

The gcodepreview PythonSCAD library*

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Abstract

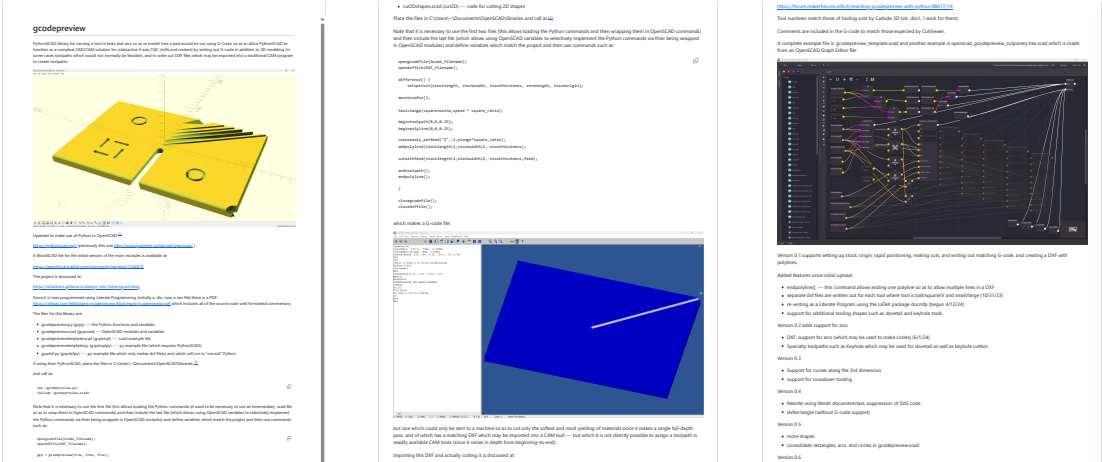
The gcodepreview library allows using PythonSCAD (OpenPythonSCAD) to move a tool in lines and arcs and output DXF and G-code files so as to work as a CAD/CAM program for CNC.

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*This file (gcodepreview) has version number vo.8, last revised 2025/01/29.

1 **readme.md**



```
1 rdme # gcodepreview
2 rdme
3 rdme PythonSCAD 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
      PythonSCAD 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 gcodepreview Unit Tests](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://willadams.gitbook.io/design-into-3d/programming
21 rdme
22 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.
23 rdme
24 rdme The files for this library are:
25 rdme
26 rdme - gcodepreview.py (gcpy) --- the Python functions and variables
27 rdme - gcodepreview.scad (gcpscad) --- OpenSCAD modules and variables
28 rdme - gcodepreviewtemplate.scad (gcptmpl) --- .scad example file
29 rdme - gcodepreviewtemplate.py (gcptmplpy) --- .py example file (which
      requires PythonSCAD)
30 rdme - gcpdxf.py (gcpdxfpy) --- .py example file which only makes dxf
      file(s) and which will run in "normal" Python
31 rdme
32 rdme If using from PythonSCAD, place the files in C:\Users\\~\Documents
      \OpenSCAD\libraries [^libraries]
33 rdme
34 rdme [^libraries]: C:\Users\\~\Documents\RapCAD\libraries is deprecated
      since RapCAD is no longer needed since Python is now used for
      writing out files.
35 rdme
36 rdme and call as:
37 rdme
38 rdme     use <gcodepreview.py>
39 rdme     include <gcodepreview.scad>
```

```
40 rdme
41 rdme Note that it is necessary to use the first file (this allows
    loading the Python commands (it used to be necessary to use an
    intermediary .scad file so as to wrap 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:
42 rdme
43 rdme    .opengcodefile(Gcode_filename);
44 rdme    .opendxffile(DXF_filename);
45 rdme
46 rdme     gcp = gcodepreview(true, true, true);
47 rdme
48 rdme     setupstock(219, 150, 8.35, "Top", "Center");
49 rdme
50 rdme     movetosafeZ();
51 rdme
52 rdme     toolchange(102,17000);
53 rdme
54 rdme     cutline(219/2,150/2,-8.35);
55 rdme
56 rdme     stockandtoolpaths();
57 rdme
58 rdme     closegcodefile();
59 rdme     closedxfile();
60 rdme
61 rdme which makes a G-code file:
62 rdme
63 rdme ![OpenSCAD template G-code file](https://raw.githubusercontent.com/
    WillAdams/gcodepreview/main/gcodepreview_template.png?raw=true)
64 rdme
65 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).
66 rdme
67 rdme Importing this DXF and actually cutting it is discussed at:
68 rdme
69 rdme https://forum.makerforums.info/t/rewriting-gcodepreview-with-python
    /88617/14
70 rdme
71 rdme Alternately, gcodepreview.py may be placed in a Python library
    location and used directly from Python --- note that it is
    possible to use it from a "normal" Python when generating only
    DXFs.
72 rdme
73 rdme Tool numbers match those of tooling sold by Carbide 3D (ob. discl.,
    I work for them).
74 rdme
75 rdme Comments are included in the G-code to match those expected by
    CutViewer, allowing a direct preview without the need to
    maintain a tool library.
76 rdme
77 rdme Supporting OpenSCAD usage makes possible such examples as:
    openscad_gcodepreview_cutjoinery.tres.scad which is made from an
    OpenSCAD Graph Editor file:
78 rdme
79 rdme ![OpenSCAD Graph Editor Cut Joinery File](https://raw.
    githubusercontent.com/WillAdams/gcodepreview/main/
    OSGE_cutjoinery.png?raw=true)
80 rdme
81 rdme | Version          | Notes          |
82 rdme | -----          | -----          |
83 rdme | 0.1 | Version supports setting up stock, origin, rapid
    positioning, making cuts, and writing out matching G-code, and
    creating a DXF with polylines. |
84 rdme | | - separate dxf files are written out for each tool where
    tool is ball/square/V and small/large (10/31/23) |
85 rdme | | - re-writing as a Literate Program using the LaTeX package
    docmfp (begun 4/12/24) |
86 rdme | | - support for additional tooling shapes such as dovetail
    and keyhole tools |
87 rdme | 0.2 | Adds support for arcs, specialty toolpaths such as Keyhole
    which may be used for dovetail as well as keyhole cutters |
88 rdme | 0.3 | Support for curves along the 3rd dimension, roundover
```

```

        tooling
89 rdme | 0.4 | Rewrite using literati documentclass, suppression of SVG
        code, dxfrectangle
90 rdme | 0.5 | More shapes, consolidate rectangles, arcs, and circles in
        gcodepreview.scad
91 rdme | 0.6 | Notes on modules, change file for setupstock

|
92 rdme | 0.61| Validate all code so that it runs without errors from
        sample (NEW: Note that this version is archived as gcodepreview-
        openscad_0_6.tex and the matching PDF is available as well|
93 rdme | 0.7 | Re-write completely in Python

|
94 rdme | 0.8 | Re-re-write completely in Python and OpenSCAD, iteratively
        testing |
95 rdme
96 rdme Possible future improvements:
97 rdme
98 rdme - support for additional tooling shapes (bowl bits with flat
        bottom, tapered ball nose, lollipop cutters)
99 rdme - create a single line font for use where text is wanted
100 rdme - Support Bézier curves (required for fonts if not to be limited
        to lines and arcs) and surfaces
101 rdme
102 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 as
        noted above. Working from a DXF of course allows one to off-load
        such considerations to a specialized CAM tool.

103 rdme
104 rdme Deprecated feature:
105 rdme
106 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 Usage and Templates

The gcodepreview library allows the modeling of 2D geometry and 3D shapes using Python or by calling Python from within (Open)PythonSCAD, enabling the creation of 2D DXFs, G-code, or 3D models as a preview of how the file will cut. These abilities may be accessed in “plain” Python (to make DXFs), or Python or OpenSCAD in PythonSCAD (to make G-code and/or for 3D modeling)

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 (note that the sparse template in `readme.md` eschews variables), and that files are opened before being written to, and that each is closed at the end in the correct order. 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 the readme at the project page which serves as an overview, and this section (which serves as a tutorial) is all the documentation which most users will need (and arguably is still too much). A command glossary may be added in a future version. The balance of the document after this section shows all the code and implementation details, and will where appropriate show examples of usage excerpted from the template files (serving as a how-to guide as well as documenting the code) as well as Indices (which serve as a front-end for reference).

Some comments on the templates:

- minimal — each is intended as a framework for a minimal working example (MWE) — it should be possible to comment out unused/unneeded 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 mechanism to handle everything.
- shortcuts — as the various examples show, 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 and implementing Depth per Pass (but note that this will lose the previewing of scalloped tool marks in places where they might appear otherwise)

Further features will be added to the templates as they are created, and the main image updated to reflect the capabilities of the system.

2.1 gcpdxf.py

The most basic usage, with the fewest dependencies is to use “plain” Python to create dxf files. Note that this example includes an optional command `(openscad.)nimport(<URL>)` which if enabled/uncommented (and the following line commented out), will import the library from Github, sidestepping the need to download and install the library.

```

1 gcpdxfpy from openscad import *
2 gcpdxfpy #nimport("https://raw.githubusercontent.com/WillAdams/gcodepreview/
           refs/heads/main/gcodepreview.py")
3 gcpdxfpy from gcodepreview import *
4 gcpdxfpy
5 gcpdxfpy gcp = gcodepreview(False, #generatepaths
6 gcpdxfpy                                False, #generategcode
7 gcpdxfpy                                True #generatedxf
8 gcpdxfpy                                )
9 gcpdxfpy
10 gcpdxfpy # [Stock] */
11 gcpdxfpy stockXwidth = 100
12 gcpdxfpy # [Stock] */
13 gcpdxfpy stockYheight = 50
14 gcpdxfpy
15 gcpdxfpy # [Export] */
16 gcpdxfpy Base_filename = "dxfexport"
17 gcpdxfpy
18 gcpdxfpy
19 gcpdxfpy # [CAM] */
20 gcpdxfpy large_square_tool_num = 102
21 gcpdxfpy # [CAM] */
22 gcpdxfpy small_square_tool_num = 0
23 gcpdxfpy # [CAM] */
24 gcpdxfpy large_ball_tool_num = 0
25 gcpdxfpy # [CAM] */
26 gcpdxfpy small_ball_tool_num = 0
27 gcpdxfpy # [CAM] */
28 gcpdxfpy large_V_tool_num = 0
29 gcpdxfpy # [CAM] */
30 gcpdxfpy small_V_tool_num = 0

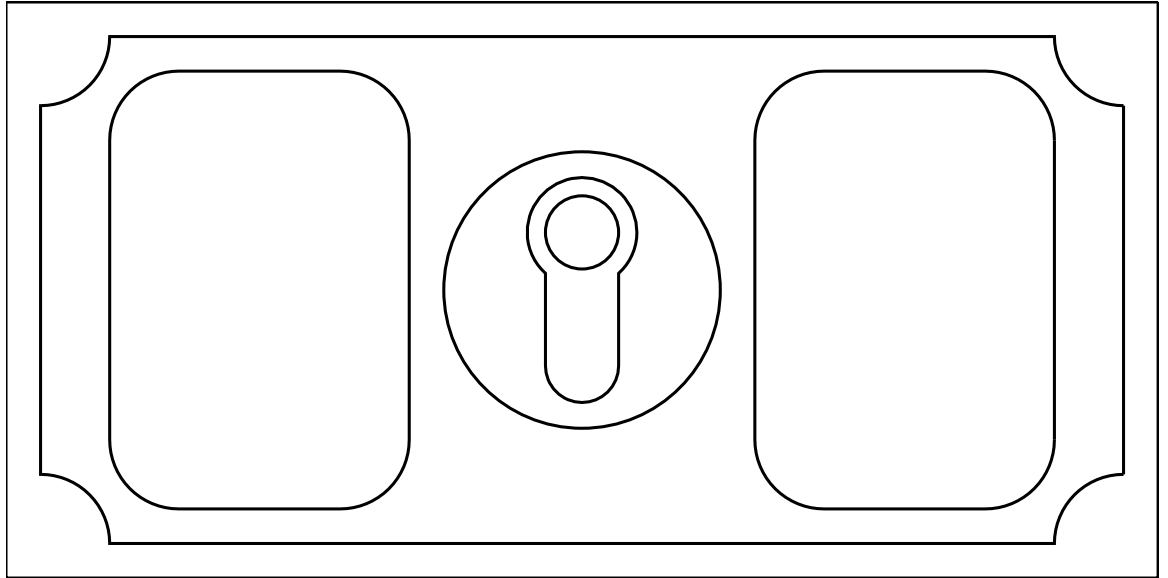
```

```

31 gcpdxftp # [CAM] */
32 gcpdxftp DT_tool_num = 374
33 gcpdxftp # [CAM] */
34 gcpdxftp KH_tool_num = 0
35 gcpdxftp # [CAM] */
36 gcpdxftp Roundover_tool_num = 0
37 gcpdxftp # [CAM] */
38 gcpdxftp MISC_tool_num = 0
39 gcpdxftp
40 gcpdxftp # [Design] */
41 gcpdxftp inset = 3
42 gcpdxftp # [Design] */
43 gcpdxftp radius = 6
44 gcpdxftp # [Design] */
45 gcpdxftp cornerstyle = "Fillet" # "Chamfer", "Flipped Fillet"
46 gcpdxftp
47 gcpdxftp gcp.opendxfile(Base_filename)
48 gcpdxftp #gcp.opendxfiles(Base_filename,
49 gcpdxftp #           large_square_tool_num,
50 gcpdxftp #           small_square_tool_num,
51 gcpdxftp #           large_ball_tool_num,
52 gcpdxftp #           small_ball_tool_num,
53 gcpdxftp #           large_V_tool_num,
54 gcpdxftp #           small_V_tool_num,
55 gcpdxftp #           DT_tool_num,
56 gcpdxftp #           KH_tool_num,
57 gcpdxftp #           Roundover_tool_num,
58 gcpdxftp #           MISC_tool_num)
59 gcpdxftp
60 gcpdxftp gcp.dxfrectangle(large_square_tool_num, 0, 0, stockXwidth,
61 gcpdxftp stockYheight)
62 gcpdxftp gcp.dxfarc(large_square_tool_num, inset, inset, radius, 0, 90)
63 gcpdxftp gcp.dxfarc(large_square_tool_num, stockXwidth - inset, inset,
64 gcpdxftp radius, 90, 180)
65 gcpdxftp gcp.dxfarc(large_square_tool_num, stockXwidth - inset, stockYheight
66 gcpdxftp - inset, radius, 180, 270)
67 gcpdxftp gcp.dxfarc(large_square_tool_num, inset, stockYheight - inset,
68 gcpdxftp radius, 270, 360)
69 gcpdxftp
70 gcpdxftp gcp.dxfline(large_square_tool_num, inset, inset + radius, inset,
71 gcpdxftp stockYheight - (inset + radius))
72 gcpdxftp gcp.dxfline(large_square_tool_num, inset + radius, inset,
73 gcpdxftp stockXwidth - (inset + radius), inset)
74 gcpdxftp gcp.dxfline(large_square_tool_num, stockXwidth - inset, inset +
75 gcpdxftp radius, stockXwidth - inset, stockYheight - (inset + radius))
76 gcpdxftp gcp.dxfline(large_square_tool_num, inset + radius, stockYheight -
77 gcpdxftp inset, stockXwidth - (inset + radius), stockYheight - inset)
78 gcpdxftp
79 gcpdxftp gcp.dxfrectangle(large_square_tool_num, radius + inset, radius,
80 gcpdxftp stockXwidth/2 - (radius * 4), stockYheight - (radius * 2),
81 gcpdxftp cornerstyle, radius)
82 gcpdxftp gcp.dxfrectangle(large_square_tool_num, stockXwidth/2 + (radius *
83 gcpdxftp 2) + inset, radius, stockXwidth/2 - (radius * 4), stockYheight -
84 gcpdxftp (radius * 2), cornerstyle, radius)
85 gcpdxftp #gcp.dxfrectangleround(large_square_tool_num, 64, 7, 24, 36, radius
86 gcpdxftp )
87 gcpdxftp #gcp.dxfrectanglechamfer(large_square_tool_num, 64, 7, 24, 36,
88 gcpdxftp radius)
89 gcpdxftp #gcp.dxfrectangleflippedfillet(large_square_tool_num, 64, 7, 24,
90 gcpdxftp 36, radius)
91 gcpdxftp
92 gcpdxftp gcp.dxfcircle(large_square_tool_num, stockXwidth/2, stockYheight/2,
93 gcpdxftp radius * 2)
94 gcpdxftp
95 gcpdxftp gcp.dxfKH(374, stockXwidth/2, stockYheight/5*3, 0, -7, 270,
96 gcpdxftp 11.5875)
97 gcpdxftp
98 gcpdxftp #gcp.closedxfiles()
99 gcpdxftp gcp.closedxfile()

```

which creates:



Note that the lines referencing multiple files (open/closedxfiles) may be uncommented if the project wants separate dxf files for different tools.

As shown/implied by the above code, the following commands/shapes are implemented:

- `dxfrectangle` (specify lower-left and upper-right corners)
 - `dxfrectangleround` (specified as “Fillet” and radius for the round option)
 - `dxfrectanglechamfer` (specified as “Chamfer” and radius for the round option)
 - `dxfrectangleflippedfillet` (specified as “Flipped Fillet” and radius for the option)
- `dxfcircle` (specifying their center and radius)
- `dxfline` (specifying begin/end points)
- `dxfarc` (specifying arc center, radius, and beginning/ending angles)
- `dxfkH` (specifying origin, depth, angle, distance)

2.2 gcodepreviewtemplate.py

Note that since the vo.7 re-write, it is possible to directly use the underlying Python code. Using Python to generate 3D previews of how DXFs or G-code will cut requires the use of PythonSCAD.

```

1 gcptmplpy #!/usr/bin/env python
2 gcptmplpy
3 gcptmplpy import sys
4 gcptmplpy
5 gcptmplpy try:
6 gcptmplpy     if 'gcodepreview' in sys.modules:
7 gcptmplpy         del sys.modules['gcodepreview']
8 gcptmplpy except AttributeError:
9 gcptmplpy     pass
10 gcptmplpy
11 gcptmplpy from gcodepreview import *
12 gcptmplpy
13 gcptmplpy fa = 2
14 gcptmplpy fs = 0.125
15 gcptmplpy
16 gcptmplpy # [Export] */
17 gcptmplpy Base_filename = "aexport"
18 gcptmplpy # [Export] */
19 gcptmplpy generatepaths = False
20 gcptmplpy # [Export] */
21 gcptmplpy generatedxf = True
22 gcptmplpy # [Export] */
23 gcptmplpy generategcode = True
24 gcptmplpy
25 gcptmplpy # [Stock] */
26 gcptmplpy stockXwidth = 220
27 gcptmplpy # [Stock] */
28 gcptmplpy stockYheight = 150
29 gcptmplpy # [Stock] */
30 gcptmplpy stockZthickness = 8.35
31 gcptmplpy # [Stock] */
32 gcptmplpy zeroheight = "Top" # [Top, Bottom]
33 gcptmplpy # [Stock] */

```

```

34 gcptmplpy stockzero = "Center" # [Lower-Left, Center-Left, Top-Left, Center]
35 gcptmplpy # [Stock] */
36 gcptmplpy retractheight = 9
37 gcptmplpy
38 gcptmplpy # [CAM] */
39 gcptmplpy toolradius = 1.5875
40 gcptmplpy # [CAM] */
41 gcptmplpy large_square_tool_num = 201 # [0:0,112:112,102:102,201:201]
42 gcptmplpy # [CAM] */
43 gcptmplpy small_square_tool_num = 102 # [0:0,122:122,112:112,102:102]
44 gcptmplpy # [CAM] */
45 gcptmplpy large_ball_tool_num = 202 # [0:0,111:111,101:101,202:202]
46 gcptmplpy # [CAM] */
47 gcptmplpy small_ball_tool_num = 101 # [0:0,121:121,111:111,101:101]
48 gcptmplpy # [CAM] */
49 gcptmplpy large_V_tool_num = 301 # [0:0,301:301,690:690]
50 gcptmplpy # [CAM] */
51 gcptmplpy small_V_tool_num = 390 # [0:0,390:390,301:301]
52 gcptmplpy # [CAM] */
53 gcptmplpy DT_tool_num = 814 # [0:0,814:814]
54 gcptmplpy # [CAM] */
55 gcptmplpy KH_tool_num = 374 # [0:0,374:374,375:375,376:376,378]
56 gcptmplpy # [CAM] */
57 gcptmplpy Roundover_tool_num = 56142 # [56142:56142, 56125:56125, 1570:1570]
58 gcptmplpy # [CAM] */
59 gcptmplpy MISC_tool_num = 0 #
60 gcptmplpy
61 gcptmplpy # [Feeds and Speeds] */
62 gcptmplpy plunge = 100
63 gcptmplpy # [Feeds and Speeds] */
64 gcptmplpy feed = 400
65 gcptmplpy # [Feeds and Speeds] */
66 gcptmplpy speed = 16000
67 gcptmplpy # [Feeds and Speeds] */
68 gcptmplpy small_square_ratio = 0.75 # [0.25:2]
69 gcptmplpy # [Feeds and Speeds] */
70 gcptmplpy large_ball_ratio = 1.0 # [0.25:2]
71 gcptmplpy # [Feeds and Speeds] */
72 gcptmplpy small_ball_ratio = 0.75 # [0.25:2]
73 gcptmplpy # [Feeds and Speeds] */
74 gcptmplpy large_V_ratio = 0.875 # [0.25:2]
75 gcptmplpy # [Feeds and Speeds] */
76 gcptmplpy small_V_ratio = 0.625 # [0.25:2]
77 gcptmplpy # [Feeds and Speeds] */
78 gcptmplpy DT_ratio = 0.75 # [0.25:2]
79 gcptmplpy # [Feeds and Speeds] */
80 gcptmplpy KH_ratio = 0.75 # [0.25:2]
81 gcptmplpy # [Feeds and Speeds] */
82 gcptmplpy RO_ratio = 0.5 # [0.25:2]
83 gcptmplpy # [Feeds and Speeds] */
84 gcptmplpy MISC_ratio = 0.5 # [0.25:2]
85 gcptmplpy
86 gcptmplpy gcp = gcodepreview(generatepaths,
87 gcptmplpy                      generategcode,
88 gcptmplpy                      generatedxf,
89 gcptmplpy                      )
90 gcptmplpy
91 gcptmplpy gcp.opengcodefile(Base_filename)
92 gcptmplpy gcp.opendxfile(Base_filename)
93 gcptmplpy gcp.opendxfiles(Base_filename,
94 gcptmplpy                      large_square_tool_num,
95 gcptmplpy                      small_square_tool_num,
96 gcptmplpy                      large_ball_tool_num,
97 gcptmplpy                      small_ball_tool_num,
98 gcptmplpy                      large_V_tool_num,
99 gcptmplpy                      small_V_tool_num,
100 gcptmplpy                      DT_tool_num,
101 gcptmplpy                      KH_tool_num,
102 gcptmplpy                      Roundover_tool_num,
103 gcptmplpy                      MISC_tool_num)
104 gcptmplpy gcp.setupstock(stockXwidth,stockYheight,stockZthickness,"Top","
    Center",retractheight)
105 gcptmplpy
106 gcptmplpy #print(pygcpcversion())
107 gcptmplpy
108 gcptmplpy #print(gcp.myfunc(4))
109 gcptmplpy
110 gcptmplpy #print(gcp.getvv())

```



