

The gcodepreview PythonSCAD library*

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Abstract

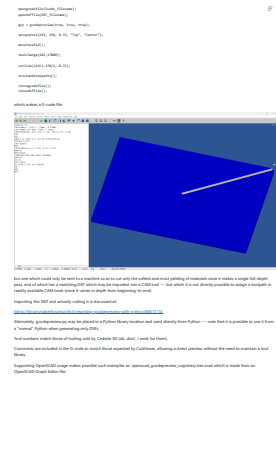
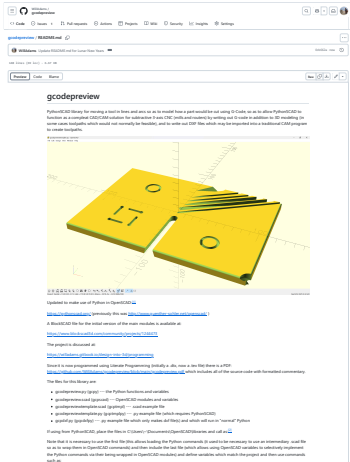
The gcodepreview library allows using PythonSCAD (OpenPythonSCAD) to move a tool in lines and arcs and output DXF and G-code files so as to work as a CAD/CAM program for CNC.

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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 at this time, 4th-axis
  support may come in a future version) 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)

