
1175 gcpy             elif (kh_angle == 270):
1176 gcpy #Upper left of entry hole
1177 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),90,180, kh_tool_num)
1178 gcpy #Upper right of entry hole
1179 gcpy                 self.dxfarc(self.xpos(),self.ypos(),self.tool_radius(
                         kh_tool_num, 1),0,90, kh_tool_num)
1180 gcpy #left slot
```

```
1181 gcpy             self.dxfline(kh_tool_num, self.xpos()-r, self.ypos()-ro
                          , self.xpos()-r, self.ypos()-kh_distance)
1182 gcpy #right slot
1183 gcpy             self.dxfline(kh_tool_num, self.xpos()+r, self.ypos()-ro
                          , self.xpos()+r, self.ypos()-kh_distance)
1184 gcpy #lower left of end of slot
1185 gcpy             self.dxfarc(self.xpos(),self.ypos()-kh_distance,r
                          ,180,270, kh_tool_num)
1186 gcpy #lower right of end of slot
1187 gcpy             self.dxfarc(self.xpos(),self.ypos()-kh_distance,r
                          ,270,360, kh_tool_num)
1188 gcpy #lower right of entry hole
1189 gcpy             self.dxfarc(self.xpos(), self.ypos(), rt, 180, 270-
                          angle, kh_tool_num)
1190 gcpy #lower left of entry hole
1191 gcpy             self.dxfarc(self.xpos(), self.ypos(), rt, 270+angle,
                          360, kh_tool_num)
1192 gcpy             toolpath = toolpath.union(self.cutline(self.xpos(),
                          self.ypos()-kh_distance, -kh_max_depth))
1193 gcpy #         print(self.zpos())
1194 gcpy          self.setxpos(oXpos)
1195 gcpy          self.setypos(oYpos)
1196 gcpy          return toolpath
1197 gcpy
1198 gcpy #  } else if (kh_angle == 90) {
1199 gcpy #    //Lower left of entry hole
1200 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,180,270, KH_tool_num);
1201 gcpy #    //Lower right of entry hole
1202 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
1203 gcpy #    //Upper right of entry hole
1204 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,0,acos(tool_diameter(
          KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
1205 gcpy #    //Upper left of entry hole
1206 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,180-acos(tool_diameter(
          KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 180,KH_tool_num)
          ;
1207 gcpy #    //Actual line of cut
1208 gcpy #    dxfline(getxpos(),getypos(),getxpos(),getypos()+kh_distance);
1209 gcpy #    //upper right of slot
1210 gcpy #    dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
          KH_tool_num, (kh_max_depth+4.36))/2,0,90, KH_tool_num);
1211 gcpy #    //upper left of slot
1212 gcpy #    dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
          KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
1213 gcpy #    //right of slot
1214 gcpy #    dxfline(
1215 gcpy #        getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
1216 gcpy #        getypos()+(sqrt((tool_diameter(KH_tool_num,1)^2)-(
          tool_diameter(KH_tool_num,5)^2))/2),//( (kh_max_depth-6.34))/2)
          ^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
1217 gcpy #        getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
1218 gcpy #    //end position at top of slot
1219 gcpy #        getypos()+kh_distance,
1220 gcpy #        KH_tool_num);
1221 gcpy #    dxfline(getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))
          /2, getypos()+(sqrt((tool_diameter(KH_tool_num,1)^2)-(
          tool_diameter(KH_tool_num,5)^2))/2), getxpos()-tool_diameter(
          KH_tool_num, (kh_max_depth+6.35))/2,getypos()+kh_distance,
          KH_tool_num);
1222 gcpy #    hull(){
1223 gcpy #      translate([xpos(), ypos(), zpos()]){
1224 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1225 gcpy #      }
1226 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1227 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1228 gcpy #      }
1229 gcpy #    }
1230 gcpy #    hull(){
1231 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1232 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1233 gcpy #      }
1234 gcpy #      translate([xpos(), ypos()+kh_distance, zpos()-kh_max_depth])
          {
1235 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1236 gcpy #      }
1237 gcpy #    }
1238 gcpy #    cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
1239 gcpy #    cutwithfeed(getxpos(),getypos()+kh_distance,-kh_max_depth,feed
```