```

111 gcptmplpy
112 gcptmplpy #ts = cylinder(12.7, 1.5875, 1.5875)
113 gcptmplpy #toolpaths = gcp.cutshape(stockXwidth/2,stockYheight/2,-
      stockZthickness)
114 gcptmplpy
115 gcptmplpy gcp.movetosafeZ()
116 gcptmplpy
117 gcptmplpy gcp.toolchange(102,10000)
118 gcptmplpy
119 gcptmplpy #gcp.rapidXY(6,12)
120 gcptmplpy gcp.rapidZ(0)
121 gcptmplpy
122 gcptmplpy #print (gcp.xpos())
123 gcptmplpy #print (gcp.ypos())
124 gcptmplpy #psetzpos(7)
125 gcptmplpy #gcp.setzpos(-12)
126 gcptmplpy #print (gcp.zpos())
127 gcptmplpy
128 gcptmplpy #print ("X", str(gcp.xpos()))
129 gcptmplpy #print ("Y", str(gcp.ypos()))
130 gcptmplpy #print ("Z", str(gcp.zpos()))
131 gcptmplpy
132 gcptmplpy toolpaths = gcp.currenttool()
133 gcptmplpy
134 gcptmplpy #toolpaths = gcp.outline(stockXwidth/2,stockYheight/2,-
      stockZthickness)
135 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/2,
      stockYheight/2, -stockZthickness))
136 gcptmplpy
137 gcptmplpy gcp.rapidZ(retractheight)
138 gcptmplpy gcp.toolchange(201,10000)
139 gcptmplpy gcp.rapidXY(0, stockYheight/16)
140 gcptmplpy gcp.rapidZ(0)
141 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*7,
      stockYheight/2, -stockZthickness))
142 gcptmplpy
143 gcptmplpy gcp.rapidZ(retractheight)
144 gcptmplpy gcp.toolchange(202,10000)
145 gcptmplpy gcp.rapidXY(0, stockYheight/8)
146 gcptmplpy gcp.rapidZ(0)
147 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*6,
      stockYheight/2, -stockZthickness))
148 gcptmplpy
149 gcptmplpy gcp.rapidZ(retractheight)
150 gcptmplpy gcp.toolchange(101,10000)
151 gcptmplpy gcp.rapidXY(0, stockYheight/16*3)
152 gcptmplpy gcp.rapidZ(0)
153 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*5,
      stockYheight/2, -stockZthickness))
154 gcptmplpy
155 gcptmplpy gcp.setzpos(retractheight)
156 gcptmplpy gcp.toolchange(390,10000)
157 gcptmplpy gcp.rapidXY(0, stockYheight/16*4)
158 gcptmplpy gcp.rapidZ(0)
159 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*4,
      stockYheight/2, -stockZthickness))
160 gcptmplpy gcp.rapidZ(retractheight)
161 gcptmplpy
162 gcptmplpy gcp.toolchange(301,10000)
163 gcptmplpy gcp.rapidXY(0, stockYheight/16*6)
164 gcptmplpy gcp.rapidZ(0)
165 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/16*2,
      stockYheight/2, -stockZthickness))
166 gcptmplpy
167 gcptmplpy rapids = gcp.rapid(gcp.xpos(),gcp.ypos(),retractheight)
168 gcptmplpy gcp.toolchange(102,10000)
169 gcptmplpy
170 gcptmplpy rapids = gcp.rapid(-stockXwidth/4+stockYheight/16, +stockYheight
      /4,0)
171 gcptmplpy
172 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCC(0,90, gcp.xpos()-
      stockYheight/16, gcp.ypos(), stockYheight/16, -stockZthickness
      /4))
173 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCC(90,180, gcp.xpos(), gcp.
      ypos()-stockYheight/16, stockYheight/16, -stockZthickness/4))
174 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCC(180,270, gcp.xpos()+
      stockYheight/16, gcp.ypos(), stockYheight/16, -stockZthickness
      /4))

```

```

175 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCC(270,360, gcp.xpos(), gcp.
      ypos()+stockYheight/16, stockYheight/16, -stockZthickness/4))
176 gcptmplpy
177 gcptmplpy rapids = gcp.movetosafeZ()
178 gcptmplpy rapids = gcp.rapidXY(stockXwidth/4-stockYheight/16, -stockYheight
      /4)
179 gcptmplpy rapids = gcp.rapidZ(0)
180 gcptmplpy
181 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCW(180,90, gcp.xpos()+
      stockYheight/16, gcp.ypos(), stockYheight/16, -stockZthickness
      /4))
182 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCW(90,0, gcp.xpos(), gcp.ypos
      )-stockYheight/16, stockYheight/16, -stockZthickness/4))
183 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCW(360,270, gcp.xpos()-
      stockYheight/16, gcp.ypos(), stockYheight/16, -stockZthickness
      /4))
184 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCW(270,180, gcp.xpos(), gcp.
      ypos()+stockYheight/16, stockYheight/16, -stockZthickness/4))
185 gcptmplpy
186 gcptmplpy rapids = gcp.movetosafeZ()
187 gcptmplpy gcp.toolchange(201,10000)
188 gcptmplpy rapids = gcp.rapidXY(stockXwidth/2, -stockYheight/2)
189 gcptmplpy rapids = gcp.rapidZ(0)
190 gcptmplpy
191 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()
      , -stockZthickness))
192 gcptmplpy #test = gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness)
193 gcptmplpy
194 gcptmplpy rapids = gcp.movetosafeZ()
195 gcptmplpy rapids = gcp.rapidXY(stockXwidth/2-6.34, -stockYheight/2)
196 gcptmplpy rapids = gcp.rapidZ(0)
197 gcptmplpy
198 gcptmplpy toolpaths = toolpaths.union(gcp.cutarcCW(180,90, stockXwidth/2, -
      stockYheight/2, 6.34, -stockZthickness))
199 gcptmplpy
200 gcptmplpy rapids = gcp.movetosafeZ()
201 gcptmplpy gcp.toolchange(814,10000)
202 gcptmplpy rapids = gcp.rapidXY(0, -(stockYheight/2+12.7))
203 gcptmplpy rapids = gcp.rapidZ(0)
204 gcptmplpy
205 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()
      , -stockZthickness))
206 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos(), -12.7, -
      stockZthickness))
207 gcptmplpy
208 gcptmplpy rapids = gcp.rapidXY(0, -(stockYheight/2+12.7))
209 gcptmplpy rapids = gcp.movetosafeZ()
210 gcptmplpy gcp.toolchange(374,10000)
211 gcptmplpy rapids = gcp.rapidXY(stockXwidth/4-stockXwidth/16, -(stockYheight
      /4+stockYheight/16))
212 gcptmplpy rapids = gcp.rapidZ(0)
213 gcptmplpy
214 gcptmplpy gcp.rapidZ(retractheight)
215 gcptmplpy gcp.toolchange(374,10000)
216 gcptmplpy gcp.rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4+
      stockYheight/16))
217 gcptmplpy gcp.rapidZ(0)
218 gcptmplpy
219 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), -
      stockZthickness/2))
220 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos()+
      stockYheight/9, gcp.ypos(), gcp.zpos()))
221 gcptmplpy #below should probably be cutlinegc
222 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos()-stockYheight/9,
      gcp.ypos(), gcp.zpos()))
223 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), 0))
224 gcptmplpy
225 gcptmplpy #key = gcp.cutkeyholegcdxf(KH_tool_num, 0, stockZthickness*0.75, "E
      ", stockYheight/9)
226 gcptmplpy #key = gcp.cutKHgcdxf(374, 0, stockZthickness*0.75, 90,
      stockYheight/9)
227 gcptmplpy #toolpaths = toolpaths.union(key)
228 gcptmplpy
229 gcptmplpy gcp.rapidZ(retractheight)
230 gcptmplpy gcp.rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4+
      stockYheight/16))
231 gcptmplpy gcp.rapidZ(0)
232 gcptmplpy #toolpaths = toolpaths.union(gcp.cutkeyholegcdxf(KH_tool_num, 0,

```

```

        stockZthickness*0.75, "N", stockYheight/9))
233 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), -
        stockZthickness/2))
234 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()
        +stockYheight/9, gcp.zpos()))
235 gcptmplpy #below should probably be cutlinegc
236 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos()-
        stockYheight/9, gcp.zpos()))
237 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), 0))
238 gcptmplpy
239 gcptmplpy gcp.rapidZ(retractheight)
240 gcptmplpy gcp.rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4-
        stockYheight/8))
241 gcptmplpy gcp.rapidZ(0)
242 gcptmplpy #toolpaths = toolpaths.union(gcp.cutkeyholegdcxf(KH_tool_num, 0,
        stockZthickness*0.75, "W", stockYheight/9))
243 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), -
        stockZthickness/2))
244 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos()-
        stockYheight/9, gcp.ypos(), gcp.zpos()))
245 gcptmplpy #below should probably be cutlinegc
246 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos()+stockYheight/9,
        gcp.ypos(), gcp.zpos()))
247 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), 0))
248 gcptmplpy
249 gcptmplpy gcp.rapidZ(retractheight)
250 gcptmplpy gcp.rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4-
        stockYheight/8))
251 gcptmplpy gcp.rapidZ(0)
252 gcptmplpy #toolpaths = toolpaths.union(gcp.cutkeyholegdcxf(KH_tool_num, 0,
        stockZthickness*0.75, "S", stockYheight/9))
253 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), -
        stockZthickness/2))
254 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos()
        -stockYheight/9, gcp.zpos()))
255 gcptmplpy #below should probably be cutlinegc
256 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos()+
        stockYheight/9, gcp.zpos()))
257 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(), 0))
258 gcptmplpy
259 gcptmplpy gcp.rapidZ(retractheight)
260 gcptmplpy gcp.toolchange(56142,10000)
261 gcptmplpy gcp.rapidXY(-stockXwidth/2, -(stockYheight/2+0.508/2))
262 gcptmplpy #gcp.cutZgcfeed(-1.531,plunge)
263 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(),
        -1.531))
264 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/2+0.508/2,
        -(stockYheight/2+0.508/2), -1.531))
265 gcptmplpy
266 gcptmplpy gcp.rapidZ(retractheight)
267 gcptmplpy #gcp.toolchange(56125,10000)
268 gcptmplpy #gcp.cutZgcfeed(-1.531,plunge)
269 gcptmplpy toolpaths = toolpaths.union(gcp.cutline(gcp.xpos(), gcp.ypos(),
        -1.531))
270 gcptmplpy toolpaths = toolpaths.union(gcp.cutlinedxfgc(stockXwidth/2+0.508/2,
        (stockYheight/2+0.508/2), -1.531))
271 gcptmplpy
272 gcptmplpy
273 gcptmplpy part = gcp.stock.difference(toolpaths)
274 gcptmplpy
275 gcptmplpy output (part)
276 gcptmplpy #output(test)
277 gcptmplpy #output (key)
278 gcptmplpy #output(dt)
279 gcptmplpy #gcp.stockandtoolpaths()
280 gcptmplpy #gcp.stockandtoolpaths("stock")
281 gcptmplpy #output (gcp.stock)
282 gcptmplpy #output (gcp.toolpaths)
283 gcptmplpy #output (toolpaths)
284 gcptmplpy
285 gcptmplpy #gcp.makecube(3, 2, 1)
286 gcptmplpy #
287 gcptmplpy #gcp.placecube()
288 gcptmplpy #
289 gcptmplpy #c = gcp.instantiatecube()
290 gcptmplpy #
291 gcptmplpy #output(c)
292 gcptmplpy

```

```

293 gcptmplpy gcp.closegcodefile()
294 gcptmplpy gcp.closedxfiles()
295 gcptmplpy gcp.closedxfile()

```

2.3 gcodepreviewtemplate.scad

Since the project began in OpenSCAD, having an implementation in that language has always been a goal. This is quite straight-forward since the Python code when imported into OpenSCAD may be accessed by quite simple modules which are for the most part, a series of decorators/de-descriptors which wrap up the Python definitions as OpenSCAD modules. Moreover, such an implementation will facilitate usage by tools intended for this application such as OpenSCAD Graph Editor: <https://github.com/derkork/openscad-graph-editor>. A further consideration worth noting is that when called from OpenSCAD, Python will not halt for errors, but will run through to the end which is an expedient thing for viewing the end result of in-process code.

```

1 gcptmpl //!OpenSCAD
2 gcptmpl
3 gcptmpl use <gcodepreview.py>
4 gcptmpl include <gcodepreview.scad>
5 gcptmpl
6 gcptmpl $fa = 2;
7 gcptmpl $fs = 0.125;
8 gcptmpl fa = 2;
9 gcptmpl fs = 0.125;
10 gcptmpl
11 gcptmpl /* [Stock] */
12 gcptmpl stockXwidth = 219;
13 gcptmpl /* [Stock] */
14 gcptmpl stockYheight = 150;
15 gcptmpl /* [Stock] */
16 gcptmpl stockZthickness = 8.35;
17 gcptmpl /* [Stock] */
18 gcptmpl zeroheight = "Top"; // [Top, Bottom]
19 gcptmpl /* [Stock] */
20 gcptmpl stockzero = "Center"; // [Lower-Left, Center-Left, Top-Left, Center
    ]
21 gcptmpl /* [Stock] */
22 gcptmpl retractheight = 9;
23 gcptmpl
24 gcptmpl /* [Export] */
25 gcptmpl Base_filename = "export";
26 gcptmpl /* [Export] */
27 gcptmpl generatepaths = true;
28 gcptmpl /* [Export] */
29 gcptmpl generatedxf = true;
30 gcptmpl /* [Export] */
31 gcptmpl generategcode = true;
32 gcptmpl
33 gcptmpl /* [CAM] */
34 gcptmpl toolradius = 1.5875;
35 gcptmpl /* [CAM] */
36 gcptmpl large_square_tool_num = 0; // [0:0,112:112,102:102,201:201]
37 gcptmpl /* [CAM] */
38 gcptmpl small_square_tool_num = 102; // [0:0,122:122,112:112,102:102]
39 gcptmpl /* [CAM] */
40 gcptmpl large_ball_tool_num = 0; // [0:0,111:111,101:101,202:202]
41 gcptmpl /* [CAM] */
42 gcptmpl small_ball_tool_num = 0; // [0:0,121:121,111:111,101:101]
43 gcptmpl /* [CAM] */
44 gcptmpl large_V_tool_num = 0; // [0:0,301:301,690:690]
45 gcptmpl /* [CAM] */
46 gcptmpl small_V_tool_num = 0; // [0:0,390:390,301:301]
47 gcptmpl /* [CAM] */
48 gcptmpl DT_tool_num = 0; // [0:0,814:814]
49 gcptmpl /* [CAM] */
50 gcptmpl KH_tool_num = 0; // [0:0,374:374,375:375,376:376,378]
51 gcptmpl /* [CAM] */
52 gcptmpl Roundover_tool_num = 0; // [56142:56142, 56125:56125, 1570:1570]
53 gcptmpl /* [CAM] */
54 gcptmpl MISC_tool_num = 0; // [648:648]
55 gcptmpl
56 gcptmpl /* [Feeds and Speeds] */
57 gcptmpl plunge = 100;
58 gcptmpl /* [Feeds and Speeds] */
59 gcptmpl feed = 400;
60 gcptmpl /* [Feeds and Speeds] */

```

```

61 gcptmpl speed = 16000;
62 gcptmpl /* [Feeds and Speeds] */
63 gcptmpl small_square_ratio = 0.75; // [0.25:2]
64 gcptmpl /* [Feeds and Speeds] */
65 gcptmpl large_ball_ratio = 1.0; // [0.25:2]
66 gcptmpl /* [Feeds and Speeds] */
67 gcptmpl small_ball_ratio = 0.75; // [0.25:2]
68 gcptmpl /* [Feeds and Speeds] */
69 gcptmpl large_V_ratio = 0.875; // [0.25:2]
70 gcptmpl /* [Feeds and Speeds] */
71 gcptmpl small_V_ratio = 0.625; // [0.25:2]
72 gcptmpl /* [Feeds and Speeds] */
73 gcptmpl DT_ratio = 0.75; // [0.25:2]
74 gcptmpl /* [Feeds and Speeds] */
75 gcptmpl KH_ratio = 0.75; // [0.25:2]
76 gcptmpl /* [Feeds and Speeds] */
77 gcptmpl RO_ratio = 0.5; // [0.25:2]
78 gcptmpl /* [Feeds and Speeds] */
79 gcptmpl MISC_ratio = 0.5; // [0.25:2]
80 gcptmpl
81 gcptmpl thegeneratepaths = generatepaths == true ? 1 : 0;
82 gcptmpl thegeneratedxf = generatedxf == true ? 1 : 0;
83 gcptmpl thegenerategcode = generategcode == true ? 1 : 0;
84 gcptmpl
85 gcptmpl gcp = gcodepreview(thegeneratepaths,
86 gcptmpl                      thegenerategcode,
87 gcptmpl                      thegeneratedxf,
88 gcptmpl                      );
89 gcptmpl
90 gcptmpl.opengcodefile(Base_filename);
91 gcptmpl.opendxf(file(Base_filename));
92 gcptmpl.opendxf(files(Base_filename,
93 gcptmpl                      large_square_tool_num,
94 gcptmpl                      small_square_tool_num,
95 gcptmpl                      large_ball_tool_num,
96 gcptmpl                      small_ball_tool_num,
97 gcptmpl                      large_V_tool_num,
98 gcptmpl                      small_V_tool_num,
99 gcptmpl                      DT_tool_num,
100 gcptmpl                      KH_tool_num,
101 gcptmpl                      Roundover_tool_num,
102 gcptmpl                      MISC_tool_num));
103 gcptmpl
104 gcptmpl.setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight,
105 gcptmpl                      stockzero);
106 gcptmpl //echo(gcp);
107 gcptmpl //gcpversion();
108 gcptmpl
109 gcptmpl //c = myfunc(4);
110 gcptmpl //echo(c);
111 gcptmpl
112 gcptmpl //echo(getvv());
113 gcptmpl
114 gcptmpl.cutline(stockXwidth/2, stockYheight/2, -stockZthickness);
115 gcptmpl
116 gcptmpl.rapidZ(retractheight);
117 gcptmpl.toolchange(201, 10000);
118 gcptmpl.rapidXY(0, stockYheight/16);
119 gcptmpl.rapidZ(0);
120 gcptmpl.cutlinedxfgc(stockXwidth/16*7, stockYheight/2, -stockZthickness);
121 gcptmpl
122 gcptmpl
123 gcptmpl.rapidZ(retractheight);
124 gcptmpl.toolchange(202, 10000);
125 gcptmpl.rapidXY(0, stockYheight/8);
126 gcptmpl.rapidZ(0);
127 gcptmpl.cutlinedxfgc(stockXwidth/16*6, stockYheight/2, -stockZthickness);
128 gcptmpl
129 gcptmpl.rapidZ(retractheight);
130 gcptmpl.toolchange(101, 10000);
131 gcptmpl.rapidXY(0, stockYheight/16*3);
132 gcptmpl.rapidZ(0);
133 gcptmpl.cutlinedxfgc(stockXwidth/16*5, stockYheight/2, -stockZthickness);
134 gcptmpl
135 gcptmpl.rapidZ(retractheight);
136 gcptmpl.toolchange(390, 10000);
137 gcptmpl.rapidXY(0, stockYheight/16*4);

```

```

138 gcptmpl rapidZ(0);
139 gcptmpl
140 gcptmpl cutlinedxfgc(stockXwidth/16*4, stockYheight/2, -stockZthickness);
141 gcptmpl rapidZ(retractheight);
142 gcptmpl
143 gcptmpl toolchange(301,10000);
144 gcptmpl rapidXY(0, stockYheight/16*6);
145 gcptmpl rapidZ(0);
146 gcptmpl
147 gcptmpl cutlinedxfgc(stockXwidth/16*2, stockYheight/2, -stockZthickness);
148 gcptmpl
149 gcptmpl
150 gcptmpl movetosafeZ();
151 gcptmpl rapid(gcp.xpos(),gcp.ypos(),retractheight);
152 gcptmpl toolchange(102,10000);
153 gcptmpl
154 gcptmpl //rapidXY(stockXwidth/4+stockYheight/8+stockYheight/16, +
        stockYheight/8);
155 gcptmpl rapidXY(-stockXwidth/4+stockXwidth/16, (stockYheight/4));//+
        stockYheight/16
156 gcptmpl rapidZ(0);
157 gcptmpl
158 gcptmpl //cutarcCW(360,270, gcp.xpos()-stockYheight/16, gcp.ypos(),
        stockYheight/16,-stockZthickness);
159 gcptmpl //gcp.cutarcCW(270,180, gcp.xpos(), gcp.ypos()+stockYheight/16,
        stockYheight/16))
160 gcptmpl cutarcCC(0,90, gcp.xpos()-stockYheight/16, gcp.ypos(), stockYheight
        /16, -stockZthickness/4);
161 gcptmpl cutarcCC(90,180, gcp.xpos(), gcp.ypos()-stockYheight/16,
        stockYheight/16, -stockZthickness/4);
162 gcptmpl cutarcCC(180,270, gcp.xpos()+stockYheight/16, gcp.ypos(),
        stockYheight/16, -stockZthickness/4);
163 gcptmpl cutarcCC(270,360, gcp.xpos(), gcp.ypos()+stockYheight/16,
        stockYheight/16, -stockZthickness/4);
164 gcptmpl
165 gcptmpl movetosafeZ();
166 gcptmpl //rapidXY(stockXwidth/4+stockYheight/8-stockYheight/16, -
        stockYheight/8);
167 gcptmpl rapidXY(stockXwidth/4-stockYheight/16, -(stockYheight/4));
168 gcptmpl rapidZ(0);
169 gcptmpl
170 gcptmpl cutarcCW(180,90, gcp.xpos()+stockYheight/16, gcp.ypos(),
        stockYheight/16, -stockZthickness/4);
171 gcptmpl cutarcCW(90,0, gcp.xpos(), gcp.ypos()-stockYheight/16, stockYheight
        /16, -stockZthickness/4);
172 gcptmpl cutarcCW(360,270, gcp.xpos()-stockYheight/16, gcp.ypos(),
        stockYheight/16, -stockZthickness/4);
173 gcptmpl cutarcCW(270,180, gcp.xpos(), gcp.ypos()+stockYheight/16,
        stockYheight/16, -stockZthickness/4);
174 gcptmpl
175 gcptmpl movetosafeZ();
176 gcptmpl toolchange(201, 10000);
177 gcptmpl rapidXY(stockXwidth /2 -6.34, - stockYheight /2);
178 gcptmpl rapidZ(0);
179 gcptmpl cutarcCW(180, 90, stockXwidth /2 , -stockYheight/2, 6.34, -
        stockZthickness);
180 gcptmpl
181 gcptmpl movetosafeZ();
182 gcptmpl rapidXY(stockXwidth/2, -stockYheight/2);
183 gcptmpl rapidZ(0);
184 gcptmpl
185 gcptmpl gcp.cutlinedxfgc(gcp.xpos(), gcp.ypos(), -stockZthickness);
186 gcptmpl
187 gcptmpl movetosafeZ();
188 gcptmpl toolchange(814, 10000);
189 gcptmpl rapidXY(0, -(stockYheight/2+12.7));
190 gcptmpl rapidZ(0);
191 gcptmpl
192 gcptmpl cutlinedxfgc(xpos(), ypos(), -stockZthickness);
193 gcptmpl cutlinedxfgc(xpos(), -12.7 , -stockZthickness);
194 gcptmpl rapidXY(0, -(stockYheight/2+12.7));
195 gcptmpl
196 gcptmpl //rapidXY(stockXwidth/2-6.34, -stockYheight/2);
197 gcptmpl //rapidZ(0);
198 gcptmpl
199 gcptmpl //movetosafeZ();
200 gcptmpl //toolchange(374, 10000);
201 gcptmpl //rapidXY(-(stockXwidth/4 - stockXwidth /16), -(stockYheight/4 +

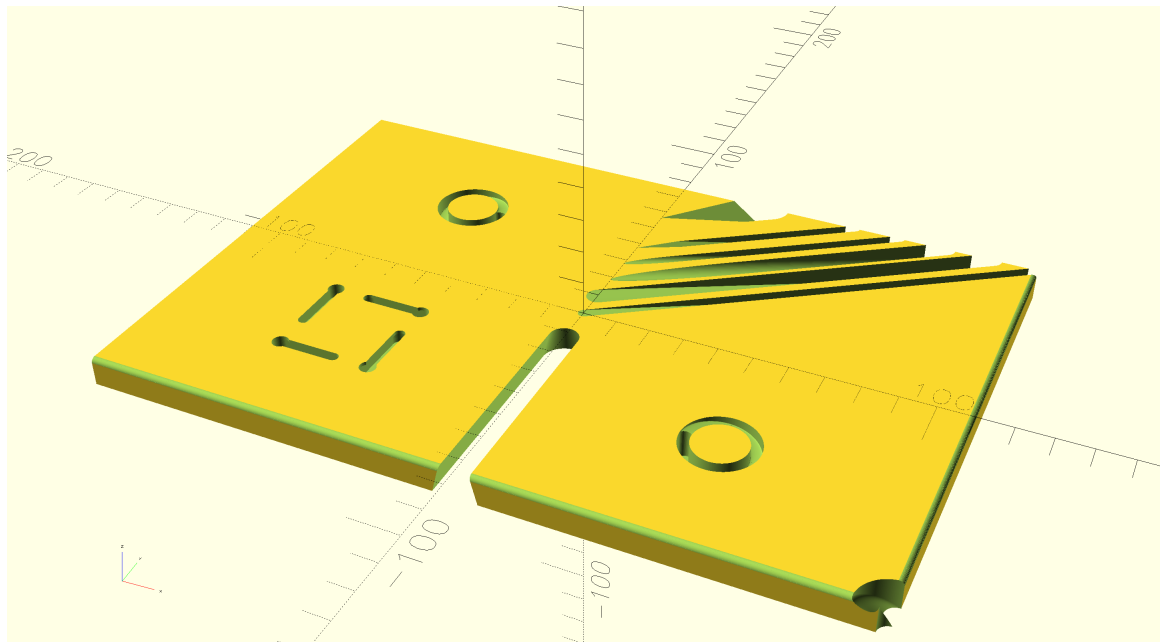
```

```

        stockYheight/16))
202 gcptmpl
203 gcptmpl //cutline(xpos(), ypos(), (stockZthickness/2) * -1);
204 gcptmpl //cutlinedxfgc(xpos() + stockYheight /9, ypos(), zpos());
205 gcptmpl //cutline(xpos() - stockYheight /9, ypos(), zpos());
206 gcptmpl //cutline(xpos(), ypos(), 0);
207 gcptmpl
208 gcptmpl movetosafeZ();
209 gcptmpl
210 gcptmpl stockandtoolpaths();
211 gcptmpl //stockwotoolpaths();
212 gcptmpl //outputtoolpaths();
213 gcptmpl
214 gcptmpl //makecube(3, 2, 1);
215 gcptmpl
216 gcptmpl //instantiatecube();
217 gcptmpl
218 gcptmpl closegcodefile();
219 gcptmpl closedxfiles();
220 gcptmpl closedxfile();

```

Which generates a 3D model which previews in OpenSCAD as:



```

opengcodefile(filename_gcode);
opendxfile(filename_dxf);

difference() {
  setupstock(stockXwidth, stockYheight, stockZthickness, zeroheight, stockzero);

  movetosafez();

  toolchange(small_square_tool_num,speed * small_square_ratio);

  begintoolpath(0,0,0.25);

  cutoneaxis_setfeed("Z",0,plunge*small_square_ratio);

  cutwithfeed(stockXwidth/2,stockYheight/2,-stockZthickness,feed);
  dxfline(getxpos(),getypos(),stockXwidth/2,stockYheight/2, small_square_tool_num);

  endtoolpath();
  rapid(-(stockXwidth/4-stockYheight/16),stockYheight/4,0);
  cutoneaxis_setfeed("Z",-stockZthickness,plunge*small_square_ratio);

  cutarcNECCdxf(-(stockXwidth/4, stockYheight/4+stockYheight/16, -stockZthickness, -stockXwidth/4, stockYheight/4);
  cutarcNWCCdxf(-(stockXwidth/4+stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stockYheight/4);
  cutarcSWCCdxf(-(stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYheight/4);
  cutarcSECCdxf(-(stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stockYheight/4);

  rapid(getxpos(),getypos(),stockZthickness);
  toolchange(KH_tool_num,speed * KH_ratio);
  rapid(-stockXwidth/8,-stockYheight/4,0);

```

```

cutkeyhole_toolpath((stockZthickness), (stockZthickness), "N", stockYheight/8, KH_tool_num);
rapid(getxpos(),getypos(),stockZthickness);
rapid(-stockXwidth/4,-stockYheight/4,0);
cutkeyhole_toolpath((stockZthickness), (stockZthickness), "S", stockYheight/8, KH_tool_num);
rapid(getxpos(),getypos(),stockZthickness);
rapid(-stockXwidth/4,-stockYheight/8,0);
cutkeyhole_toolpath((stockZthickness), (stockZthickness), "E", stockYheight/8, KH_tool_num);
rapid(getxpos(),getypos(),stockZthickness);
rapid(-stockXwidth/8,-stockYheight/8*3,0);
cutkeyhole_toolpath((stockZthickness), (stockZthickness), "W", stockYheight/8, KH_tool_num);

rapid(getxpos(),getypos(),stockZthickness);
toolchange(DT_tool_num,speed * DT_ratio);
rapid(0,-(stockYheight/2+tool_diameter(DT_tool_num,0)),0);

cutoneaxis_setfeed("Z",-stockZthickness,plunge*DT_ratio);
cutwithfeed(0,-(stockYheight/4),-stockZthickness,feed*DT_ratio);
rapid(0,-(stockYheight/2+tool_diameter(DT_tool_num,0)),-stockZthickness);

rapid(getxpos(),getypos(),stockZthickness);
toolchange(Roundover_tool_num, speed * R0_ratio);
rapid(-(stockXwidth/2),-(stockYheight/2),0);
cutoneaxis_setfeed("Z",-4.509,plunge*R0_ratio);

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);

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);
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);
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);

//for (i = [0 : abs(1) : 80]) {
//  cutwithfeed(stockXwidth/4,-stockYheight/4,-stockZthickness/4,feed);
//  cutwithfeed(stockXwidth/8+(stockXwidth/256*i),-stockYheight/2,-stockZthickness*3/4,feed);
// }

hull(){
  cutwithfeed(stockXwidth/4,-stockYheight/4,-stockZthickness/4,feed);
  cutwithfeed(stockXwidth/8,-stockYheight/2,-stockZthickness*3/4,feed);
  cutwithfeed(stockXwidth/8+(stockXwidth*0.3125),-stockYheight/2,-stockZthickness*3/4,feed);
}
}

closegcodefile();
closedxfile();

```

Note that there are several possible ways to work with the 3D models of the cuts, either directly displaying the returned 3D model when explicitly called for after storing it in a variable or calling it up as a calculation (Python command `output(<foo>)` or OpenSCAD returning a model, or calling an appropriate OpenSCAD command):

- `generatepaths = true` — this has the Python code collect toolpath cuts and rapid movements in variables which are then instantiated by appropriate commands/options (shown in the OpenSCAD template `gcodepreview.scad`)
- `generatepaths = false` — this option affords the user control over how the model elements are handled (shown in the Python template `gcodepreview.py`)

the templates set up these options as noted, and for OpenSCAD, implement code to ensure that `True == true`, and a set of commands are provided to output the stock, toolpaths, or part (toolpaths and rapids differenced from stock).

3 *gcodepreview*

This library for PythonSCAD 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 (note that at least a 4th additional axis may be worked up as a future option) 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 and using a traditional CAM application). There are multiple modes for this, doing so requires two 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 an additional OpenSCAD module which allows accessing it
- An OpenSCAD file: `gcodepreview.scad` (`gcpscad`) — which uses the Python file and which is included allowing it to access OpenSCAD variables for branching

Note that this architecture requires that many OpenSCAD modules are essentially “Dispatchers” (another term is “Descriptors”) which pass information from one aspect of the environment to another, but in some instances it will be necessary to re-write Python definitions in OpenSCAD rather than calling the matching Python function directly.

3.1 Module Naming Convention

The original implementation required three files and used a convention for prefacing commands with `o` or `p`, but this requirement was obviated in the full Python re-write. The current implementation depends upon the class being instantiated as `gcp` as a sufficient differentiation between the Python and the OpenSCAD version of a command.

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

Tool `#s` where used will always be the first argument — this makes it obvious if they are not used — the negative, that it then doesn’t allow for a usage where a `DEFAULT` tool is used is not an issue since the command `currenttoolnum()` may be used to access that number, and is arguably the preferred mechanism. An exception is when there are multiple tool `#s` as when opening a file — collecting them all at the end is a more straight-forward approach.

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
 - `generate` (Boolean) — used to identify which types of actions will be done
 - `write` (action) — used to write to files
 - `cut` (action — create 3D object)
 - `rapid` (action — create 3D object so as to show a collision)
 - `open` (action (file))
 - `close` (action (file))
 - `set` (action/function) — note that the matching `get` is implicit in functions which return variables, e.g., `xpos()`
 - `current`
- Nouns
 - `arc`
 - `line`
 - `rectangle`
 - `circle`
- Suffixes
 - `feed` (parameter)
 - `gcode/gc` (filetype)
 - `pos` — position
 - `tool`
 - `loop`
 - `CC/CW`
 - `number/num` — note that `num` is used internally for variable names, making it straight-forward 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	dx	gcode	cut	dx	gcode
cut	cutline		cutlinegc	cutarc		cutarcgc
dx	cutlinedx	dxline		cutarcdx	dxfar	
gcode	cutlinegc		linegc	cutarcgc		arcgc
	cutlinedxfgc			cutarcdxfgc		

Note that certain commands (`dxlinegc`, `dxfar`, `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>gc` commands was warranted during the initial development of `arc`-related commands.

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)`, `dx`, `gcode`, `tool`, etc.) note the `gcodepreview` class which will normally be imported as `gcp` so that module `<foo>` will be called as `gcp.<foo>` from Python and by the same `<foo>` in OpenSCAD

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

There are multiple modes for programming PythonSCAD:

- Python — in `gcodepreview` this allows writing out `dx` files
- OpenSCAD — see: <https://openscad.org/documentation.html>
- Programming in OpenSCAD with variables and calling Python — this requires 3 files and was originally used in the project as written up at: https://github.com/WillAdams/gcodepreview/blob/main/gcodepreview-openscad_0_6.pdf (for further details see below)
- Programming in OpenSCAD and calling Python where all variables as variables are held in Python classes (this is the technique used as of v0.8)
- Programming in Python and calling OpenSCAD — https://old.reddit.com/r/OpenPythonSCAD/comments/1heczmi/finally_using_scad_modules/

For reference, structurally, when developing OpenSCAD commands which make use of Python variables this was rendered as:

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 style of definition might not have been necessary for some later modules since they are in turn calling internal modules which already use this structure.

Lastly note that this style of programming was abandoned in favour of object-oriented dot notation after vo.6 (see below).

3.1.1 Parameters and Default Values

Ideally, there would be *no* hard-coded values — every value used for calculation will be parameterized, and subject to control/modification. Fortunately, Python affords a feature which specifically addresses this, optional arguments with default values:

<https://stackoverflow.com/questions/9539921/how-do-i-define-a-function-with-optional-arguments>

In short, rather than hard-code numbers, for example in loops, they will be assigned as default values, and thus afford the user/programmer the option of changing them after.

3.2 Implementation files and gcodepreview class

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

```

1 gcpy #!/usr/bin/env python
2 gcpy #icon "C:\Program Files\PythonSCAD\bin\openscad.exe" --trust -
   python
3 gcpy #Currently tested with PythonSCAD_nolibfive-2025.01.02-x86-64-
   Installer.exe and Python 3.11
4 gcpy #gcodepreview 0.8, for use with PythonSCAD,
5 gcpy #if using from PythonSCAD using OpenSCAD code, see gcodepreview.
   scad

6 gcpy
7 gcpy import sys
8 gcpy
9 gcpy # getting openscad functions into namespace
10 gcpy #https://github.com/gsohler/openscad/issues/39
11 gcpy try:
12 gcpy     from openscad import *
13 gcpy except ModuleNotFoundError as e:
14 gcpy     print("OpenSCAD module not loaded.")
15 gcpy
16 gcpy # add math functions (using radians by default, convert to degrees
   where necessary)
17 gcpy import math
18 gcpy
19 gcpy def pygcpversion():
20 gcpy     thegcpversion = 0.8
21 gcpy     return thegcpversion

```

The OpenSCAD file must use the Python file (note that some test/example code is commented out):

```

1 gcpscad #!/OpenSCAD
2 gcpscad
3 gcpscad //gcodepreview version 0.8
4 gcpscad //
5 gcpscad //used via include <gcodepreview.scad>;
6 gcpscad //
7 gcpscad
8 gcpscad use <gcodepreview.py>
9 gcpscad
10 gcpscad module gcpversion(){
11 gcpscad echo(pygcpversion());
12 gcpscad }
13 gcpscad
14 gcpscad //function myfunc(var) = gcp.myfunc(var);
15 gcpscad //
16 gcpscad //function getvv() = gcp.getvv();
17 gcpscad //
18 gcpscad //module makecube(xdim, ydim, zdim){
19 gcpscad //gcp.makecube(xdim, ydim, zdim);
20 gcpscad //}
21 gcpscad //
22 gcpscad //module placecube(){
23 gcpscad //gcp.placecube();
24 gcpscad //}
25 gcpscad //
26 gcpscad //module instantiatecube(){
27 gcpscad //gcp.instantiatecube();
28 gcpscad //}

```

29 gpcscad //

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

```

23 gcpy class gcodepreview:
24 gcpy
25 gcpy     def __init__(self, #basefilename = "export",
26 gcpy                     generatepaths = False,
27 gcpy                     generategcode = False,
28 gcpy                     generatedxf = False,
29 gcpy #                     stockXwidth = 25,
30 gcpy #                     stockYheight = 25,
31 gcpy #                     stockZthickness = 1,
32 gcpy #                     zeroheight = "Top",
33 gcpy #                     stockzero = "Lower-left" ,
34 gcpy #                     retractheight = 6,
35 gcpy #                     currenttoolnum = 102,
36 gcpy #                     toolradius = 3.175,
37 gcpy #                     plunge = 100,
38 gcpy #                     feed = 400,
39 gcpy #                     speed = 10000
40 gcpy                     ):
41 gcpy #         self.basefilename = basefilename
42 gcpy         if (generatepaths == 1):
43 gcpy             self.generatepaths = True
44 gcpy         if (generatepaths == 0):
45 gcpy             self.generatepaths = False
46 gcpy         else:
47 gcpy             self.generatepaths = generatepaths
48 gcpy         if (generategcode == 1):
49 gcpy             self.generategcode = True
50 gcpy         if (generategcode == 0):

```

```
51 gcpy             self.generategcode = False
52 gcpy             else:
53 gcpy             self.generategcode = generategcode
54 gcpy             if (generatedxf == 1):
55 gcpy             self.generatedxf = True
56 gcpy             if (generatedxf == 0):
57 gcpy             self.generatedxf = False
58 gcpy             else:
59 gcpy             self.generatedxf = generatedxf
60 gcpy #           self.stockXwidth = stockXwidth
61 gcpy #           self.stockYheight = stockYheight
62 gcpy #           self.stockZthickness = stockZthickness
63 gcpy #           self.zeroheight = zeroheight
64 gcpy #           self.stockzero = stockzero
65 gcpy #           self.retractheight = retractheight
66 gcpy #           self.currenttoolnum = currenttoolnum
67 gcpy #           self.toolradius = toolradius
68 gcpy #           self.plunge = plunge
69 gcpy #           self.feed = feed
70 gcpy #           self.speed = speed
71 gcpy #           global toolpaths
72 gcpy #           if (openscadloaded == True):
73 gcpy #             self.toolpaths = cylinder(0.1, 0.1)
74 gcpy             self.generatedxfs = False
75 gcpy
76 gcpy             def checkgeneratepaths():
77 gcpy             return self.generatepaths
78 gcpy
79 gcpy #           def myfunc(self, var):
80 gcpy #             self.vv = var * var
81 gcpy #             return self.vv
82 gcpy #
83 gcpy #           def getvv(self):
84 gcpy #             return self.vv
85 gcpy #
86 gcpy #           def checkint(self):
87 gcpy #             return self.mc
88 gcpy #
89 gcpy #           def makecube(self, xdim, ydim, zdim):
90 gcpy #             self.c=cube([xdim, ydim, zdim])
91 gcpy #
92 gcpy #           def placecube(self):
93 gcpy #             output(self.c)
94 gcpy #
95 gcpy #           def instantiatecube(self):
96 gcpy #             return self.c
97 gcpy #
```

3.2.1 Position and Variables

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

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, or the increment which a cut advances — this is done using an internal variable, tpzinc.

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

- currenttoolnum
- currenttoolnum

Note that the currenttoolnum variable should always be accessed and 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.

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

```
xpos
ypos
zpos
97 gcpy             def xpos(self):
98 gcpy #             global mpx
99 gcpy             return self.mpx
```

```
100 gcpy
101 gcpy      def ypos(self):
102 gcpy #          global mpy
103 gcpy          return self.mpy
104 gcpy
105 gcpy      def zpos(self):
106 gcpy #          global mpz
107 gcpy          return self.mpz
108 gcpy
109 gcpy #      def tpzinc(self):
110 gcpy #          global tpzinc
111 gcpy #          return self.tpzinc
```

Wrapping these in OpenSCAD functions allows use of this positional information from OpenSCAD:

```
29 gcpscad function xpos() = gcp.xpos();
30 gcpscad
31 gcpscad function ypos() = gcp.ypos();
32 gcpscad
33 gcpscad function zpos() = gcp.zpos();
```

and in turn, functions which set the positions: setxpos, setypos, and setzpos.

```
setxpos
setypos
setzpos 113 gcpy      def setxpos(self, newxpos):
114 gcpy #          global mpx
115 gcpy          self.mpx = newxpos
116 gcpy
117 gcpy      def setypos(self, newypos):
118 gcpy #          global mpy
119 gcpy          self.mpy = newypos
120 gcpy
121 gcpy      def setzpos(self, newzpos):
122 gcpy #          global mpz
123 gcpy          self.mpz = newzpos
124 gcpy
125 gcpy #      def settpzinc(self, newtpzinc):
126 gcpy #          global tpzinc
127 gcpy #          self.tpzinc = newtpzinc
```

Using the set... routines will afford a single point of control if specific actions are found to be contingent on changes to these positions.

3.2.2 Initial Modules

gcodepreview
setupstock
gcp.setupstock

The first such routine, (actually a subroutine, see gcodepreview) setupstock 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 version handles all necessary actions.

Since part of a class, it will be called as gcp.setupstock. It requires that the user set parameters for stock dimensions and so forth, and will create comments in the G-code (if generating that file is enabled) which incorporate the stock dimensions and its position relative to the zero as set relative to the stock.