```
        );
1240 gcpy #     setypos(getypos()-kh_distance);
1241 gcpy #   } else if (kh_angle == 180) {
1242 gcpy #     //Lower right of entry hole
1243 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
1244 gcpy #     //Upper right of entry hole
1245 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
1246 gcpy #     //Upper left of entry hole
1247 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,90, 90+acos(tool_diameter(
        KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
1248 gcpy #     //Lower left of entry hole
1249 gcpy #     dxfarc(getxpos(),getypos(),9.525/2, 270-acos(tool_diameter(
        KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 270, KH_tool_num
        );
1250 gcpy #     //upper left of slot
1251 gcpy #     dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
        KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
1252 gcpy #     //lower left of slot
1253 gcpy #     dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
        KH_tool_num, (kh_max_depth+6.35))/2,180,270, KH_tool_num);
1254 gcpy #     //Actual line of cut
1255 gcpy #     dxfline(getxpos(),getypos(),getxpos()-kh_distance,getypos());
1256 gcpy #     //upper left slot
1257 gcpy #     dxfline(
1258 gcpy #         getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
        tool_diameter(KH_tool_num,5)^2))/2),
1259 gcpy #         getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,//(
         (kh_max_depth-6.34))/2)^2-(tool_diameter(KH_tool_num, (
        kh_max_depth-6.34))/2)^2,
1260 gcpy #         getxpos()-kh_distance,
1261 gcpy #     //end position at top of slot
1262 gcpy #         getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
1263 gcpy #         KH_tool_num);
1264 gcpy #     //lower right slot
1265 gcpy #     dxfline(
1266 gcpy #         getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
        tool_diameter(KH_tool_num,5)^2))/2),
1267 gcpy #         getypos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,//(
         (kh_max_depth-6.34))/2)^2-(tool_diameter(KH_tool_num, (
        kh_max_depth-6.34))/2)^2,
1268 gcpy #         getxpos()-kh_distance,
1269 gcpy #     //end position at top of slot
1270 gcpy #         getypos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
1271 gcpy #         KH_tool_num);
1272 gcpy #     hull(){
1273 gcpy #       translate([xpos(), ypos(), zpos()]){
1274 gcpy #         gcp_keyhole_shaft(6.35, 9.525);
1275 gcpy #       }
1276 gcpy #       translate([xpos(), ypos(), zpos()-kh_max_depth]){
1277 gcpy #         gcp_keyhole_shaft(6.35, 9.525);
1278 gcpy #       }
1279 gcpy #     }
1280 gcpy #     hull(){
1281 gcpy #       translate([xpos(), ypos(), zpos()-kh_max_depth]){
1282 gcpy #         gcp_keyhole_shaft(6.35, 9.525);
1283 gcpy #       }
1284 gcpy #       translate([xpos()-kh_distance, ypos(), zpos()-kh_max_depth])
        {
1285 gcpy #         gcp_keyhole_shaft(6.35, 9.525);
1286 gcpy #       }
1287 gcpy #     }
1288 gcpy #     cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
1289 gcpy #     cutwithfeed(getxpos()-kh_distance,getypos(),-kh_max_depth,feed
        );
1290 gcpy #     setxpos(getxpos()+kh_distance);
1291 gcpy #   } else if (kh_angle == 270) {
1292 gcpy #     //Upper right of entry hole
1293 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
1294 gcpy #     //Upper left of entry hole
1295 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,90,180, KH_tool_num);
1296 gcpy #     //lower right of slot
1297 gcpy #     dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
        KH_tool_num, (kh_max_depth+4.36))/2,270,360, KH_tool_num);
1298 gcpy #     //lower left of slot
1299 gcpy #     dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
        KH_tool_num, (kh_max_depth+4.36))/2,180,270, KH_tool_num);
1300 gcpy #     //Actual line of cut
1301 gcpy #     dxfline(getxpos(),getypos(),getxpos(),getypos()-kh_distance);
```