```
129 gcpy      def setupstock(self, stockXwidth,
130 gcpy          stockYheight,
131 gcpy          stockZthickness,
132 gcpy          zeroheight,
133 gcpy          stockzero,
134 gcpy          retractheight):
135 gcpy          self.stockXwidth = stockXwidth
136 gcpy          self.stockYheight = stockYheight
137 gcpy          self.stockZthickness = stockZthickness
138 gcpy          self.zeroheight = zeroheight
139 gcpy          self.stockzero = stockzero
140 gcpy          self.retractheight = retractheight
141 gcpy #          global mpx
142 gcpy          self.mpx = float(0)
143 gcpy #          global mpy
144 gcpy          self.mpy = float(0)
145 gcpy #          global mpz
146 gcpy          self.mpz = float(0)
147 gcpy #          global tpz
148 gcpy #          self.tpzinc = float(0)
149 gcpy #          global currenttoolnum
150 gcpy          self.currenttoolnum = 102
```

```

151 gcpy #          global currenttoolshape
152 gcpy          self.currenttoolshape = cylinder(12.7, 1.5875)
153 gcpy          self.rapids = self.currenttoolshape
154 gcpy #          global stock
155 gcpy          self.stock = cube([stockXwidth, stockYheight,
                                stockZthickness])
156 gcpy %%WRITEGC          if self.generategcode == True:
157 gcpy %%WRITEGC          self.writegc("(Design File: " + self.
                                basefilename + ")")
158 gcpy          self.toolpaths = cylinder(0.1, 0.1)

```

Note that since Python in PythonSCAD 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 describes it in comments using the terms described for CutViewer.

```

159 gcpy          if self.zeroheight == "Top":
160 gcpy              if self.stockzero == "Lower-Left":
161 gcpy                  self.stock = self.stock.translate([0,0,-self.
                                stockZthickness])
162 gcpy              if self.generategcode == True:
163 gcpy                  self.writegc("(stockMin:0.00mm,␣0.00mm,␣-",str(
                                self.stockZthickness),"mm)")
164 gcpy                  self.writegc("(stockMax:",str(self.stockXwidth)
                                ,"mm,␣",str(stockYheight),"mm,␣0.00mm)")
165 gcpy                  self.writegc("(STOCK/BLOCK,␣",str(self.
                                stockXwidth),"␣",str(self.stockYheight),"␣
                                ",str(self.stockZthickness),"␣0.00,␣0.00,␣"
                                ,str(self.stockZthickness),")")
166 gcpy              if self.stockzero == "Center-Left":
167 gcpy                  self.stock = self.stock.translate([0,-stockYheight
                                / 2,-stockZthickness])
168 gcpy              if self.generategcode == True:
169 gcpy                  self.writegc("(stockMin:0.00mm,␣-",str(self.
                                stockYheight/2),"mm,␣-",str(self.
                                stockZthickness),"mm)")
170 gcpy                  self.writegc("(stockMax:",str(self.stockXwidth)
                                ,"mm,␣",str(self.stockYheight/2),"mm,␣0.00mm
                                )")
171 gcpy                  self.writegc("(STOCK/BLOCK,␣",str(self.
                                stockXwidth),"␣",str(self.stockYheight),"␣
                                ",str(self.stockZthickness),"␣0.00,␣",str(
                                self.stockYheight/2),"␣",str(self.
                                stockZthickness),")");
172 gcpy              if self.stockzero == "Top-Left":
173 gcpy                  self.stock = self.stock.translate([0,-self.
                                stockYheight,-self.stockZthickness])
174 gcpy              if self.generategcode == True:
175 gcpy                  self.writegc("(stockMin:0.00mm,␣-",str(self.
                                stockYheight),"mm,␣-",str(self.
                                stockZthickness),"mm)")
176 gcpy                  self.writegc("(stockMax:",str(self.stockXwidth)
                                ,"mm,␣0.00mm,␣0.00mm)")
177 gcpy                  self.writegc("(STOCK/BLOCK,␣",str(self.
                                stockXwidth),"␣",str(self.stockYheight),"␣
                                ",str(self.stockZthickness),"␣0.00,␣",str(
                                self.stockYheight),"␣",str(self.
                                stockZthickness),")")
178 gcpy              if self.stockzero == "Center":
179 gcpy                  self.stock = self.stock.translate([-self.
                                stockXwidth / 2,-self.stockYheight / 2,-self.
                                stockZthickness])
180 gcpy              if self.generategcode == True:
181 gcpy                  self.writegc("(stockMin:␣-",str(self.
                                stockXwidth/2),"␣-",str(self.stockYheight
                                /2),"mm,␣-",str(self.stockZthickness),"mm)")
182 gcpy                  self.writegc("(stockMax:",str(self.stockXwidth
                                /2),"mm,␣",str(self.stockYheight/2),"mm,␣
                                0.00mm)")
183 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),")")
184 gcpy          if self.zeroheight == "Bottom":
185 gcpy              if self.stockzero == "Lower-Left":

```

```
186 gcpy          self.stock = self.stock.translate([0,0,0])
187 gcpy          if self.generategcode == True:
188 gcpy              self.wrotegc("(stockMin:0.00mm,␣0.00mm,␣0.00mm
                        )")
189 gcpy              self.wrotegc("(stockMax:",str(self.stockXwidth
                        ),"mm,␣",str(self.stockYheight),"mm,␣␣",str
                        (self.stockZthickness),"mm)")
190 gcpy              self.wrotegc("(STOCK/BLOCK,␣",str(self.
                        stockXwidth),"␣",str(self.stockYheight),"
                        ,␣",str(self.stockZthickness),"␣0.00,␣0.00,
                        ␣0.00)")
191 gcpy          if self.stockzero == "Center-Left":
192 gcpy              self.stock = self.stock.translate([0,-self.
                        stockYheight / 2,0])
193 gcpy          if self.generategcode == True:
194 gcpy              self.wrotegc("(stockMin:0.00mm,␣-",str(self.
                        stockYheight/2),"mm,␣0.00mm)")
195 gcpy              self.wrotegc("(stockMax:",str(self.stockXwidth
                        ),"mm,␣",str(self.stockYheight/2),"mm,␣-",str
                        (self.stockZthickness),"mm)")
196 gcpy              self.wrotegc("(STOCK/BLOCK,␣",str(self.
                        stockXwidth),"␣",str(self.stockYheight),"␣
                        ",str(self.stockZthickness),"␣0.00,␣",str(
                        self.stockYheight/2),"␣0.00mm)");
197 gcpy          if self.stockzero == "Top-Left":
198 gcpy              self.stock = self.stock.translate([0,-self.
                        stockYheight,0])
199 gcpy          if self.generategcode == True:
200 gcpy              self.wrotegc("(stockMin:0.00mm,␣-",str(self.
                        stockYheight),"mm,␣0.00mm)")
201 gcpy              self.wrotegc("(stockMax:",str(self.stockXwidth
                        ),"mm,␣0.00mm,␣",str(self.stockZthickness),"
                        mm)")
202 gcpy              self.wrotegc("(STOCK/BLOCK,␣",str(self.
                        stockXwidth),"␣",str(self.stockYheight),"␣
                        ",str(self.stockZthickness),"␣0.00,␣",str(
                        self.stockYheight),"␣0.00)")
203 gcpy          if self.stockzero == "Center":
204 gcpy              self.stock = self.stock.translate([-self.
                        stockXwidth / 2,-self.stockYheight / 2,0])
205 gcpy          if self.generategcode == True:
206 gcpy              self.wrotegc("(stockMin:␣-",str(self.
                        stockXwidth/2),"␣-",str(self.stockYheight
                        /2),"mm,␣0.00mm)")
207 gcpy              self.wrotegc("(stockMax:",str(self.stockXwidth
                        /2),"mm,␣",str(self.stockYheight/2),"mm,␣",
                        str(self.stockZthickness),"mm)")
208 gcpy              self.wrotegc("(STOCK/BLOCK,␣",str(self.
                        stockXwidth),"␣",str(self.stockYheight),"␣
                        ",str(self.stockZthickness),"␣",str(self.
                        stockXwidth/2),"␣", str(self.stockYheight
                        /2),"␣0.00)")
209 gcpy          if self.generategcode == True:
210 gcpy              self.wrotegc("G90");
211 gcpy              self.wrotegc("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. The OpenSCAD version is simply a descriptor:

```
38 gcpscad module setupstock(stockXwidth, stockYheight, stockZthickness,
                             zeroheight, stockzero, retractheight) {
39 gcpscad     gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
                             zeroheight, stockzero, retractheight);
40 gcpscad }
```

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()
```


3.3 Tools and Changes

currenttoolnumber

settool

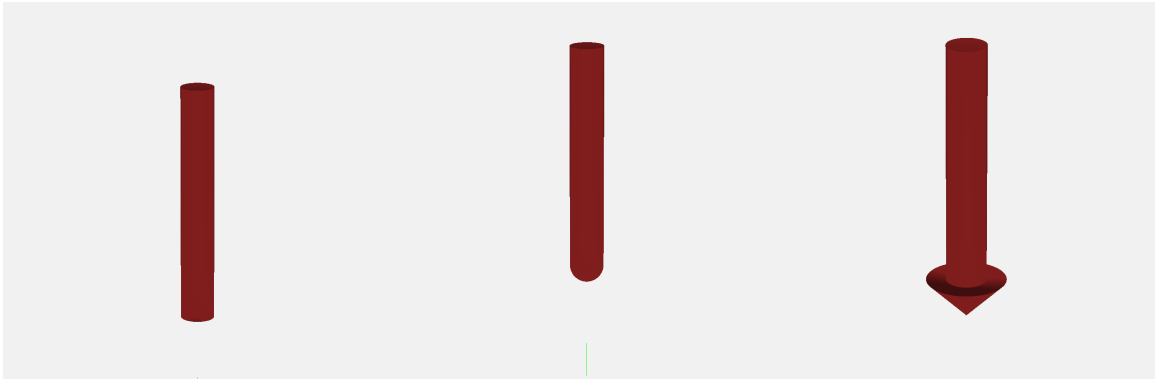
Similarly Python functions and variables will be used in: currenttoolnumber (note that it is important to use a different name than the variable currenttoolnum and settool to track and set and return the current tool:

```
213 gcpy      def settool(self,tn):
214 gcpy #          global currenttoolnum
215 gcpy          self.currenttoolnum = tn
216 gcpy
217 gcpy      def currenttoolnumber(self):
218 gcpy #          global currenttoolnum
219 gcpy          return self.currenttoolnum
220 gcpy
221 gcpy #      def currentroundovertoolnumber(self):
222 gcpy #          global Roundover_tool_num
223 gcpy #          return self.Roundover_tool_num
```

3.3.1 3D Shapes for Tools

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

3.3.1.1 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:

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

ballnose

The ballnose is modeled as a hemisphere joined with a cylinder:

```
228 gcpy      def ballnose(self, es_diameter, es_flute_length):
229 gcpy          b = sphere(r=(es_diameter / 2))
230 gcpy          s = cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h=
                            es_flute_length, center=False)
231 gcpy          p = union(b,s)
232 gcpy          return p.translate([0, 0, (es_diameter / 2)])
```

endmill v

The 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):

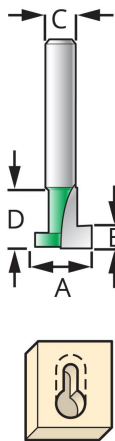
```
234 gcpy      def endmill_v(self, es_v_angle, es_diameter):
235 gcpy          es_v_angle = math.radians(es_v_angle)
236 gcpy          v = cylinder(r1=0, r2=(es_diameter / 2), h=((es_diameter /
                    2) / math.tan((es_v_angle / 2))), center=False)
```

```
237 gcpy      s = cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h
              =((es_diameter * 8) ), center=False)
238 gcpy      sh = s.translate([0, 0, ((es_diameter / 2) / math.tan((
              es_v_angle / 2))))])
239 gcpy      return union(v,sh)
```

3.3.1.2 Tooling for Undercutting Toolpaths There are several notable candidates for undercutting tooling.

- 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 completeness’ sake and are not (at this time) implemented
- Threadmill — used for cutting threads, normally a single form geometry is used on a CNC.

3.3.1.2.1 Keyhole tools Keyhole toolpaths (see: subsection 3.4.3.2.3 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.



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 The keyhole is modeled in two parts, first the cutting base:

```
241 gcpy      def keyhole(self, es_diameter, es_flute_length):
242 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:

```
244 gcpy      def keyhole_shaft(self, es_diameter, es_flute_length):
245 gcpy      return cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2),
                             h=es_flute_length, center=False)
```

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

```
247 gcpy      def threadmill(self, minor_diameter, major_diameter, cut_height
248 gcpy      ):
249 gcpy      btm = cylinder(r1=(minor_diameter / 2), r2=(major_diameter
250 gcpy      / 2), h=cut_height, center = False)
251 gcpy      top = cylinder(r1=(major_diameter / 2), r2=(minor_diameter
252 gcpy      / 2), h=cut_height, center = False)
253 gcpy      top = top.translate([0, 0, cut_height/2])
254 gcpy      tm = btm.union(top)
255 gcpy      return tm
```

```
254 gcpy      def threadmill_shaft(self, diameter, cut_height, height):
255 gcpy          shaft = cylinder(r1=(diameter / 2), r2=(diameter / 2), h=
                        height, center = False)
256 gcpy          shaft = shaft.translate([0, 0, cut_height/2])
257 gcpy          return shaft
```

dovetail **3.3.1.2.3 Dovetails** The 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)

```
259 gcpy      def dovetail(self, dt_bottomdiameter, dt_topdiameter, dt_height
                        , dt_angle):
260 gcpy          return cylinder(r1=(dt_bottomdiameter / 2), r2=(
                        dt_topdiameter / 2), h= dt_height, center=False)
```

3.3.1.3 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 sections or even slices of the tool shape to be modeled separately 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-bits/43723>.

Because it is necessary to divide the tooling into vertical slices and call the hull operation for each slice the tool definitions have to be called separately in the cut... modules.

3.3.1.4 Roundover tooling It is not possible to represent all tools using tool changes as coded above which require using a hull operation between 3D representations of the tools at the beginning and end points. Tooling which cannot be so represented will be implemented separately below, see paragraph 3.3.1.3.

```
42 gpcscad module cutroundover(bx, by, bz, ex, ey, ez, radiustn) {
43 gpcscad     if (radiustn == 56125) {
44 gpcscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.508/2, 1.531);
45 gpcscad     } else if (radiustn == 56142) {
46 gpcscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.508/2, 2.921);
47 gpcscad //     } else if (radiustn == 312) {
48 gpcscad //         cutroundovertool(bx, by, bz, ex, ey, ez, 1.524/2, 3.175);
49 gpcscad     } else if (radiustn == 1570) {
50 gpcscad         cutroundovertool(bx, by, bz, ex, ey, ez, 0.507/2, 4.509);
51 gpcscad     }
52 gpcscad }
```

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.

3.3.2 toolchange

toolchange Then 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.

Note that the comments written out in G-code correspond to those 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 there are many varieties of tooling and not all will be implemented, especially in the early iterations of this project.

3.3.2.1 Selecting Tools The original implementation created the model for the tool at the current position, and a duplicate at the end 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 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.

currenttoolshape

```
262 gcpy      def currenttool(self):
263 gcpy #          global currenttoolshape
264 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:

3.3.2.2 Square and ball nose (including tapered ball nose)

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

3.3.2.3 Roundover (corner rounding)

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

3.3.2.4 Dovetails Unfortunately, tools which support undercuts such as dovetails are not supported by CutViewer (CAMotics will work for such tooling, at least dovetails which may be defined as "stub" endmills with a bottom diameter greater than upper diameter).

3.3.2.5 toolchange routine The Python definition for toolchange requires the tool number (used to write out the G-code comment description for CutViewer and also expects the speed for the current tool since this is passed into the G-code tool change command as part of the spindle on command.

```
266 gcpy      def toolchange(self,tool_number,speed = 10000):
267 gcpy #          global currenttoolshape
268 gcpy          self.currenttoolshape = self.endmill_square(0.001, 0.001)
269 gcpy
270 gcpy          self.settool(tool_number)
271 gcpy          if (self.generategcode == True):
272 gcpy              self.writegc("Toolpath")
273 gcpy              self.writegc("M05")
274 gcpy          if (tool_number == 201):
275 gcpy              self.writegc("(TOOL/MILL,6.35,▯0.00,▯0.00,▯0.00)")
276 gcpy              self.currenttoolshape = self.endmill_square(6.35,
277 gcpy                  19.05)
278 gcpy          elif (tool_number == 102):
279 gcpy              self.writegc("(TOOL/MILL,3.175,▯0.00,▯0.00,▯0.00)")
280 gcpy              self.currenttoolshape = self.endmill_square(3.175,
281 gcpy                  12.7)
282 gcpy          elif (tool_number == 112):
283 gcpy              self.writegc("(TOOL/MILL,1.5875,▯0.00,▯0.00,▯0.00)")
284 gcpy              self.currenttoolshape = self.endmill_square(1.5875,
285 gcpy                  6.35)
286 gcpy          elif (tool_number == 122):
287 gcpy              self.writegc("(TOOL/MILL,0.79375,▯0.00,▯0.00,▯0.00)")
288 gcpy              self.currenttoolshape = self.endmill_square(0.79375,
289 gcpy                  1.5875)
290 gcpy          elif (tool_number == 202):
291 gcpy              self.writegc("(TOOL/MILL,6.35,▯3.175,▯0.00,▯0.00)")
292 gcpy              self.currenttoolshape = self.ballnose(6.35, 19.05)
293 gcpy          elif (tool_number == 101):
294 gcpy              self.writegc("(TOOL/MILL,3.175,▯1.5875,▯0.00,▯0.00)")
295 gcpy              self.currenttoolshape = self.ballnose(3.175, 12.7)
296 gcpy          elif (tool_number == 111):
297 gcpy              self.writegc("(TOOL/MILL,1.5875,▯0.79375,▯0.00,▯0.00)")
298 gcpy              self.currenttoolshape = self.ballnose(1.5875, 6.35)
299 gcpy          elif (tool_number == 121):
300 gcpy              self.writegc("(TOOL/MILL,3.175,▯0.79375,▯0.00,▯0.00)")
301 gcpy              self.currenttoolshape = self.ballnose(0.79375, 1.5875)
302 gcpy          elif (tool_number == 327):
303 gcpy              self.writegc("(TOOL/MILL,0.03,▯0.00,▯13.4874,▯30.00)")
304 gcpy              self.currenttoolshape = self.endmill_v(60, 26.9748)
305 gcpy          elif (tool_number == 301):
306 gcpy              self.writegc("(TOOL/MILL,0.03,▯0.00,▯6.35,▯45.00)")
307 gcpy              self.currenttoolshape = self.endmill_v(90, 12.7)
308 gcpy          elif (tool_number == 302):
309 gcpy              self.writegc("(TOOL/MILL,0.03,▯0.00,▯10.998,▯30.00)")
310 gcpy              self.currenttoolshape = self.endmill_v(60, 12.7)
311 gcpy          elif (tool_number == 390):
312 gcpy              self.writegc("(TOOL/MILL,0.03,▯0.00,▯1.5875,▯45.00)")
313 gcpy              self.currenttoolshape = self.endmill_v(90, 3.175)
314 gcpy          elif (tool_number == 374):
315 gcpy              self.writegc("(TOOL/MILL,9.53,▯0.00,▯3.17,▯0.00)")
316 gcpy          elif (tool_number == 375):
317 gcpy              self.writegc("(TOOL/MILL,9.53,▯0.00,▯3.17,▯0.00)")
318 gcpy          elif (tool_number == 376):
319 gcpy              self.writegc("(TOOL/MILL,12.7,▯0.00,▯4.77,▯0.00)")
320 gcpy          elif (tool_number == 378):
321 gcpy              self.writegc("(TOOL/MILL,12.7,▯0.00,▯4.77,▯0.00)")
```

```
318 gcpy          elif (tool_number == 814):
319 gcpy            self.writegc("(TOOL/MILL,12.7,␣6.367,␣12.7,␣0.00)")
320 gcpy            #dt_bottomdiameter, dt_topdiameter, dt_height, dt_angle
                    )
321 gcpy            #https://www.leevalley.com/en-us/shop/tools/power-tool-
                    accessories/router-bits/30172-dovetail-bits?item=18
                    J1607
322 gcpy            self.currenttoolshape = self.dovetail(12.7, 6.367,
                    12.7, 14)
323 gcpy          elif (tool_number == 56125):#0.508/2, 1.531
324 gcpy            self.writegc("(TOOL/CRMILL,␣0.508,␣6.35,␣3.175,␣7.9375,
                    ␣3.175)")
325 gcpy          elif (tool_number == 56142):#0.508/2, 2.921
326 gcpy            self.writegc("(TOOL/CRMILL,␣0.508,␣3.571875,␣1.5875,␣
                    5.55625,␣1.5875)")
327 gcpy #          elif (tool_number == 312):#1.524/2, 3.175
328 gcpy #            self.writegc("(TOOL/CRMILL, Diameter1, Diameter2,
                    Radius, Height, Length)")
329 gcpy          elif (tool_number == 1570):#0.507/2, 4.509
330 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.

```
331 gcpy          self.writegc("M6T",str(tool_number))
332 gcpy          self.writegc("M03S",str(speed))
```

Note that the if...else constructs will need to be extended into the command cutline for those toolshapes (keyhole, roundover, &c.) which will not work with a straight-forward hull... implementation.

As per usual, the OpenSCAD command is simply a dispatcher:

```
54 gpcpscad module toolchange(tool_number,speed){
55 gpcpscad     gcp.toolchange(tool_number,speed);
56 gpcpscad }
```

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 and feed rates/ratios being calculated to provide the correct chipload at that setting.)

3.3.3 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:

```
56 gpcpscad function tool_diameter(td_tool, td_depth) = otool_diameter(td_tool,
                    td_depth);
```

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

```
334 gcpy          def tool_diameter(self, ptd_tool, ptd_depth):
335 gcpy # Square 122,112,102,201
336 gcpy          if ptd_tool == 122:
337 gcpy              return 0.79375
338 gcpy          if ptd_tool == 112:
339 gcpy              return 1.5875
340 gcpy          if ptd_tool == 102:
341 gcpy              return 3.175
342 gcpy          if ptd_tool == 201:
343 gcpy              return 6.35
344 gcpy # Ball 121,111,101,202
345 gcpy          if ptd_tool == 122:
```

```
346 gcpy          if ptd_depth > 0.396875:
347 gcpy              return 0.79375
348 gcpy          else:
349 gcpy              return ptd_tool
350 gcpy          if ptd_tool == 112:
351 gcpy              if ptd_depth > 0.79375:
352 gcpy                  return 1.5875
353 gcpy          else:
354 gcpy              return ptd_tool
355 gcpy          if ptd_tool == 101:
356 gcpy              if ptd_depth > 1.5875:
357 gcpy                  return 3.175
358 gcpy          else:
359 gcpy              return ptd_tool
360 gcpy          if ptd_tool == 202:
361 gcpy              if ptd_depth > 3.175:
362 gcpy                  return 6.35
363 gcpy          else:
364 gcpy              return ptd_tool
365 gcpy # V 301, 302, 390
366 gcpy          if ptd_tool == 301:
367 gcpy              return ptd_tool
368 gcpy          if ptd_tool == 302:
369 gcpy              return ptd_tool
370 gcpy          if ptd_tool == 390:
371 gcpy              return ptd_tool
372 gcpy # Keyhole
373 gcpy          if ptd_tool == 374:
374 gcpy              if ptd_depth < 3.175:
375 gcpy                  return 9.525
376 gcpy          else:
377 gcpy              return 6.35
378 gcpy          if ptd_tool == 375:
379 gcpy              if ptd_depth < 3.175:
380 gcpy                  return 9.525
381 gcpy          else:
382 gcpy              return 8
383 gcpy          if ptd_tool == 376:
384 gcpy              if ptd_depth < 4.7625:
385 gcpy                  return 12.7
386 gcpy          else:
387 gcpy              return 6.35
388 gcpy          if ptd_tool == 378:
389 gcpy              if ptd_depth < 4.7625:
390 gcpy                  return 12.7
391 gcpy          else:
392 gcpy              return 8
393 gcpy # Dovetail
394 gcpy          if ptd_tool == 814:
395 gcpy              if ptd_depth > 12.7:
396 gcpy                  return 6.35
397 gcpy          else:
398 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:

```
400 gcpy          def tool_radius(self, ptd_tool, ptd_depth):
401 gcpy              tr = self.tool_diameter(ptd_tool, ptd_depth)/2
402 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.)

3.3.4 Feeds and Speeds

feed There are several possibilities for handling feeds and speeds. Currently, base values for feed, plunge plunge, and speed are used, which may then be adjusted using various <tooldescriptor>_ratio speed 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.

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

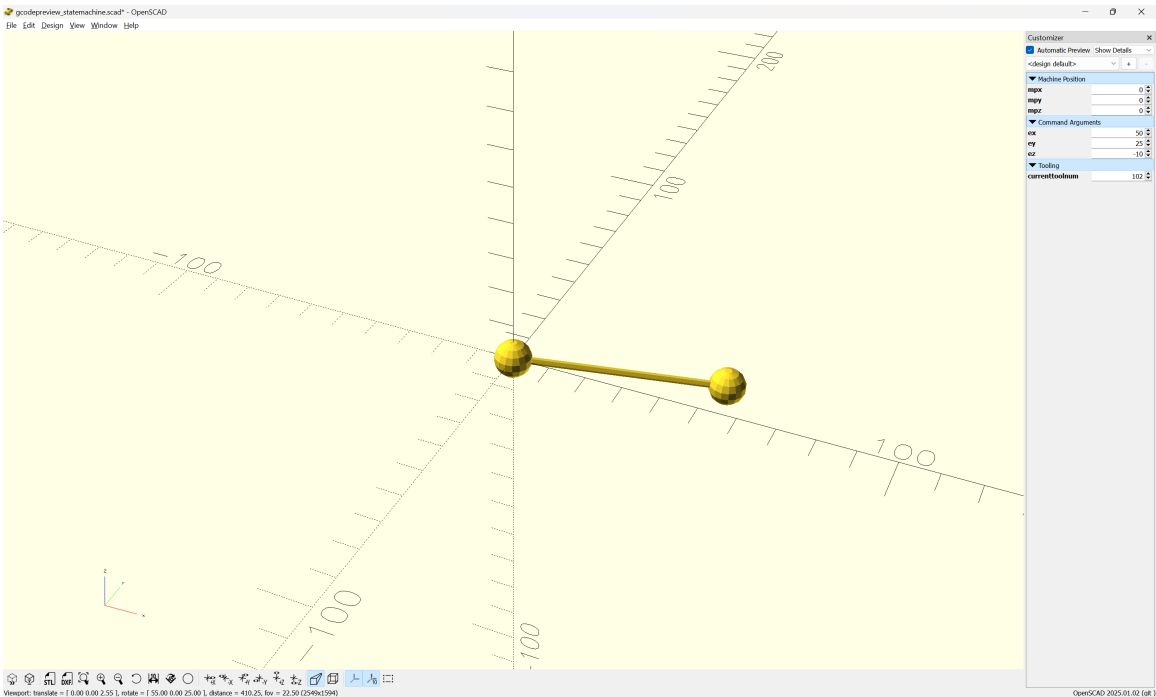
3.4 Movement and Cutting

With all the scaffolding in place, it is possible to model the tool and hull() between copies of the cut... 3D model of the tool, or a cross-section of it for both cut... and rapid... operations.
rapid... Note that the variables self.rapids and self.toolpaths are used to hold the accumulated (unioned) 3D models of the rapid motions and cuts so that they may be differenced from the stock when the value generatepaths is set to True.

In order to manage the various options when cutting it will be necessary to have a command where the actual cut is made, passing in the shape used for the cut as a parameter. Since the 3D aspect of rapid and cut operations are fundamentally the same, the command rcs which returns the hull of the begin (the current machine position as accessed by the x/y/zpos() commands and end positioning (provided as arguments ex, ey, and ez) of the tool shape/cross-section will be defined for the common aspects:

```
404 gcpy      def rcs(self,ex, ey, ez, shape):
405 gcpy          start = shape
406 gcpy          end = shape
407 gcpy          toolpath = hull(start.translate([self.xpos(), self.ypos(),
408 gcpy                                     self.zpos()]),
409 gcpy                                     end.translate([ex,ey,ez]))
409 gcpy          return toolpath
```

Diagramming this is quite straight-forward — there is simply a movement made from the current position to the end. If we start at the origin, X0, Y0, Z0, then it is simply a straight-line movement (rapid)/cut (possibly a partial cut in the instance of a keyhole or roundover tool), and no variables change value.
The code for diagramming this is quite straight-forward. A BlockSCAD implementation is available at: <https://www.blockscad3d.com/community/projects/1894400>, and the OpenSCAD version is only a little more complex (adding code to ensure positioning):



Note that this routine does *not* alter the machine position variables since it may be called multiple times for a given toolpath. This command will then be called in the definitions for rapid and cutshape which only differ in which variable the 3D model is unioned with:
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.

```
411 gcpy      def rapid(self,ex, ey, ez):
412 gcpy          cts = self.currenttoolshape
413 gcpy          toolpath = self.rcs(ex, ey, ez, cts)
414 gcpy          self.setxpos(ex)
415 gcpy          self.setypos(ey)
416 gcpy          self.setzpos(ez)
```

```

417 gcpy          if self.generatepaths == True:
418 gcpy              self.rapids = self.rapids.union(toolpath)
419 gcpy #          return cylinder(0.01, 0, 0.01, center = False, fn = 3)
420 gcpy              return cube([0.001,0.001,0.001])
421 gcpy          else:
422 gcpy              return toolpath
423 gcpy
424 gcpy          def cutshape(self,ex, ey, ez):
425 gcpy              cts = self.currenttoolshape
426 gcpy              toolpath = self.rcs(ex, ey, ez, cts)
427 gcpy              if self.generatepaths == True:
428 gcpy                  self.toolpaths = self.toolpaths.union(toolpath)
429 gcpy                  return cube([0.001,0.001,0.001])
430 gcpy              else:
431 gcpy                  return toolpath

```

Note that it is necessary to return a shape so that modules which use a `<variable>.union` command will function as expected even when the 3D model created is stored in a variable.

It is then possible to add specific rapid... commands to match typical usages of G-code. 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:

```

433 gcpy          def movetosafeZ(self):
434 gcpy              rapid = self.rapid(self.xpos(),self.ypos(),self.
                    retractheight)
435 gcpy #          if self.generatepaths == True:
436 gcpy #              rapid = self.rapid(self.xpos(),self.ypos(),self.
                    retractheight)
437 gcpy #              self.rapids = self.rapids.union(rapid)
438 gcpy #          else:
439 gcpy #          if (generategcode == true) {
440 gcpy #              // writecomment("PREPOSITION FOR RAPID PLUNGE");Z25.650
441 gcpy #              //G1Z24.663F381.0 ,"F",str(plunge)
442 gcpy              if self.generatepaths == False:
443 gcpy                  return rapid
444 gcpy              else:
445 gcpy                  return cube([0.001,0.001,0.001])
446 gcpy
447 gcpy          def rapidXY(self, ex, ey):
448 gcpy              rapid = self.rapid(ex,ey,self.zpos())
449 gcpy #              if self.generatepaths == True:
450 gcpy #                  self.rapids = self.rapids.union(rapid)
451 gcpy #              else:
452 gcpy              if self.generatepaths == False:
453 gcpy                  return rapid
454 gcpy
455 gcpy          def rapidZ(self, ez):
456 gcpy              rapid = self.rapid(self.xpos(),self.ypos(),ez)
457 gcpy #              if self.generatepaths == True:
458 gcpy #                  self.rapids = self.rapids.union(rapid)
459 gcpy #              else:
460 gcpy              if self.generatepaths == False:
461 gcpy                  return rapid

```

Note that rather than re-create the matching OpenSCAD commands as descriptors, due to the issue of redirection and return values and the possibility for errors it is more expedient to simply re-create the matching command (at least for the rapids):

```

58 gcpscad module movetosafeZ(){
59 gcpscad     gcp.rapid(gcp.xpos(),gcp.ypos(),retractheight);
60 gcpscad }
61 gcpscad
62 gcpscad module rapid(ex, ey, ez) {
63 gcpscad     gcp.rapid(ex, ey, ez);
64 gcpscad }
65 gcpscad
66 gcpscad module rapidXY(ex, ey) {
67 gcpscad     gcp.rapid(ex, ey, gcp.zpos());
68 gcpscad }
69 gcpscad
70 gcpscad module rapidZ(ez) {
71 gcpscad     gcp.rapid(gcp.xpos(),gcp.ypos(),ez);

```

72 gpcscad }

3.4.1 Lines

cut... The Python commands cut... add the currenttool to the toolpath hulled together at the current position and the end position of the move. For cutline, this is a straight-forward connection of the current (beginning) and ending coordinates:

```

460 gcpy      def cutline(self,ex, ey, ez):\
461 gcpy #below will need to be integrated into if/then structure not yet
           copied
462 gcpy #          cts = self.currenttoolshape
463 gcpy          if (self.currenttoolnumber() == 374):
464 gcpy #              self.writegc("(TOOL/MILL,9.53, 0.00, 3.17, 0.00)")
465 gcpy              self.currenttoolshape = self.keyhole(9.53/2, 3.175)
466 gcpy              toolpath = self.cutshape(ex, ey, ez)
467 gcpy              self.currenttoolshape = self.keyhole_shaft(6.35/2,
                           12.7)
468 gcpy              toolpath = toolpath.union(self.cutshape(ex, ey, ez))
469 gcpy #          elif (self.currenttoolnumber() == 375):
470 gcpy #              self.writegc("(TOOL/MILL,9.53, 0.00, 3.17, 0.00)")
471 gcpy #          elif (self.currenttoolnumber() == 376):
472 gcpy #              self.writegc("(TOOL/MILL,12.7, 0.00, 4.77, 0.00)")
473 gcpy #          elif (self.currenttoolnumber() == 378):
474 gcpy #              self.writegc("(TOOL/MILL,12.7, 0.00, 4.77, 0.00)")
475 gcpy #          elif (self.currenttoolnumber() == 56125):#0.508/2, 1.531
476 gcpy #              self.writegc("(TOOL/CRMILL, 0.508, 6.35, 3.175,
                           7.9375, 3.175)")
477 gcpy          elif (self.currenttoolnumber() == 56142):#0.508/2, 2.921
478 gcpy #              self.writegc("(TOOL/CRMILL, 0.508, 3.571875, 1.5875,
                           5.55625, 1.5875)")
479 gcpy              toolpath = self.cutroundovertool(self.xpos(), self.ypos
                           (), self.zpos(), ex, ey, ez, 0.508/2, 1.531)
480 gcpy #          elif (self.currenttoolnumber() == 1570):#0.507/2, 4.509
481 gcpy #              self.writegc("(TOOL/CRMILL, 0.17018, 9.525, 4.7625,
                           12.7, 4.7625)")
482 gcpy          else:
483 gcpy              toolpath = self.cutshape(ex, ey, ez)
484 gcpy              self.setxpos(ex)
485 gcpy              self.setypos(ey)
486 gcpy              self.setzpos(ez)
487 gcpy #              if self.generatepaths == True:
488 gcpy #                  self.toolpaths = union([self.toolpaths, toolpath])
489 gcpy #              else:
490 gcpy #                  if self.generatepaths == False:
491 gcpy #                      return toolpath
492 gcpy #                  else:
493 gcpy #                      return cube([0.001,0.001,0.001])
494 gcpy
495 gcpy      def cutlinedxfgc(self,ex, ey, ez):
496 gcpy          self.dxfline(self.currenttoolnumber(), self.xpos(), self.
                           ypos(), ex, ey)
497 gcpy          self.writegc("G01_X", str(ex), "Y", str(ey), "Z", str(ez)
                           )
498 gcpy #          if self.generatepaths == False:
499 gcpy #              return self.cutline(ex, ey, ez)
500 gcpy
501 gcpy      def cutroundovertool(self, bx, by, bz, ex, ey, ez,
                           tool_radius_tip, tool_radius_width):
502 gcpy #          n = 90 + fn*3
503 gcpy #          print("Tool dimensions", tool_radius_tip,
                           tool_radius_width, "begin ",bx, by, bz,"end ", ex, ey, ez)
504 gcpy          step = 4 #360/n
505 gcpy          shaft = cylinder(step,tool_radius_tip,tool_radius_tip)
506 gcpy          toolpath = hull(shaft.translate([bx,by,bz]), shaft.
                           translate([ex,ey,ez]))
507 gcpy          shaft = cylinder(tool_radius_width*2,tool_radius_tip+
                           tool_radius_width,tool_radius_tip+tool_radius_width)
508 gcpy          toolpath = toolpath.union(hull(shaft.translate([bx,by,bz+
                           tool_radius_width]), shaft.translate([ex,ey,ez+
                           tool_radius_width])))
509 gcpy          for i in range(1, 90, 1):
510 gcpy              angle = i
511 gcpy              dx = tool_radius_width*math.cos(math.radians(angle))
512 gcpy              dxx = tool_radius_width*math.cos(math.radians(angle+1))
513 gcpy              dzz = tool_radius_width*math.sin(math.radians(angle))
514 gcpy              dz = tool_radius_width*math.sin(math.radians(angle+1))

```

```
515 gcpy          dh = abs(dzz-dz)+0.0001
516 gcpy          slice = cylinder(dh,tool_radius_tip+tool_radius_width-
                                dx,tool_radius_tip+tool_radius_width-dxx)
517 gcpy          toolpath = toolpath.union(hull(slice.translate([bx,by,
                                bz+dz]), slice.translate([ex,ey,ez+dz])))
518 gcpy          if self.generatepaths == True:
519 gcpy              self.toolpaths = self.toolpaths.union(toolpath)
520 gcpy          else:
521 gcpy              return toolpath
```

The matching OpenSCAD command is a descriptor:

```
74 gpcpscad module cutline(ex, ey, ez){
75 gpcpscad     gcp.cutline(ex, ey, ez);
76 gpcpscad }
77 gpcpscad
78 gpcpscad module cutlinedxfgc(ex, ey, ez){
79 gpcpscad     gcp.cutlinedxfgc(ex, ey, ez);
80 gpcpscad }
```

3.4.2 Arcs for toolpaths and DXFs

A further consideration here is that G-code and DXF support arcs in addition to the lines already implemented. Implementing arcs wants at least the following options for quadrant and direction:

- cutarcCW — cut a partial arc described in a clock-wise direction
- cutarcCC — counter-clock-wise
- cutarcNWCW — cut the upper-left quadrant of a circle moving clockwise
- cutarcNWCC — upper-left quadrant counter-clockwise
- cutarcNECW
- cutarcNECC
- cutarcSECW
- cutarcSECC
- cutarcNECW
- cutarcNECC
- cutcircleCC — while it wont matter for generating a DXF, when G-code is implemented direction of cut will be a consideration for that
- cutcircleCW
- cutcircleCCdxf
- cutcircleCWdxf

It will be necessary to have two separate representations of arcs — the G-code and 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 cutting in each direction and at changing Z-heights so as to allow for threading and similar operations. 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) in both clock-wise and counter-clock-wise directions

Cutting the quadrant arcs greatly simplifies the calculation and interface for the modules. A full set of 8 will be necessary, then circles will have a pair of modules (one for each cut direction) made for them.

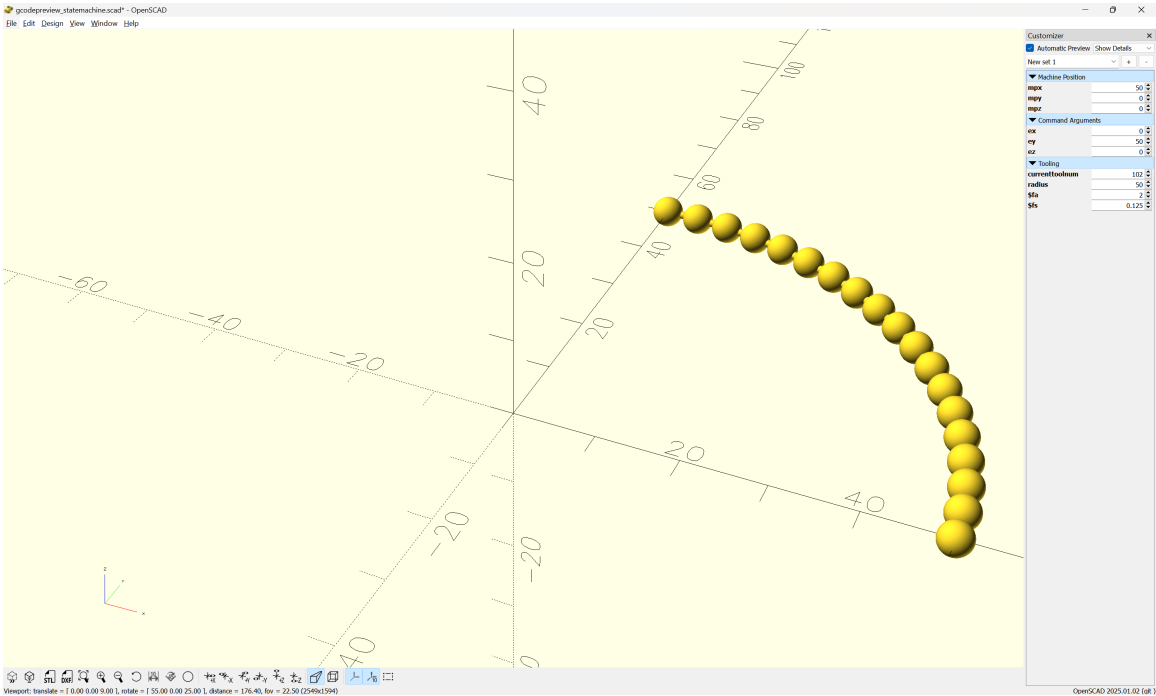
Parameters which will need to be passed in are:

- ex — note that the matching origins (bx, by, bz) as well as the (current) toolnumber are accessed using the appropriate commands
- ey

- ez — allowing a different Z position will make possible threading and similar helical tool-paths
- 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
- tpzreldim — the relative depth (or increase in height) of the current cutting motion

Since OpenSCAD does not have an arc movement command it is necessary to iterate through a loop: cutarcCW (clockwise) or cutarcCC (counterclockwise) to handle the drawing and processing of the cutline() 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 (the line version is used rather than shape so as to capture the changing machine positions with each step through the loop). 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.