```
1302 gcpy #    //right of slot
1303 gcpy #    dxfline(
1304 gcpy #        getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
1305 gcpy #        getypos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
                tool_diameter(KH_tool_num,5)^2))/2),//( (kh_max_depth-6.34))/2)
                ^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
1306 gcpy #        getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
1307 gcpy #    //end position at top of slot
1308 gcpy #        getypos()-kh_distance,
1309 gcpy #        KH_tool_num);
1310 gcpy #    //left of slot
1311 gcpy #    dxfline(
1312 gcpy #        getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
1313 gcpy #        getypos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
                tool_diameter(KH_tool_num,5)^2))/2),//( (kh_max_depth-6.34))/2)
                ^2-(tool_diameter(KH_tool_num, (kh_max_depth-6.34))/2)^2,
1314 gcpy #        getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
1315 gcpy #    //end position at top of slot
1316 gcpy #        getypos()-kh_distance,
1317 gcpy #        KH_tool_num);
1318 gcpy #    //Lower right of entry hole
1319 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,360-acos(tool_diameter(
                KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), 360, KH_tool_num
                );
1320 gcpy #    //Lower left of entry hole
1321 gcpy #    dxfarc(getxpos(),getypos(),9.525/2,180, 180+acos(tool_diameter
                (KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
1322 gcpy #    hull(){
1323 gcpy #      translate([xpos(), ypos(), zpos()]){
1324 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1325 gcpy #      }
1326 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1327 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1328 gcpy #      }
1329 gcpy #    }
1330 gcpy #    hull(){
1331 gcpy #      translate([xpos(), ypos(), zpos()-kh_max_depth]){
1332 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1333 gcpy #      }
1334 gcpy #      translate([xpos(), ypos()-kh_distance, zpos()-kh_max_depth])
                {
1335 gcpy #        gcp_keyhole_shaft(6.35, 9.525);
1336 gcpy #      }
1337 gcpy #    }
1338 gcpy #    cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
1339 gcpy #    cutwithfeed(getxpos(),getypos()-kh_distance,-kh_max_depth,feed
                );
1340 gcpy #    setypos(getypos()+kh_distance);
1341 gcpy #  }
1342 gcpy #}
```

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.

begincutdxf **3.3.1.1 begincutdxf** The first command, `begincutdxf` 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.

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 the
continuecutdxf use of `continuecutdxf`.

```
395 gcpscad module begincutdxf(rh, ex, ey, ez, fr) {
```

```
396 gcpscad    rapid(getxpos(),getypos(),rh);
397 gcpscad    cutwithfeed(ex,ey,ez,fr);
398 gcpscad }
```

```
400 gcpscad module continuecutdxf(ex, ey, ez, fr) {
401 gcpscad    cutwithfeed(ex,ey,ez,fr);
402 gcpscad }
```

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. Whether a given module is an interior pocket or an outline (interior or exterior) will be determined by the specifics of the module and its usage/positioning, with `outline` being added to those modules which cut perimeter.

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` Th routine `cutrectangledxf` cuts the outline of a rectangle creating sharp corners. Note that the initial version would work as a beginning point for vertical cutting if the `hull()` operation was removed and the loop was uncommented:

```
404 gcpscad module cutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn)
        {//passes
405 gcpscad    movetosafez();
406 gcpscad    hull(){
407 gcpscad      //  for (i = [0 : abs(1) : passes]) {
408 gcpscad      //      rapid(bx+tool_radius(rtn)+i*(rwidth-tool_diameter(
                    current_tool()))/passes,bx+tool_radius(rtn),1);
409 gcpscad      //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter
                    (current_tool()))/passes,by+tool_radius(rtn),bz-rdepth,feed)
                    ;
410 gcpscad      //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter
                    (current_tool()))/passes,by+rheight-tool_radius(rtn),bz-
                    rdepth,feed);
411 gcpscad
412 gcpscad      cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,
                    feed);
413 gcpscad      cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-
                    rdepth,feed);
414 gcpscad      cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(
                    rtn),bz-rdepth,feed);
415 gcpscad      cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-
                    rdepth,feed);
416 gcpscad    }
417 gcpscad    //dxfarc(xcenter,ycenter,radius,anglebegin,endangle, tn)
418 gcpscad    dxfarc(bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn)
                    ,180,270, rtn);
419 gcpscad    //dxfline(xbegin,ybegin,xend,yend, tn)
420 gcpscad    dxfline(bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(rtn),
                    rtn);
421 gcpscad    dxfarc(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),
                    tool_radius(rtn),90,180, rtn);
422 gcpscad    dxfline(bx+tool_radius(rtn),by+rheight,bx+rwidth-tool_radius(rtn)
                    ,by+rheight, rtn);
423 gcpscad    dxfarc(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),
                    tool_radius(rtn),0,90, rtn);
424 gcpscad    dxfline(bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,by+
                    tool_radius(rtn), rtn);
425 gcpscad    dxfarc(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),tool_radius
                    (rtn),270,360, rtn);
426 gcpscad    dxfline(bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn),by, rtn
                    );
427 gcpscad }
```

`cutrectangleoutlinedxf` A matching command: `cutrectangleoutlinedxf` cuts the outline of a rounded rectangle and is a simplification of the above:

```
429 gcpscad module cutrectangleoutlinedxf(bx, by, bz, rwidth, rheight, rdepth,
        rtn) {//passes
430 gcpscad    movetosafez();
431 gcpscad    cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,
                feed);
```

```
gcpscad    cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-
               rdepth,feed);
gcpscad    cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn
               ),bz-rdepth,feed);
gcpscad    cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-
               rdepth,feed);
gcpscad    dxfarc(bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn)
               ,180,270, rtn);
gcpscad    dxfline(bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(rtn),
               rtn);
gcpscad    dxfarc(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),
               tool_radius(rtn),90,180, rtn);
gcpscad    dxfline(bx+tool_radius(rtn),by+rheight,bx+rwidth-tool_radius(rtn)
               ,by+rheight, rtn);
gcpscad    dxfarc(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),
               tool_radius(rtn),0,90, rtn);
gcpscad    dxfline(bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,by+
               tool_radius(rtn), rtn);
gcpscad    dxfarc(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),tool_radius
               (rtn),270,360, rtn);
gcpscad    dxfline(bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn),by, rtn
               );
gcpscad }
```

rectangleoutlinedxf Which suggests a further command, `rectangleoutlinedxf` for simply adding a rectangle (a potential use of which would be in Job Setup to add the stock outline to DXFs to assist in registration of jobs with multiple tools):

```
gcpscad module rectangleoutlinedxf(bx, by, bz, rwidth, rheight, rtn) {
gcpscad    dxfline(bx,by,bx,by+rheight, rtn);
gcpscad    dxfline(bx,by+rheight,bx+rwidth,by+rheight, rtn);
gcpscad    dxfline(bx+rwidth,by+rheight,bx+rwidth,by, rtn);
gcpscad    dxfline(bx+rwidth,by,bx,by, rtn);
gcpscad }
```

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

cutoutrectangledxf A variant of the cutting version of that file, `cutoutrectangledxf` will cut to the outside:

```
gcpscad module cutoutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn)
               {
gcpscad    movetosafez();
gcpscad    cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,
               feed);
gcpscad    cutwithfeed(bx+rwidth+tool_radius(rtn),by-tool_radius(rtn),bz-
               rdepth,feed);
gcpscad    cutwithfeed(bx+rwidth+tool_radius(rtn),by+rheight+tool_radius(rtn
               ),bz-rdepth,feed);
gcpscad    cutwithfeed(bx-tool_radius(rtn),by+rheight+tool_radius(rtn),bz-
               rdepth,feed);
gcpscad    cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,
               feed);
gcpscad    dxfline(bx,by,bx,by+rheight, rtn);
gcpscad    dxfline(bx,by+rheight,bx+rwidth,by+rheight, rtn);
gcpscad    dxfline(bx+rwidth,by+rheight,bx+rwidth,by, rtn);
gcpscad    dxfline(bx+rwidth,by,bx,by, rtn);
gcpscad }
```

4 Future

Images

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

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

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

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:

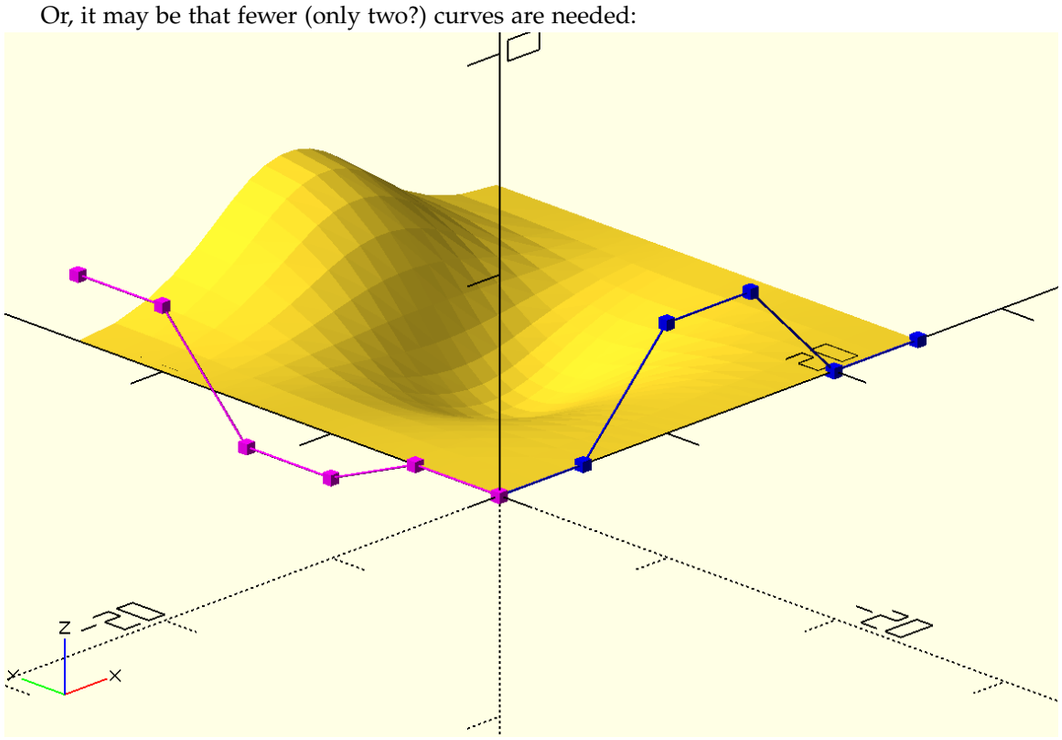
- XY
- XZ
- ZY

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
c.f., https://github.com/BelfrySCAD/BOSL2/wiki/nurbs.scad and https://old.reddit.com/r/OpenPythonSCAD/comments/1gjcz4z/pythonscad_will_get_a_new_spline_function/

5 Other Resources

Holidays are from https://nationaltoday.com/

DXFs

http://www.paulbourke.net/dataformats/dxf/
https://paulbourke.net/dataformats/dxf/min3d.html

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