This brings to the fore the fact that at its heart, this program is simply graphing math in 3D using tools (as presaged by the book series *Make:Geometry/Trigonometry/Calculus*). This is clear in a depiction of the algorithm for the cutarcCC/CW commands, where the x value is the cos of the radius and the y value the sin:



The code for which makes this obvious:

```
/* [Machine Position] */
mpx = 0;
/* [Machine Position] */
mpy = 0;
/* [Machine Position] */
mpz = 0;

/* [Command Arguments] */
ex = 50;
/* [Command Arguments] */
ey = 25;
/* [Command Arguments] */
ez = -10;

/* [Tooling] */
currenttoolnum = 102;

machine_extents();

radius = 50;
$fa = 2;
$fs = 0.125;

plot_arc(radius, 0, 0, 0, radius, 0, 0,0, radius, 0,90, 5);
```

```

module plot_arc(bx, by, bz, ex, ey, ez, acx,acy, radius, barc,earc, inc){
for (i = [barc : inc : earc-inc]) {
  union(){
    hull()
    {
      translate([acx + cos(i)*radius,
                acy + sin(i)*radius,
                0]){
        sphere(r=0.5);
      }
      translate([acx + cos(i+inc)*radius,
                acy + sin(i+inc)*radius,
                0]){
        sphere(r=0.5);
      }
    }
    translate([acx + cos(i)*radius,
              acy + sin(i)*radius,
              0]){
      sphere(r=2);
    }
    translate([acx + cos(i+inc)*radius,
              acy + sin(i+inc)*radius,
              0]){
      sphere(r=2);
    }
  }
}
}

module machine_extents(){
translate([-200, -200, 20]){
  cube([0.001, 0.001, 0.001], center=true);
}
translate([200, 200, 20]){
  cube([0.001, 0.001, 0.001], center=true);
}
}

module plot_cut(bx, by, bz, ex, ey, ez) {
  union(){
    translate([bx, by, bz]){
      sphere(r=5);
    }
    translate([ex, ey, ez]){
      sphere(r=5);
    }
  }
  hull(){
    translate([bx, by, bz]){
      sphere(r=1);
    }
    translate([ex, ey, ez]){
      sphere(r=1);
    }
  }
}
}

```

Note that it is necessary to move to the beginning cutting position before calling, and that it is necessary to pass in the relative change in Z position/depth. (Previous iterations calculated the increment of change outside the loop, but it is more workable to do so inside.)

```

562 gcpy      def cutarcCC(self, barc, earc, xcenter, ycenter, radius,
                    tpzreldim, steps=1):
563 gcpy #          tpzinc = ez - self.zpos() / (earc - barc)
564 gcpy          tpzinc = tpzreldim / (earc - barc)
565 gcpy          cts = self.currenttoolshape
566 gcpy          toolpath = cts
567 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                    .zpos()])
568 gcpy          i = barc
569 gcpy          while i < earc:
570 gcpy              toolpath = toolpath.union(self.cutline(xcenter + radius
                    * math.cos(math.radians(i)), ycenter + radius *
                    math.sin(math.radians(i)), self.zpos()+tpzinc))
571 gcpy              i += steps
572 gcpy          if self.generatepaths == False:
573 gcpy              return toolpath

```

```

574 gcpy          else:
575 gcpy              return cube([0.01,0.01,0.01])
576 gcpy
577 gcpy          def cutarcCW(self, barc,earc, xcenter, ycenter, radius,
tpzreldim, steps=1):
578 gcpy #              print(str(self.zpos()))
579 gcpy #              print(str(ez))
580 gcpy #              print(str(barc - earc))
581 gcpy #              tpzinc = ez - self.zpos() / (barc - earc)
582 gcpy #              print(str(tpzinc))
583 gcpy #              global toolpath
584 gcpy #              print("Entering n toolpath")
585 gcpy              tpzinc = tpzreldim / (barc - earc)
586 gcpy              cts = self.currenttoolshape
587 gcpy              toolpath = cts
588 gcpy              toolpath = toolpath.translate([self.xpos(),self.ypos(),self
.zpos()])
589 gcpy              i = barc
590 gcpy              while i > earc:
591 gcpy                  toolpath = toolpath.union(self.cutline(xcenter + radius
* math.cos(math.radians(i)), ycenter + radius *
math.sin(math.radians(i)), self.zpos()+tpzinc))
592 gcpy #                  self.setxpos(xcenter + radius * math.cos(math.radians(
i)))
593 gcpy #                  self.setypos(ycenter + radius * math.sin(math.radians(
i)))
594 gcpy #                  print(str(self.xpos()), str(self.ypos()), str(self.zpos
()))
595 gcpy #                  self.setzpos(self.zpos()+tpzinc)
596 gcpy                  i += abs(steps) * -1
597 gcpy #                  self.dxfarc(self.currentttoolnumber(), xcenter, ycenter,
radius, barc, earc)
598 gcpy #                  if self.generatepaths == True:
599 gcpy #                      print("Unioning n toolpath")
600 gcpy #                      self.toolpaths = self.toolpaths.union(toolpath)
601 gcpy #                  else:
602 gcpy                  if self.generatepaths == False:
603 gcpy                      return toolpath
604 gcpy                  else:
605 gcpy                      return cube([0.01,0.01,0.01])

```

Matching OpenSCAD modules are easily made:

```

78 gpcscad module cutarcCC(barC, earC, xcenter, ycenter, radius, tpzreldim){
79 gpcscad     gcp.cutarcCC(barC, earC, xcenter, ycenter, radius, tpzreldim);
80 gpcscad }
81 gpcscad
82 gpcscad module cutarcCW(barC, earC, xcenter, ycenter, radius, tpzreldim){
83 gpcscad     gcp.cutarcCW(barC, earC, xcenter, ycenter, radius, tpzreldim);
84 gpcscad }

```

3.4.3 Cutting shapes and expansion

Certain basic shapes (arcs, circles, rectangles), will be incorporated in the main code. Other shapes will be added 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 be consolidated in 3.3.2) 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.

3.4.3.1 Building blocks The outlines of shapes will be defined using:

- lines — `dxflines`
- arcs — `dxfarC`

It may be that splines or Bézier curves will be added as well.

3.4.3.2 List of shapes 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.

- 0
 - circle — `dxfcircle`
 - ellipse (oval) (requires some sort of non-arc curve)
 - * egg-shaped
 - annulus (one circle within another, forming a ring) — handled by nested circles
 - 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 sector¹
 - two convex, one concave arc
- 4
 - rectangle (including square) — `dxfrectangle`, `dxfrectangleround`
 - 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

Note that most shapes will also exist in a rounded form where sharp angles/points are replaced by arcs/portions of circles, with the most typical being `dxfrectangleround`.

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

- two straight edges, one concave arc—oddly, 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 arc—with the above named, the term arrowhead is freed up to use as the name for this shape.

¹en.wikipedia.org/wiki/Hyperbolic_sector and www.reddit.com/r/Geometry/comments/bkbzgh/is_there_a_name_for_a_3_pointed_figure_with_two

- 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?

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., dxfrectangleround
- 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, the command for this also models 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.
- 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)

3.4.3.2.1 circles Circles are made up of a series of arcs:

```
613 gcpy      def dxfcircle(self, tool_num, xcenter, ycenter, radius):
614 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 0, 90)
615 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 90, 180)
616 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 180, 270)
617 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 270, 360)
```

A Drill toolpath is a simple plunge operation will will have a matching circle to define it.

3.4.3.2.2 rectangles There are two forms for rectangles, square cornered and rounded:

```
619 gcpy      def dxfrectangle(self, tool_num, xorigin, yorigin, xwidth,
620 gcpy          yheight, corners = "Square", radius = 6):
621 gcpy          if corners == "Square":
622 gcpy              self.dxfline(tool_num, xorigin, yorigin, xorigin +
623 gcpy                  xwidth, yorigin)
624 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin,
625 gcpy                  xorigin + xwidth, yorigin + yheight)
626 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin +
627 gcpy                  yheight, xorigin, yorigin + yheight)
628 gcpy              self.dxfline(tool_num, xorigin, yorigin + yheight,
629 gcpy                  xorigin, yorigin)
630 gcpy          elif corners == "Fillet":
631 gcpy              self.dxfrectangleround(tool_num, xorigin, yorigin,
632 gcpy                  xwidth, yheight, radius)
633 gcpy          elif corners == "Chamfer":
634 gcpy              self.dxfrectanglechamfer(tool_num, xorigin, yorigin,
635 gcpy                  xwidth, yheight, radius)
636 gcpy          elif corners == "Flipped_Fillet":
637 gcpy              self.dxfrectangleflippedfillet(tool_num, xorigin,
638 gcpy                  yorigin, xwidth, yheight, radius)
```

Note that the rounded shape below would be described as a rectangle with the “Fillet” corner treatment in Carbide Create.

```
625 gcpy      def dxfrectangleround(self, tool_num, xorigin, yorigin, xwidth,
626 gcpy          yheight, radius):
627 gcpy          self.dxfarc(tool_num, xorigin + xwidth - radius, yorigin +
628 gcpy              yheight - radius, radius, 0, 90)
```

```
627 gcpy      self.dxfarc(tool_num, xorigin + radius, yorigin + yheight -
              radius, radius, 90, 180)
628 gcpy      self.dxfarc(tool_num, xorigin + radius, yorigin + radius,
              radius, 180, 270)
629 gcpy      self.dxfarc(tool_num, xorigin + xwidth - radius, yorigin +
              radius, radius, 270, 360)
630 gcpy
631 gcpy      self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
              xwidth - radius, yorigin)
632 gcpy      self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
              xorigin + xwidth, yorigin + yheight - radius)
633 gcpy      self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
              yheight, xorigin + radius, yorigin + yheight)
634 gcpy      self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
              xorigin, yorigin + radius)
```

So we add the balance of the corner treatments which are decorative (and easily implemented), Chamfer:

```
636 gcpy      def dxfrectanglechamfer(self, tool_num, xorigin, yorigin,
              xwidth, yheight, radius):
637 gcpy      self.dxfline(tool_num, xorigin + radius, yorigin, xorigin,
              yorigin + radius)
638 gcpy      self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
              xorigin + radius, yorigin + yheight)
639 gcpy      self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
              yheight, xorigin + xwidth, yorigin + yheight - radius)
640 gcpy      self.dxfline(tool_num, xorigin + xwidth - radius, yorigin,
              xorigin + xwidth, yorigin + radius)
641 gcpy
642 gcpy      self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
              xwidth - radius, yorigin)
643 gcpy      self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
              xorigin + xwidth, yorigin + yheight - radius)
644 gcpy      self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
              yheight, xorigin + radius, yorigin + yheight)
645 gcpy      self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
              xorigin, yorigin + radius)
```

Flipped Fillet:

```
647 gcpy      def dxfrectangleflippedfillet(self, tool_num, xorigin, yorigin,
              xwidth, yheight, radius):
648 gcpy      self.dxfarc(tool_num, xorigin, yorigin, radius, 0, 90)
649 gcpy      self.dxfarc(tool_num, xorigin + xwidth, yorigin, radius,
              90, 180)
650 gcpy      self.dxfarc(tool_num, xorigin + xwidth, yorigin + yheight,
              radius, 180, 270)
651 gcpy      self.dxfarc(tool_num, xorigin, yorigin + yheight, radius,
              270, 360)
652 gcpy
653 gcpy      self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
              xwidth - radius, yorigin)
654 gcpy      self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
              xorigin + xwidth, yorigin + yheight - radius)
655 gcpy      self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
              yheight, xorigin + radius, yorigin + yheight)
656 gcpy      self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
              xorigin, yorigin + radius)
```

\paragraph{Rectangles}

Cutting rectangles while writing out their perimeter in the DXF files (so that they may be assigned a material)

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

The routine \DescribeRoutine{cutrectangledxf} cuts the outline of a rectangle creating sharp corners. Note

```
\lstset{firstnumber=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module cutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn) { //passes
  movetosafez();
  hull(){
    // for (i = [0 : abs(1) : passes]) {
    //   rapid(bx+tool_radius(rtn)+i*(rwidth-tool_diameter(current_tool()))/passes,bx+tool_radius(rtn),
```



```

        //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter(current_tool()))/passes,by+tool_rad
rdepth,feed);
        //      cutwithfeed(bx+tool_radius(rtn)+i*(rwidth-tool_diameter(current_tool()))/passes,by+rheight-
tool_radius(rtn),bz-rdepth,feed);

        cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,feed);
        cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,feed);
        cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),bz-rdepth,feed);
        cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-rdepth,feed);
    }
    //dxfarc(xcenter,ycenter,radius,anglebegin,endangle, tn)
    dxfarc(bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn),180,270, rtn);
    //dxfline(xbegin,ybegin,xend,yend, tn)
    dxfline(bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(rtn), rtn);
    dxfarc(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),tool_radius(rtn),90,180, rtn);
    dxfline(bx+tool_radius(rtn),by+rheight,bx+rwidth-tool_radius(rtn),by+rheight, rtn);
    dxfarc(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),tool_radius(rtn),0,90, rtn);
    dxfline(bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,by+tool_radius(rtn), rtn);
    dxfarc(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn),270,360, rtn);
    dxfline(bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn),by, rtn);
}

\end{writecode}
\addtocounter{gcpscad}{25}

```

A matching command: `\DescribeRoutine{cutrectangleoutlinedxf}` cuts the outline of a rounded rectangle and

```

\lstset{firstnumber=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module cutrectangleoutlinedxf(bx, by, bz, rwidth, rheight, rdepth, rtn) { //passes
    movetosafez();
    cutwithfeed(bx+tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),bz-rdepth,feed);
    dxfarc(bx+tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn),180,270, rtn);
    dxfline(bx,by+tool_radius(rtn),bx,by+rheight-tool_radius(rtn), rtn);
    dxfarc(bx+tool_radius(rtn),by+rheight-tool_radius(rtn),tool_radius(rtn),90,180, rtn);
    dxfline(bx+tool_radius(rtn),by+rheight,bx+rwidth-tool_radius(rtn),by+rheight, rtn);
    dxfarc(bx+rwidth-tool_radius(rtn),by+rheight-tool_radius(rtn),tool_radius(rtn),0,90, rtn);
    dxfline(bx+rwidth,by+rheight-tool_radius(rtn),bx+rwidth,by+tool_radius(rtn), rtn);
    dxfarc(bx+rwidth-tool_radius(rtn),by+tool_radius(rtn),tool_radius(rtn),270,360, rtn);
    dxfline(bx+rwidth-tool_radius(rtn),by,bx+tool_radius(rtn),by, rtn);
}

\end{writecode}
\addtocounter{gcpscad}{16}

```

Which suggests a further command, `\DescribeRoutine{rectangleoutlinedxf}` for simply adding a rectangle (a

```

\lstset{firstnumber=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module rectangleoutlinedxf(bx, by, bz, rwidth, rheight, rtn) {
    dxfline(bx,by,bx,by+rheight, rtn);
    dxfline(bx,by+rheight,bx+rwidth,by+rheight, rtn);
    dxfline(bx+rwidth,by+rheight,bx+rwidth,by, rtn);
    dxfline(bx+rwidth,by,bx,by, rtn);
}

\end{writecode}
\addtocounter{gcpscad}{7}

```

`\noindent` the initial section performs the cutting operation for the 3D preview while the latter section

A variant of the cutting version of that file, `\DescribeRoutine{cutoutrectangledxf}` will cut to the out

```

\lstset{firstnumber=\thegcpscad}
\begin{writecode}{a}{gcodepreview.scad}{scad}
module cutoutrectangledxf(bx, by, bz, rwidth, rheight, rdepth, rtn) {
    movetosafez();
    cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx+rwidth+tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx+rwidth+tool_radius(rtn),by+rheight+tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx-tool_radius(rtn),by+rheight+tool_radius(rtn),bz-rdepth,feed);
    cutwithfeed(bx-tool_radius(rtn),by-tool_radius(rtn),bz-rdepth,feed);
    dxfline(bx,by,bx,by+rheight, rtn);
    dxfline(bx,by+rheight,bx+rwidth,by+rheight, rtn);
    dxfline(bx+rwidth,by+rheight,bx+rwidth,by, rtn);
}

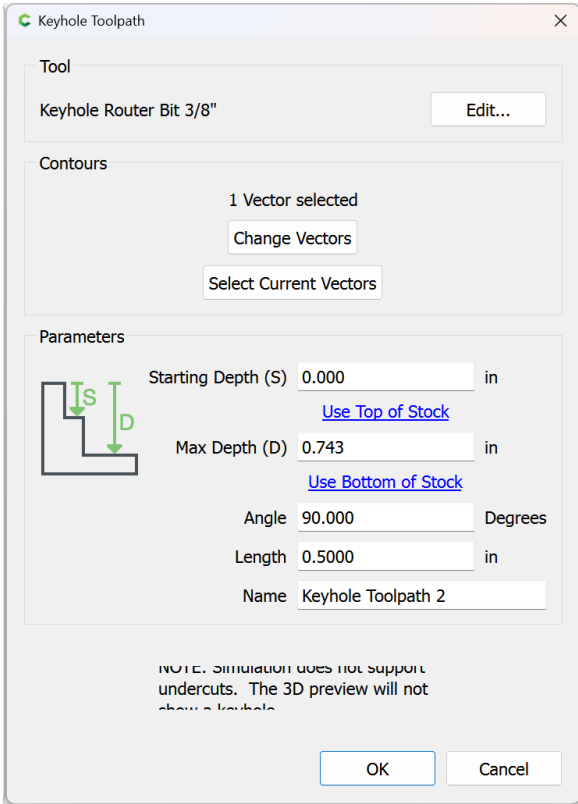
```

```
dxfline(bx+rwidth,by,bx,by, rtn);
}

\end{writecode}
\addtocounter{gcpscad}{13}
```

3.4.3.2.3 Keyhole toolpath and undercut tooling The first topologically unusual toolpath is cutkeyhole toolpath 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 3.3.1.2
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:

```
658 gcpy      def cutkeyholegdcxf(self, kh_tool_num, kh_start_depth,
659 gcpy          kh_max_depth, kht_direction, kh_distance):
660 gcpy          toolpath = self.cutKHgdcxf(kh_tool_num, kh_start_depth,
661 gcpy              kh_max_depth, 90, kh_distance)
662 gcpy          elif (kht_direction == "S"):
```

```
662 gcpy          toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
        kh_max_depth, 270, kh_distance)
663 gcpy          elif (kht_direction == "E"):
664 gcpy          toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
        kh_max_depth, 0, kh_distance)
665 gcpy          elif (kht_direction == "W"):
666 gcpy          toolpath = self.cutKHgcdxf(kh_tool_num, kh_start_depth,
        kh_max_depth, 180, kh_distance)
667 gcpy          if self.generatepaths == True:
668 gcpy          self.toolpaths = union([self.toolpaths, toolpath])
669 gcpy          return toolpath
670 gcpy          else:
671 gcpy          return cube([0.01,0.01,0.01])
```

```
672 gcpscad module cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
        kht_direction, kh_distance){
673 gcpscad     gcp.cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
        kht_direction, kh_distance);
674 gcpscad }
```

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:

```
672 gcpy          def cutKHgcdxf(self, kh_tool_num, kh_start_depth, kh_max_depth,
        kh_angle, kh_distance):
673 gcpy          oXpos = self.xpos()
674 gcpy          oYpos = self.ypos()
675 gcpy          self.dxfKH(kh_tool_num, self.xpos(), self.ypos(),
        kh_start_depth, kh_max_depth, kh_angle, kh_distance)
676 gcpy          toolpath = self.cutline(self.xpos(), self.ypos(), -
        kh_max_depth)
677 gcpy          self.setxpos(oXpos)
678 gcpy          self.setypos(oYpos)
679 gcpy          if self.generatepaths == False:
680 gcpy          return toolpath
681 gcpy          else:
682 gcpy          return cube([0.001,0.001,0.001])
```

```
684 gcpy          def dxfKH(self, kh_tool_num, oXpos, oYpos, kh_start_depth,
        kh_max_depth, kh_angle, kh_distance):
685 gcpy          # oXpos = self.xpos()
686 gcpy          # oYpos = self.ypos()
687 gcpy          #Circle at entry hole
688 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7), 0, 90)
689 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7), 90,180)
690 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7),180,270)
691 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7),270,360)
```

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

```
696 gcpy #pre-calculate needed values
697 gcpy          r = self.tool_radius(kh_tool_num, 7)
698 gcpy          print(r)
699 gcpy          rt = self.tool_radius(kh_tool_num, 1)
700 gcpy          print(rt)
701 gcpy          ro = math.sqrt((self.tool_radius(kh_tool_num, 1))**2-(self.
        tool_radius(kh_tool_num, 7))**2)
702 gcpy          print(ro)
703 gcpy          angle = math.degrees(math.acos(ro/rt))
704 gcpy          #Outlines of entry hole and slot
705 gcpy          if (kh_angle == 0):
706 gcpy          #Lower left of entry hole
707 gcpy          self.dxfarc(kh_tool_num, self.xpos(),self.ypos(),self.
        tool_radius(kh_tool_num, 1),180,270)
708 gcpy          #Upper left of entry hole
709 gcpy          self.dxfarc(kh_tool_num, self.xpos(),self.ypos(),self.
        tool_radius(kh_tool_num, 1),90,180)
```

```

710 gcpy #Upper right of entry hole
711 gcpy #         self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
          41.810, 90)
712 gcpy         self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
          angle, 90)
713 gcpy #Lower right of entry hole
714 gcpy         self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
          270, 360-angle)
715 gcpy #         self.dxfarc(kh_tool_num, 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))))
716 gcpy #Actual line of cut
717 gcpy #         self.dxfline(kh_tool_num, self.xpos(),self.ypos(),self
          .xpos()+kh_distance,self.ypos())
718 gcpy #upper right of end of slot (kh_max_depth+4.36))/2
719 gcpy         self.dxfarc(kh_tool_num, self.xpos()+kh_distance,self.
          ypos(),self.tool_diameter(kh_tool_num, (kh_max_depth
          +4.36))/2,0,90)
720 gcpy #lower right of end of slot
721 gcpy         self.dxfarc(kh_tool_num, self.xpos()+kh_distance,self.
          ypos(),self.tool_diameter(kh_tool_num, (kh_max_depth
          +4.36))/2,270,360)
722 gcpy #upper right slot
723 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))
724 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)
725 gcpy #end position at top of slot
726 gcpy #lower right slot
727 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))
728 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)
729 gcpy #end position at top of slot
730 gcpy #         hull(){
731 gcpy #             translate([xpos(), ypos(), zpos()]){
732 gcpy #                 keyhole_shaft(6.35, 9.525);
733 gcpy #             }
734 gcpy #             translate([xpos(), ypos(), zpos()-kh_max_depth]){
735 gcpy #                 keyhole_shaft(6.35, 9.525);
736 gcpy #             }
737 gcpy #         }
738 gcpy #         hull(){
739 gcpy #             translate([xpos(), ypos(), zpos()-kh_max_depth]){
740 gcpy #                 keyhole_shaft(6.35, 9.525);
741 gcpy #             }
742 gcpy #             translate([xpos()+kh_distance, ypos(), zpos()-kh_max_depth])
          {
743 gcpy #                 keyhole_shaft(6.35, 9.525);
744 gcpy #             }
745 gcpy #         }
746 gcpy #         cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
747 gcpy #         cutwithfeed(getxpos()+kh_distance,getypos(),-kh_max_depth,feed
          );
748 gcpy #         setxpos(getxpos()-kh_distance);
749 gcpy #     } else if (kh_angle > 0 && kh_angle < 90) {
750 gcpy # //echo(kh_angle);
751 gcpy #     dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
          kh_max_depth))/2,90+kh_angle,180+kh_angle, KH_tool_num);
752 gcpy #     dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
          kh_max_depth))/2,180+kh_angle,270+kh_angle, KH_tool_num);
753 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);
754 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);
755 gcpy #dxfarc(getxpos()+(kh_distance*cos(kh_angle)),
756 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);
757 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);
758 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))),
759 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))),
760 gcpy #   getxpos()+(kh_distance*cos(kh_angle))-((tool_diameter(KH_tool_num
    , (kh_max_depth+4.36))/2)*sin(kh_angle)),
761 gcpy #   getypos()+(kh_distance*sin(kh_angle))+((tool_diameter(KH_tool_num
    , (kh_max_depth+4.36))/2)*cos(kh_angle)), KH_tool_num);
762 gcpy #//echo("a",tool_diameter(KH_tool_num, (kh_max_depth+4.36))/2);
763 gcpy #//echo("c",tool_diameter(KH_tool_num, (kh_max_depth))/2);
764 gcpy #echo("Aangle",asin((tool_diameter(KH_tool_num, (kh_max_depth+4.36)
    )/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2)));
765 gcpy #//echo(kh_angle);
766 gcpy #   cutwithfeed(getxpos()+(kh_distance*cos(kh_angle)),getypos()+(
    kh_distance*sin(kh_angle)),-kh_max_depth,feed);
767 gcpy #       toolpath = toolpath.union(self.cutline(self.xpos()+
    kh_distance, self.ypos(), -kh_max_depth))
768 gcpy         elif (kh_angle == 90):
769 gcpy #Lower left of entry hole
770 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
    kh_tool_num, 1),180,270)
771 gcpy #Lower right of entry hole
772 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
    kh_tool_num, 1),270,360)
773 gcpy #left slot
774 gcpy         self.dxfline(kh_tool_num, oXpos-r, oYpos+ro, oXpos-r,
    oYpos+kh_distance)
775 gcpy #right slot
776 gcpy         self.dxfline(kh_tool_num, oXpos+r, oYpos+ro, oXpos+r,
    oYpos+kh_distance)
777 gcpy #upper left of end of slot
778 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos+kh_distance,r
    ,90,180)
779 gcpy #upper right of end of slot
780 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos+kh_distance,r
    ,0,90)
781 gcpy #Upper right of entry hole
782 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 0, 90-angle)
783 gcpy #Upper left of entry hole
784 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90+angle,
    180)
785 gcpy #       toolpath = toolpath.union(self.cutline(oXpos, oYpos+
    kh_distance, -kh_max_depth))
786 gcpy         elif (kh_angle == 180):
787 gcpy #Lower right of entry hole
788 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
    kh_tool_num, 1),270,360)
789 gcpy #Upper right of entry hole
790 gcpy         self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
    kh_tool_num, 1),0,90)
791 gcpy #Upper left of entry hole
792 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90, 180-
    angle)
793 gcpy #Lower left of entry hole
794 gcpy         self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180+angle,
    270)
795 gcpy #upper slot
796 gcpy         self.dxfline(kh_tool_num, oXpos-ro, oYpos-r, oXpos-
    kh_distance, oYpos-r)
797 gcpy #lower slot
798 gcpy         self.dxfline(kh_tool_num, oXpos-ro, oYpos+r, oXpos-
    kh_distance, oYpos+r)
799 gcpy #upper left of end of slot
800 gcpy         self.dxfarc(kh_tool_num, oXpos-kh_distance,oYpos,r
    ,90,180)

```

```

801 gcpy #lower left of end of slot
802 gcpy          self.dxfarc(kh_tool_num, oXpos-kh_distance,oYpos,r
                        ,180,270)
803 gcpy #          toolpath = toolpath.union(self.cutline(oXpos-
                        kh_distance, oYpos, -kh_max_depth))
804 gcpy          elif (kh_angle == 270):
805 gcpy #Upper left of entry hole
806 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
                        kh_tool_num, 1),90,180)
807 gcpy #Upper right of entry hole
808 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
                        kh_tool_num, 1),0,90)
809 gcpy #left slot
810 gcpy          self.dxfline(kh_tool_num, oXpos-r, oYpos-ro, oXpos-r,
                        oYpos-kh_distance)
811 gcpy #right slot
812 gcpy          self.dxfline(kh_tool_num, oXpos+r, oYpos-ro, oXpos+r,
                        oYpos-kh_distance)
813 gcpy #lower left of end of slot
814 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos-kh_distance,r
                        ,180,270)
815 gcpy #lower right of end of slot
816 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos-kh_distance,r
                        ,270,360)
817 gcpy #lower right of entry hole
818 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180, 270-
                        angle)
819 gcpy #lower left of entry hole
820 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 270+angle,
                        360)
821 gcpy #          toolpath = toolpath.union(self.cutline(oXpos, oYpos-
                        kh_distance, -kh_max_depth))
822 gcpy #          print(self.zpos())
823 gcpy #          self.setxpos(oXpos)
824 gcpy #          self.setypos(oYpos)
825 gcpy #          if self.generatepaths == False:
826 gcpy #              return toolpath
827 gcpy
828 gcpy # } else if (kh_angle == 90) {
829 gcpy # //Lower left of entry hole
830 gcpy # dxfarc(getxpos(),getypos(),9.525/2,180,270, KH_tool_num);
831 gcpy # //Lower right of entry hole
832 gcpy # dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
833 gcpy # //Upper right of entry hole
834 gcpy # dxfarc(getxpos(),getypos(),9.525/2,0,acos(tool_diameter(
KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
835 gcpy # //Upper left of entry hole
836 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)
;
837 gcpy # //Actual line of cut
838 gcpy # dxfline(getxpos(),getypos(),getxpos(),getypos()+kh_distance);
839 gcpy # //upper right of slot
840 gcpy # dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,0,90, KH_tool_num);
841 gcpy # //upper left of slot
842 gcpy # dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
843 gcpy # //right of slot
844 gcpy # dxfline(
845 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
846 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,
847 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
848 gcpy # //end position at top of slot
849 gcpy #     getypos()+kh_distance,
850 gcpy #     KH_tool_num);
851 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);
852 gcpy # hull(){
853 gcpy #     translate([xpos(), ypos(), zpos()]){
854 gcpy #         keyhole_shaft(6.35, 9.525);
855 gcpy #     }
856 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){

```

```

857 gcpy #         keyhole_shaft(6.35, 9.525);
858 gcpy #     }
859 gcpy # }
860 gcpy # hull(){
861 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){
862 gcpy #         keyhole_shaft(6.35, 9.525);
863 gcpy #     }
864 gcpy #     translate([xpos(), ypos()+kh_distance, zpos()-kh_max_depth])
{
865 gcpy #         keyhole_shaft(6.35, 9.525);
866 gcpy #     }
867 gcpy # }
868 gcpy # cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
869 gcpy # cutwithfeed(getxpos(),getypos()+kh_distance,-kh_max_depth,feed
);
870 gcpy # setypos(getypos()-kh_distance);
871 gcpy # } else if (kh_angle == 180) {
872 gcpy # //Lower right of entry hole
873 gcpy # dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
874 gcpy # //Upper right of entry hole
875 gcpy # dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
876 gcpy # //Upper left of entry hole
877 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);
878 gcpy # //Lower left of entry hole
879 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
);
880 gcpy # //upper left of slot
881 gcpy # dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
882 gcpy # //lower left of slot
883 gcpy # dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,180,270, KH_tool_num);
884 gcpy # //Actual line of cut
885 gcpy # dxfline(getxpos(),getypos(),getxpos()-kh_distance,getypos());
886 gcpy # //upper left slot
887 gcpy # dxfline(
888 gcpy #     getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
tool_diameter(KH_tool_num,5)^2))/2),
889 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,
890 gcpy #     getxpos()-kh_distance,
891 gcpy # //end position at top of slot
892 gcpy #     getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
893 gcpy #     KH_tool_num);
894 gcpy # //lower right slot
895 gcpy # dxfline(
896 gcpy #     getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
tool_diameter(KH_tool_num,5)^2))/2),
897 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,
898 gcpy #     getxpos()-kh_distance,
899 gcpy # //end position at top of slot
900 gcpy #     getypos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
901 gcpy #     KH_tool_num);
902 gcpy # hull(){
903 gcpy #     translate([xpos(), ypos(), zpos()]){
904 gcpy #         keyhole_shaft(6.35, 9.525);
905 gcpy #     }
906 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){
907 gcpy #         keyhole_shaft(6.35, 9.525);
908 gcpy #     }
909 gcpy # }
910 gcpy # hull(){
911 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){
912 gcpy #         keyhole_shaft(6.35, 9.525);
913 gcpy #     }
914 gcpy #     translate([xpos()-kh_distance, ypos(), zpos()-kh_max_depth])
{
915 gcpy #         keyhole_shaft(6.35, 9.525);
916 gcpy #     }
917 gcpy # }
918 gcpy # cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
919 gcpy # cutwithfeed(getxpos()-kh_distance,getypos(),-kh_max_depth,feed
);

```

```

920 gcpy #     setxpos(getxpos()+kh_distance);
921 gcpy # } else if (kh_angle == 270) {
922 gcpy #     //Upper right of entry hole
923 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
924 gcpy #     //Upper left of entry hole
925 gcpy #     dxfarc(getxpos(),getypos(),9.525/2,90,180, KH_tool_num);
926 gcpy #     //lower right of slot
927 gcpy #     dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,270,360, KH_tool_num);
928 gcpy #     //lower left of slot
929 gcpy #     dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,180,270, KH_tool_num);
930 gcpy #     //Actual line of cut
931 gcpy #     dxfline(getxpos(),getypos(),getxpos(),getypos()-kh_distance);
932 gcpy #     //right of slot
933 gcpy #     dxfline(
934 gcpy #         getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
935 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,
getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
936 gcpy #         //end position at top of slot
937 gcpy #         getypos()-kh_distance,
938 gcpy #         KH_tool_num);
939 gcpy #     //left of slot
940 gcpy #     dxfline(
941 gcpy #         getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
942 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,
getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
944 gcpy #         //end position at top of slot
945 gcpy #         getypos()-kh_distance,
946 gcpy #         KH_tool_num);
947 gcpy #     //Lower right of entry hole
948 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
);
949 gcpy #     //Lower left of entry hole
950 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);
951 gcpy #
952 gcpy #     hull(){
953 gcpy #         translate([xpos(), ypos(), zpos()]){
954 gcpy #             keyhole_shaft(6.35, 9.525);
955 gcpy #         }
956 gcpy #         translate([xpos(), ypos(), zpos()-kh_max_depth]){
957 gcpy #             keyhole_shaft(6.35, 9.525);
958 gcpy #         }
959 gcpy #     }
960 gcpy #     hull(){
961 gcpy #         translate([xpos(), ypos(), zpos()-kh_max_depth]){
962 gcpy #             keyhole_shaft(6.35, 9.525);
963 gcpy #         }
964 gcpy #         translate([xpos(), ypos()-kh_distance, zpos()-kh_max_depth])
{
965 gcpy #             keyhole_shaft(6.35, 9.525);
966 gcpy #         }
967 gcpy #     }
968 gcpy #     cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
969 gcpy #     cutwithfeed(getxpos(),getypos()-kh_distance,-kh_max_depth,feed
);
970 gcpy #     setypos(getypos()+kh_distance);
971 gcpy # }
972 gcpy #}

```

3.4.4 Difference of Stock, Rapids, and Toolpaths

At the end of cutting it will be necessary to subtract the accumulated toolpaths and rapids from the stock. If in OpenSCAD, the 3D model is returned, causing it to be instantiated on the 3D stage unless the Boolean `generatepaths` is `True`.

```

803 gcpy     def stockandtoolpaths(self, option = "stockandtoolpaths"):
804 gcpy         if option == "stock":
805 gcpy             if self.generatepaths == False:
806 gcpy                 output(self.stock)
807 gcpy             print("Outputting stock")
808 gcpy         else:

```



```
809 gcpy                return self.stock
810 gcpy                elif option == "toolpaths":
811 gcpy                    if self.generatepaths == False:
812 gcpy                        output(self.toolpaths)
813 gcpy                    else:
814 gcpy                        return self.toolpaths
815 gcpy                elif option == "rapids":
816 gcpy                    if self.generatepaths == False:
817 gcpy                        output(self.rapids)
818 gcpy                    else:
819 gcpy                        return self.rapids
820 gcpy                else:
821 gcpy                    part = self.stock.difference(self.toolpaths)
822 gcpy                    if self.generatepaths == False:
823 gcpy                        output(part)
824 gcpy                    else:
825 gcpy                        return part

```

```
90 gcpscad module stockandtoolpaths(){
91 gcpscad     gcp.stockandtoolpaths();
92 gcpscad }
93 gcpscad
94 gcpscad module stockwotoolpaths(){
95 gcpscad     gcp.stockandtoolpaths("stock");
96 gcpscad }
97 gcpscad
98 gcpscad module outputtoolpaths(){
99 gcpscad     gcp.stockandtoolpaths("toolpaths");
100 gcpscad }
101 gcpscad
102 gcpscad module outputrapids(){
103 gcpscad     gcp.stockandtoolpaths("rapids");
104 gcpscad }

```

3.5 Output files

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

3.5.1 G-code Overview

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

3.5.2 DXF Overview

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

3.5.3 Python and OpenSCAD File Handling

The class gcodepreview will need additional commands for opening files. The original implementation in RapSCAD used a command writeln — fortunately, this command is easily re-created in Python, though it is made as a separate file for each sort of file which may be opened. 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.

```
826 gcpy      def writegc(self, *arguments):
827 gcpy      if self.generategcode == True:
828 gcpy          line_to_write = ""
829 gcpy          for element in arguments:
830 gcpy              line_to_write += element
831 gcpy          self.gc.write(line_to_write)
832 gcpy          self.gc.write("\n")
833 gcpy
834 gcpy      def writedxf(self, toolnumber, *arguments):
835 gcpy #          global dxfclosed
836 gcpy          line_to_write = ""
837 gcpy          for element in arguments:
838 gcpy              line_to_write += element
839 gcpy          if self.generateddxf == True:
840 gcpy              if self.dxfclosed == False:
841 gcpy                  self.dxf.write(line_to_write)
842 gcpy                  self.dxf.write("\n")
843 gcpy          if self.generateddxfs == True:
844 gcpy              self.writedxfs(toolnumber, line_to_write)
845 gcpy
846 gcpy      def writedxfs(self, toolnumber, line_to_write):
847 gcpy #          print("Processing writing toolnumber", toolnumber)
848 gcpy #          line_to_write = ""
849 gcpy #          for element in arguments:
850 gcpy #              line_to_write += element
851 gcpy          if (toolnumber == 0):
852 gcpy              return
853 gcpy          elif self.generateddxfs == True:
854 gcpy              if (self.large_square_tool_num == toolnumber):
855 gcpy                  self.dxf_lgsq.write(line_to_write)
856 gcpy                  self.dxf_lgsq.write("\n")
857 gcpy              if (self.small_square_tool_num == toolnumber):
858 gcpy                  self.dxf_smsq.write(line_to_write)
859 gcpy                  self.dxf_smsq.write("\n")
860 gcpy              if (self.large_ball_tool_num == toolnumber):
861 gcpy                  self.dxf_lgbl.write(line_to_write)
862 gcpy                  self.dxf_lgbl.write("\n")
863 gcpy              if (self.small_ball_tool_num == toolnumber):
864 gcpy                  self.dxf_sbml.write(line_to_write)
865 gcpy                  self.dxf_sbml.write("\n")
866 gcpy              if (self.large_V_tool_num == toolnumber):
867 gcpy                  self.dxf_lgV.write(line_to_write)
868 gcpy                  self.dxf_lgV.write("\n")
869 gcpy              if (self.small_V_tool_num == toolnumber):
870 gcpy                  self.dxf_smV.write(line_to_write)
871 gcpy                  self.dxf_smV.write("\n")
872 gcpy              if (self.DT_tool_num == toolnumber):
873 gcpy                  self.dxf_DT.write(line_to_write)
874 gcpy                  self.dxf_DT.write("\n")
875 gcpy              if (self.KH_tool_num == toolnumber):
876 gcpy                  self.dxf_KH.write(line_to_write)
877 gcpy                  self.dxf_KH.write("\n")
878 gcpy              if (self.Roundover_tool_num == toolnumber):
879 gcpy                  self.dxf_Rt.write(line_to_write)
880 gcpy                  self.dxf_Rt.write("\n")
881 gcpy              if (self.MISC_tool_num == toolnumber):
882 gcpy                  self.dxf_Mt.write(line_to_write)
883 gcpy                  self.dxf_Mt.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).

opengcodefile For writing to files it will be necessary to have commands for opening the files opengcodefile
opendxffile and opendxffile and setting the associated defaults. 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.

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

```
140 gpcscad module opendxfile(basefilename){
141 gpcscad     gcp.opendxfile(basefilename);
142 gpcscad }
143 gpcscad
144 gpcscad module opendxfiles(Base_filename, large_square_tool_num,
    small_square_tool_num, large_ball_tool_num, small_ball_tool_num,
    large_V_tool_num, small_V_tool_num, DT_tool_num, KH_tool_num,
    Roundover_tool_num, MISC_tool_num) {
145 gpcscad     gcp.opendxfiles(Base_filename, large_square_tool_num,
    small_square_tool_num, large_ball_tool_num,
    small_ball_tool_num, large_V_tool_num, small_V_tool_num,
    DT_tool_num, KH_tool_num, Roundover_tool_num, MISC_tool_num)
    ;
146 gpcscad }
```

opengcodefile With matching OpenSCAD commands: opengcodefile for OpenSCAD:

```
148 gpcscad module opengcodefile(basefilename, currenttoolnum, toolradius,
    plunge, feed, speed) {
149 gpcscad     gcp.opengcodefile(basefilename, currenttoolnum, toolradius,
    plunge, feed, speed);
150 gpcscad }
```

and Python:

```
884 gcpy      def opengcodefile(self, basefilename = "export",
885 gcpy          currenttoolnum = 102,
886 gcpy          toolradius = 3.175,
887 gcpy          plunge = 400,
888 gcpy          feed = 1600,
889 gcpy          speed = 10000
890 gcpy      ):
891 gcpy          self.basefilename = basefilename
892 gcpy          self.currenttoolnum = currenttoolnum
893 gcpy          self.toolradius = toolradius
894 gcpy          self.plunge = plunge
895 gcpy          self.feed = feed
896 gcpy          self.speed = speed
897 gcpy          if self.generategcode == True:
898 gcpy              self.gcodefilename = basefilename + ".nc"
899 gcpy              self.gc = open(self.gcodefilename, "w")
900 gcpy
901 gcpy      def opendxfile(self, basefilename = "export"):
902 gcpy          self.basefilename = basefilename
903 gcpy          # global generatedxfs
904 gcpy          # global dxfclosed
905 gcpy          self.dxfclosed = False
906 gcpy          if self.generatedxif == True:
907 gcpy              self.generatedxfs = False
908 gcpy              self.dxffilename = basefilename + ".dxf"
909 gcpy              self.dxf = open(self.dxffilename, "w")
910 gcpy              self.dxfpreamble(-1)
911 gcpy
912 gcpy      def opendxfiles(self, basefilename = "export",
913 gcpy          large_square_tool_num = 0,
914 gcpy          small_square_tool_num = 0,
915 gcpy          large_ball_tool_num = 0,
916 gcpy          small_ball_tool_num = 0,
917 gcpy          large_V_tool_num = 0,
918 gcpy          small_V_tool_num = 0,
919 gcpy          DT_tool_num = 0,
920 gcpy          KH_tool_num = 0,
921 gcpy          Roundover_tool_num = 0,
922 gcpy          MISC_tool_num = 0):
923 gcpy          # global generatedxfs
924 gcpy          self.basefilename = basefilename
925 gcpy          self.generatedxfs = True
926 gcpy          self.large_square_tool_num = large_square_tool_num
927 gcpy          self.small_square_tool_num = small_square_tool_num
928 gcpy          self.large_ball_tool_num = large_ball_tool_num
929 gcpy          self.small_ball_tool_num = small_ball_tool_num
930 gcpy          self.large_V_tool_num = large_V_tool_num
931 gcpy          self.small_V_tool_num = small_V_tool_num
```

```

932 gcpy      self.DT_tool_num = DT_tool_num
933 gcpy      self.KH_tool_num = KH_tool_num
934 gcpy      self.Roundover_tool_num = Roundover_tool_num
935 gcpy      self.MISC_tool_num = MISC_tool_num
936 gcpy      if self.generatedxf == True:
937 gcpy          if (large_square_tool_num > 0):
938 gcpy              self.dxf_lgsqfilename = basefilename + str(
                    large_square_tool_num) + ".dxf"
939 gcpy #              print("Opening ", str(self.dxf_lgsqfilename))
940 gcpy              self.dxf_lgsq = open(self.dxf_lgsqfilename, "w")
941 gcpy      if (small_square_tool_num > 0):
942 gcpy #          print("Opening small square")
943 gcpy          self.dxf_ssqfilename = basefilename + str(
                    small_square_tool_num) + ".dxf"
944 gcpy          self.dxf_ssq = open(self.dxf_ssqfilename, "w")
945 gcpy      if (large_ball_tool_num > 0):
946 gcpy #          print("Opening large ball")
947 gcpy          self.dxf_lgbfilename = basefilename + str(
                    large_ball_tool_num) + ".dxf"
948 gcpy          self.dxf_lgb = open(self.dxf_lgbfilename, "w")
949 gcpy      if (small_ball_tool_num > 0):
950 gcpy #          print("Opening small ball")
951 gcpy          self.dxf_smbfilename = basefilename + str(
                    small_ball_tool_num) + ".dxf"
952 gcpy          self.dxf_smb = open(self.dxf_smbfilename, "w")
953 gcpy      if (large_V_tool_num > 0):
954 gcpy #          print("Opening large V")
955 gcpy          self.dxf_lgVfilename = basefilename + str(
                    large_V_tool_num) + ".dxf"
956 gcpy          self.dxf_lgV = open(self.dxf_lgVfilename, "w")
957 gcpy      if (small_V_tool_num > 0):
958 gcpy #          print("Opening small V")
959 gcpy          self.dxf_smVfilename = basefilename + str(
                    small_V_tool_num) + ".dxf"
960 gcpy          self.dxf_smV = open(self.dxf_smVfilename, "w")
961 gcpy      if (DT_tool_num > 0):
962 gcpy #          print("Opening DT")
963 gcpy          self.dxf_DTfilename = basefilename + str(DT_tool_num
                    ) + ".dxf"
964 gcpy          self.dxf_DT = open(self.dxf_DTfilename, "w")
965 gcpy      if (KH_tool_num > 0):
966 gcpy #          print("Opening KH")
967 gcpy          self.dxf_KHfilename = basefilename + str(KH_tool_num
                    ) + ".dxf"
968 gcpy          self.dxf_KH = open(self.dxf_KHfilename, "w")
969 gcpy      if (Roundover_tool_num > 0):
970 gcpy #          print("Opening Rt")
971 gcpy          self.dxf_Rtfilename = basefilename + str(
                    Roundover_tool_num) + ".dxf"
972 gcpy          self.dxf_Rt = open(self.dxf_Rtfilename, "w")
973 gcpy      if (MISC_tool_num > 0):
974 gcpy #          print("Opening Mt")
975 gcpy          self.dxf_Mtfilename = basefilename + str(
                    MISC_tool_num) + ".dxf"
976 gcpy          self.dxf_Mt = open(self.dxf_Mtfilename, "w")

```

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

```

963 gcpy      if (large_square_tool_num > 0):
964 gcpy          self.dxf_preamble(large_square_tool_num)
965 gcpy      if (small_square_tool_num > 0):
966 gcpy          self.dxf_preamble(small_square_tool_num)
967 gcpy      if (large_ball_tool_num > 0):
968 gcpy          self.dxf_preamble(large_ball_tool_num)
969 gcpy      if (small_ball_tool_num > 0):
970 gcpy          self.dxf_preamble(small_ball_tool_num)
971 gcpy      if (large_V_tool_num > 0):
972 gcpy          self.dxf_preamble(large_V_tool_num)
973 gcpy      if (small_V_tool_num > 0):
974 gcpy          self.dxf_preamble(small_V_tool_num)
975 gcpy      if (DT_tool_num > 0):
976 gcpy          self.dxf_preamble(DT_tool_num)
977 gcpy      if (KH_tool_num > 0):
978 gcpy          self.dxf_preamble(KH_tool_num)
979 gcpy      if (Roundover_tool_num > 0):
980 gcpy          self.dxf_preamble(Roundover_tool_num)
981 gcpy      if (MISC_tool_num > 0):

```

```
982 gcpy self.dxfpreamble(MISC_tool_num)
```

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

3.5.3.1 Writing to DXF 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 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).

Each tool has a matching command for each tool/size combination:

- writedxflgbl
- writedxfsmb1
- writedxflgsq
- writedxfsmsq
- writedxflgV
- writedxfsmV
- writedxfKH
- writedxfDT
- Ball nose, large (lgbl) writedxflgbl
 - Ball nose, small (smb1) writedxfsmb1
 - Square, large (lgsq) writedxflgsq
 - Square, small (smsq) writedxfsmsq
 - V, large (lgV) writedxflgV
 - V, small (smV) writedxfsmV
 - Keyhole (KH) writedxfKH
 - Dovetail (DT) writedxfDT

dxfpreamble

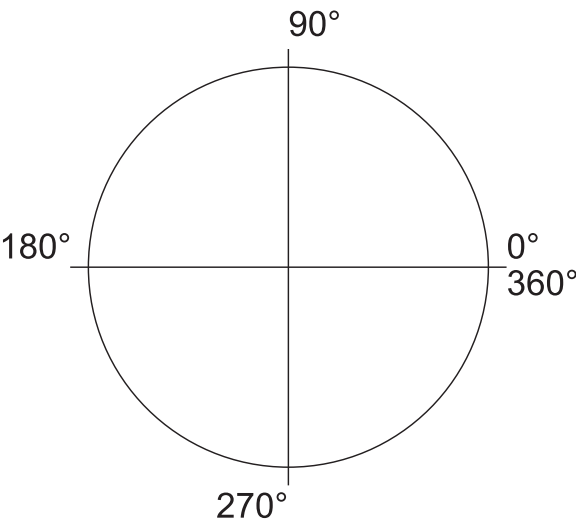
This module requires that the tool number be passed in, and after writing out dxfpreamble, that value will be used to write out to the appropriate file with a series of if statements.

```
984 gcpy def dxfpreamble(self, tn):
985 gcpy # self.writedxf(tn,str(tn))
986 gcpy self.writedxf(tn,"0")
987 gcpy self.writedxf(tn,"SECTION")
988 gcpy self.writedxf(tn,"2")
989 gcpy self.writedxf(tn,"ENTITIES")
```

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

- dxfline
- dxfar
- a line dxfline
 - ARC — a notable option would be for the arc to close on itself, creating a circle: dxfar

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:

```
dxfar(10, 10, 5, 0, 90, small_square_tool_num);
dxfar(10, 10, 5, 90, 180, small_square_tool_num);
dxfar(10, 10, 5, 180, 270, small_square_tool_num);
dxfar(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 Keyhole

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.

```
991 gcpy      def dxfline(self, tn, xbegin,ybegin,xend,yend):
992 gcpy      self.writedxf(tn,"0")
993 gcpy      self.writedxf(tn,"LWPOLYLINE")
994 gcpy      self.writedxf(tn,"90")
995 gcpy      self.writedxf(tn,"2")
996 gcpy      self.writedxf(tn,"70")
997 gcpy      self.writedxf(tn,"0")
998 gcpy      self.writedxf(tn,"43")
999 gcpy      self.writedxf(tn,"0")
1000 gcpy     self.writedxf(tn,"10")
1001 gcpy     self.writedxf(tn,str(xbegin))
1002 gcpy     self.writedxf(tn,"20")
1003 gcpy     self.writedxf(tn,str(ybegin))
1004 gcpy     self.writedxf(tn,"10")
1005 gcpy     self.writedxf(tn,str(xend))
1006 gcpy     self.writedxf(tn,"20")
1007 gcpy     self.writedxf(tn,str(yend))
```

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, and to determine if the arc is clockwise or no (G2 vs. G3).

```
1009 gcpy     def dxfarc(self, tn, xcenter, ycenter, radius, anglebegin,
                        endangle):
1010 gcpy         if (self.generatedxf == True):
1011 gcpy             self.writedxf(tn, "0")
1012 gcpy             self.writedxf(tn, "ARC")
1013 gcpy             self.writedxf(tn, "10")
1014 gcpy             self.writedxf(tn, str(xcenter))
1015 gcpy             self.writedxf(tn, "20")
1016 gcpy             self.writedxf(tn, str(ycenter))
1017 gcpy             self.writedxf(tn, "40")
1018 gcpy             self.writedxf(tn, str(radius))
1019 gcpy             self.writedxf(tn, "50")
1020 gcpy             self.writedxf(tn, str(anglebegin))
1021 gcpy             self.writedxf(tn, "51")
1022 gcpy             self.writedxf(tn, str(endangle))
1023 gcpy
1024 gcpy     def gcdearc(self, tn, xcenter, ycenter, radius, anglebegin,
                        endangle):
1025 gcpy         if (self.generategcode == True):
1026 gcpy             self.writegc(tn, "(0)")
```

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

```
1028 gcpy     def cutarcNECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1029 gcpy     #         global toolpath
1030 gcpy     #         toolpath = self.currenttool()
1031 gcpy     #         toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1032 gcpy     self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
                        radius,0,90)
1033 gcpy     if (self.zpos == ez):
1034 gcpy         self.settzpos(0)
1035 gcpy     else:
1036 gcpy         self.settzpos((self.zpos()-ez)/90)
1037 gcpy     #         self.setxpos(ex)
1038 gcpy     #         self.setypos(ey)
1039 gcpy     #         self.setzpos(ez)
1040 gcpy     if self.generatepaths == True:
```

```

1041 gcpy                print("Unioning cutarcNECCdxf toolpath")
1042 gcpy                self.arcloop(1,90, xcenter, ycenter, radius)
1043 gcpy #                self.toolpaths = self.toolpaths.union(toolpath)
1044 gcpy                else:
1045 gcpy                    toolpath = self.arcloop(1,90, xcenter, ycenter, radius)
1046 gcpy #                print("Returning cutarcNECCdxf toolpath")
1047 gcpy                return toolpath
1048 gcpy
1049 gcpy                def cutarcNWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1050 gcpy #                    global toolpath
1051 gcpy #                    toolpath = self.currenttool()
1052 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1053 gcpy                    self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,90,180)
1054 gcpy                    if (self.zpos == ez):
1055 gcpy                        self.settzpos(0)
1056 gcpy                    else:
1057 gcpy                        self.settzpos((self.zpos()-ez)/90)
1058 gcpy #                    self.setxpos(ex)
1059 gcpy #                    self.setypos(ey)
1060 gcpy #                    self.setzpos(ez)
1061 gcpy                    if self.generatepaths == True:
1062 gcpy                        self.arcloop(91,180, xcenter, ycenter, radius)
1063 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1064 gcpy                    else:
1065 gcpy                        toolpath = self.arcloop(91,180, xcenter, ycenter,
radius)
1066 gcpy                    return toolpath
1067 gcpy
1068 gcpy                def cutarcSWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1069 gcpy #                    global toolpath
1070 gcpy #                    toolpath = self.currenttool()
1071 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1072 gcpy                    self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,180,270)
1073 gcpy                    if (self.zpos == ez):
1074 gcpy                        self.settzpos(0)
1075 gcpy                    else:
1076 gcpy                        self.settzpos((self.zpos()-ez)/90)
1077 gcpy #                    self.setxpos(ex)
1078 gcpy #                    self.setypos(ey)
1079 gcpy #                    self.setzpos(ez)
1080 gcpy                    if self.generatepaths == True:
1081 gcpy                        self.arcloop(181,270, xcenter, ycenter, radius)
1082 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1083 gcpy                    else:
1084 gcpy                        toolpath = self.arcloop(181,270, xcenter, ycenter,
radius)
1085 gcpy                    return toolpath
1086 gcpy
1087 gcpy                def cutarcSECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1088 gcpy #                    global toolpath
1089 gcpy #                    toolpath = self.currenttool()
1090 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1091 gcpy                    self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,270,360)
1092 gcpy                    if (self.zpos == ez):
1093 gcpy                        self.settzpos(0)
1094 gcpy                    else:
1095 gcpy                        self.settzpos((self.zpos()-ez)/90)
1096 gcpy #                    self.setxpos(ex)
1097 gcpy #                    self.setypos(ey)
1098 gcpy #                    self.setzpos(ez)
1099 gcpy                    if self.generatepaths == True:
1100 gcpy                        self.arcloop(271,360, xcenter, ycenter, radius)
1101 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1102 gcpy                    else:
1103 gcpy                        toolpath = self.arcloop(271,360, xcenter, ycenter,
radius)
1104 gcpy                    return toolpath
1105 gcpy
1106 gcpy                def cutarcNECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1107 gcpy #                    global toolpath
1108 gcpy #                    toolpath = self.currenttool()
1109 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),

```



```

        self.zpos())
1110 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 0, 90)
1111 gcpy        if (self.zpos == ez):
1112 gcpy            self.settzpos(0)
1113 gcpy        else:
1114 gcpy            self.settzpos((self.zpos()-ez)/90)
1115 gcpy #        self.setxpos(ex)
1116 gcpy #        self.setypos(ey)
1117 gcpy #        self.setzpos(ez)
1118 gcpy        if self.generatepaths == True:
1119 gcpy            self.narcloop(89, 0, xcenter, ycenter, radius)
1120 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1121 gcpy        else:
1122 gcpy            toolpath = self.narcloop(89, 0, xcenter, ycenter, radius
                )
1123 gcpy            return toolpath
1124 gcpy
1125 gcpy        def cutarcSECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1126 gcpy #            global toolpath
1127 gcpy #            toolpath = self.currenttool()
1128 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1129 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 270, 360)
1130 gcpy        if (self.zpos == ez):
1131 gcpy            self.settzpos(0)
1132 gcpy        else:
1133 gcpy            self.settzpos((self.zpos()-ez)/90)
1134 gcpy #        self.setxpos(ex)
1135 gcpy #        self.setypos(ey)
1136 gcpy #        self.setzpos(ez)
1137 gcpy        if self.generatepaths == True:
1138 gcpy            self.narcloop(359, 270, xcenter, ycenter, radius)
1139 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1140 gcpy        else:
1141 gcpy            toolpath = self.narcloop(359, 270, xcenter, ycenter,
                radius)
1142 gcpy            return toolpath
1143 gcpy
1144 gcpy        def cutarcSWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1145 gcpy #            global toolpath
1146 gcpy #            toolpath = self.currenttool()
1147 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1148 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 180, 270)
1149 gcpy        if (self.zpos == ez):
1150 gcpy            self.settzpos(0)
1151 gcpy        else:
1152 gcpy            self.settzpos((self.zpos()-ez)/90)
1153 gcpy #        self.setxpos(ex)
1154 gcpy #        self.setypos(ey)
1155 gcpy #        self.setzpos(ez)
1156 gcpy        if self.generatepaths == True:
1157 gcpy            self.narcloop(269, 180, xcenter, ycenter, radius)
1158 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1159 gcpy        else:
1160 gcpy            toolpath = self.narcloop(269, 180, xcenter, ycenter,
                radius)
1161 gcpy            return toolpath
1162 gcpy
1163 gcpy        def cutarcNWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1164 gcpy #            global toolpath
1165 gcpy #            toolpath = self.currenttool()
1166 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1167 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 90, 180)
1168 gcpy        if (self.zpos == ez):
1169 gcpy            self.settzpos(0)
1170 gcpy        else:
1171 gcpy            self.settzpos((self.zpos()-ez)/90)
1172 gcpy #        self.setxpos(ex)
1173 gcpy #        self.setypos(ey)
1174 gcpy #        self.setzpos(ez)
1175 gcpy        if self.generatepaths == True:
1176 gcpy            self.narcloop(179, 90, xcenter, ycenter, radius)

```



```
1192 gcpy          self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1193 gcpy          if self.generatepaths == False:
1194 gcpy              return self.cutarcNWCWdxg(ex, ey, ez, xcenter, ycenter,
                    radius)
```

```
152 gpcscad module cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
153 gpcscad     gcp.cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
154 gpcscad }
155 gpcscad
156 gpcscad module cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
157 gpcscad     gcp.cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
158 gpcscad }
159 gpcscad
160 gpcscad module cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
161 gpcscad     gcp.cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
162 gpcscad }
163 gpcscad
164 gpcscad module cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
165 gpcscad     gcp.cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
166 gpcscad }
```

3.5.3.2 Closings At the end of the program it will be necessary to close each file using the `closegcodefile` commands: `closegcodefile`, and `closedxxfile`. In some instances it may be necessary to write additional information, depending on the file format. Note that these commands will need to be within the `gcodepreview` class.

```
1186 gcpy      def dxfpreamble(self,tn):
1187 gcpy      #          self.writedxf(tn,str(tn))
1188 gcpy          self.writedxf(tn,"0")
1189 gcpy          self.writedxf(tn,"ENDSEC")
1190 gcpy          self.writedxf(tn,"0")
1191 gcpy          self.writedxf(tn,"EOF")
```

```
1193 gcpy      def gcodepreamble(self):
1194 gcpy          self.writegc("Z12.700")
1195 gcpy          self.writegc("M05")
1196 gcpy          self.writegc("M02")
```

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

```
1198 gcpy      def closegcodefile(self):
1199 gcpy          self.gcodepreamble()
1200 gcpy          self.gc.close()
1201 gcpy
1202 gcpy      def closedxxfile(self):
1203 gcpy          if self.generatedxfg == True:
1204 gcpy      #              global dxfclosed
1205 gcpy                  self.dxfpreamble(-1)
1206 gcpy      #              self.dxfclosed = True
1207 gcpy                  self.dxf.close()
1208 gcpy
1209 gcpy      def closedxxfiles(self):
1210 gcpy          if self.generatedxfs == True:
1211 gcpy              if (self.large_square_tool_num > 0):
1212 gcpy                  self.dxfpreamble(self.large_square_tool_num)
1213 gcpy              if (self.small_square_tool_num > 0):
1214 gcpy                  self.dxfpreamble(self.small_square_tool_num)
1215 gcpy              if (self.large_ball_tool_num > 0):
1216 gcpy                  self.dxfpreamble(self.large_ball_tool_num)
1217 gcpy              if (self.small_ball_tool_num > 0):
1218 gcpy                  self.dxfpreamble(self.small_ball_tool_num)
1219 gcpy              if (self.large_V_tool_num > 0):
1220 gcpy                  self.dxfpreamble(self.large_V_tool_num)
1221 gcpy              if (self.small_V_tool_num > 0):
1222 gcpy                  self.dxfpreamble(self.small_V_tool_num)
1223 gcpy              if (self.DT_tool_num > 0):
1224 gcpy                  self.dxfpreamble(self.DT_tool_num)
1225 gcpy              if (self.KH_tool_num > 0):
1226 gcpy                  self.dxfpreamble(self.KH_tool_num)
1227 gcpy              if (self.Roundover_tool_num > 0):
1228 gcpy                  self.dxfpreamble(self.Roundover_tool_num)
1229 gcpy              if (self.MISC_tool_num > 0):
```

```
1230 gcpy                self.dxfpostamble(self.MISC_tool_num)
1231 gcpy
1232 gcpy                if (self.large_square_tool_num > 0):
1233 gcpy                    self.dxfllsq.close()
1234 gcpy                if (self.small_square_tool_num > 0):
1235 gcpy                    self.dxfsssq.close()
1236 gcpy                if (self.large_ball_tool_num > 0):
1237 gcpy                    self.dxfllbl.close()
1238 gcpy                if (self.small_ball_tool_num > 0):
1239 gcpy                    self.dxfssbl.close()
1240 gcpy                if (self.large_V_tool_num > 0):
1241 gcpy                    self.dxfllgV.close()
1242 gcpy                if (self.small_V_tool_num > 0):
1243 gcpy                    self.dxfssmV.close()
1244 gcpy                if (self.DT_tool_num > 0):
1245 gcpy                    self.dxfDT.close()
1246 gcpy                if (self.KH_tool_num > 0):
1247 gcpy                    self.dxfKH.close()
1248 gcpy                if (self.Roundover_tool_num > 0):
1249 gcpy                    self.dxfRt.close()
1250 gcpy                if (self.MISC_tool_num > 0):
1251 gcpy                    self.dxfMt.close()
```

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

```
202 gcpscad
203 gcpscad module closegcodefile(){
204 gcpscad     gcp.closegcodefile();
205 gcpscad }
206 gcpscad
207 gcpscad module closedxfiles(){
208 gcpscad     gcp.closedxfiles();
209 gcpscad }
210 gcpscad
211 gcpscad module closedxfile(){
212 gcpscad     gcp.closedxfile();
213 gcpscad }
```

4 Notes

Other Resources

Documentation Style

<https://diataxis.fr/> (originally developed at: <https://docs.divio.com/documentation-system/>)
— divides documentation along two axes:

- Action (Practical) vs. Cognition (Theoretical)
- Acquisition (Studying) vs. Application (Working)

resulting in a matrix of:

where:

1. `readme.md` — (Overview) Explanation (understanding-oriented)
2. `Templates` — Tutorials (learning-oriented)
3. `gcodepreview` — How-to Guides (problem-oriented)
4. `Index` — Reference (information-oriented)

Adding a Command Glossary may be a useful addition or alternative to the Index.

Holidays

Holidays are from <https://nationaltoday.com/>

DXFs

<http://www.paulbourke.net/dataformats/dxf/>

<https://paulbourke.net/dataformats/dxf/min3d.html>

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/>

<https://ciechanow.ski/curves-and-surfaces/>

<https://www.youtube.com/watch?v=aVwxzDHniEw>

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:

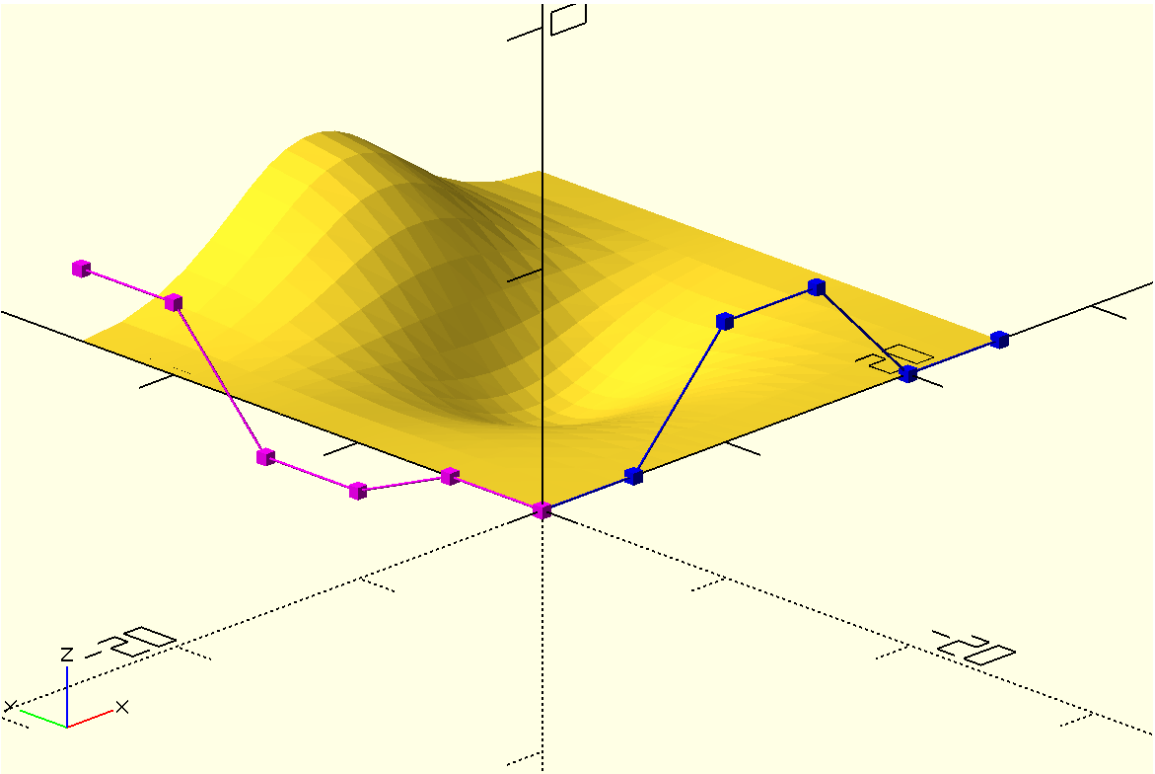
- XY
- XZ
- ZY

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/

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