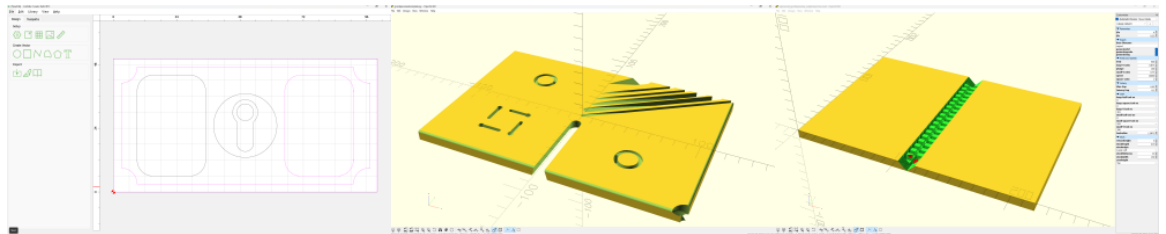
```

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). Providing them in a programmatic context allows making parts or design elements of parts (e.g., joinery) which would be tedious to draw by hand in a traditional CAD or vector drawing application. A further consideration is that this is “Design for Manufacture” taken to its ultimate extreme, and that a part so designed is inherently manufacturable.

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). 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)

One fundamental aspect of this tool is the question of *Layers of Abstraction* (as put forward by Dr. Donald Knuth as the crux of computer science) and *Problem Decomposition* (Prof. John Ousterhout’s answer to that topic). To a great degree, the basic implementation of this tool will use G-code as a reference implementation, simultaneously using the abstraction from the mechanical task of machining which it affords as a decomposed version of that task, and creating what is in essence, both a front-end, and a tool, and an API for working with G-code programmatically. This then requires an architecture which allows 3D modeling (OpenSCAD), and writing out files (Python).

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 gcpdxftp
10 gcpdxftp # [Stock] */
11 gcpdxftp stockXwidth = 100
12 gcpdxftp # [Stock] */
13 gcpdxftp stockYheight = 50
14 gcpdxftp
15 gcpdxftp # [Export] */
16 gcpdxftp Base_filename = "dxfexport"
17 gcpdxftp
18 gcpdxftp
19 gcpdxftp # [CAM] */
20 gcpdxftp large_square_tool_num = 102
21 gcpdxftp # [CAM] */
22 gcpdxftp small_square_tool_num = 0
23 gcpdxftp # [CAM] */
24 gcpdxftp large_ball_tool_num = 0
25 gcpdxftp # [CAM] */
26 gcpdxftp small_ball_tool_num = 0
27 gcpdxftp # [CAM] */
28 gcpdxftp large_V_tool_num = 0
29 gcpdxftp # [CAM] */
30 gcpdxftp 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.opendxftfile(Base_filename)
48 gcpdxftp #gcp.opendxftfiles(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                           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                       radius, 90, 180)
65 gcpdxftp gcp.dxfarc(large_square_tool_num, stockXwidth - inset, stockYheight
66                       - inset, radius, 180, 270)
67 gcpdxftp gcp.dxfarc(large_square_tool_num, inset, stockYheight - inset,
68                       radius, 270, 360)
69 gcpdxftp
70 gcpdxftp gcp.dxfline(large_square_tool_num, inset, inset + radius, inset,
71                       stockYheight - (inset + radius))
72 gcpdxftp gcp.dxfline(large_square_tool_num, inset + radius, inset,
73                       stockXwidth - (inset + radius), inset)
74 gcpdxftp gcp.dxfline(large_square_tool_num, stockXwidth - inset, inset +
75                       radius, stockYheight - (inset + radius))
76 gcpdxftp gcp.dxfline(large_square_tool_num, inset + radius, stockYheight -
77                       inset, stockXwidth - (inset + radius), stockYheight - inset)
78 gcpdxftp
79 gcpdxftp gcp.dxfrectangle(large_square_tool_num, radius + inset, radius,
80                           stockXwidth/2 - (radius * 4), stockYheight - (radius * 2),
81                           cornerstyle, radius)
82 gcpdxftp gcp.dxfrectangle(large_square_tool_num, stockXwidth/2 + (radius *
83                           2) + inset, radius, stockXwidth/2 - (radius * 4), stockYheight -
84                           (radius * 2), cornerstyle, radius)
85 gcpdxftp #gcp.dxfrectangleround(large_square_tool_num, 64, 7, 24, 36, radius

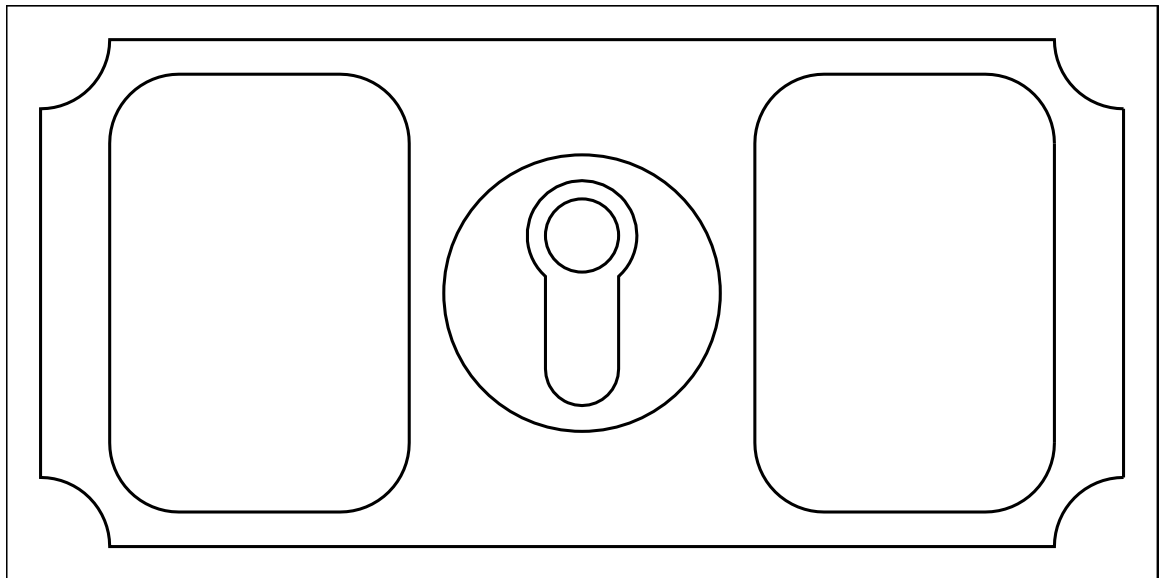
```

```

    )
75 gcpdxfpy #gcp.dxfrectanglechamfer(large_square_tool_num, 64, 7, 24, 36,
    radius)
76 gcpdxfpy #gcp.dxfrectangleflippedfillet(large_square_tool_num, 64, 7, 24,
    36, radius)
77 gcpdxfpy
78 gcpdxfpy gcp.dxfcircle(large_square_tool_num, stockXwidth/2, stockYheight/2,
    radius * 2)
79 gcpdxfpy
80 gcpdxfpy gcp.dxfKH(374, stockXwidth/2, stockYheight/5*3, 0, -7, 270,
    11.5875)
81 gcpdxfpy
82 gcpdxfpy #gcp.closedxfiles()
83 gcpdxfpy gcp.closedxfile()

```

which creates:



and which may be imported into pretty much any CAD or CAM application. 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)
- dxfar (specifying arc center, radius, and beginning/ending angles)
- dxfKH (specifying origin, depth, angle, distance)

2.2 gcodepreviewtemplate.py

Note that since the v0.7 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 R0_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.opendxffile(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(pygcpversion())
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.cutline(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.cutkeyholegcdxf(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.cutkeyholegcdxf(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)

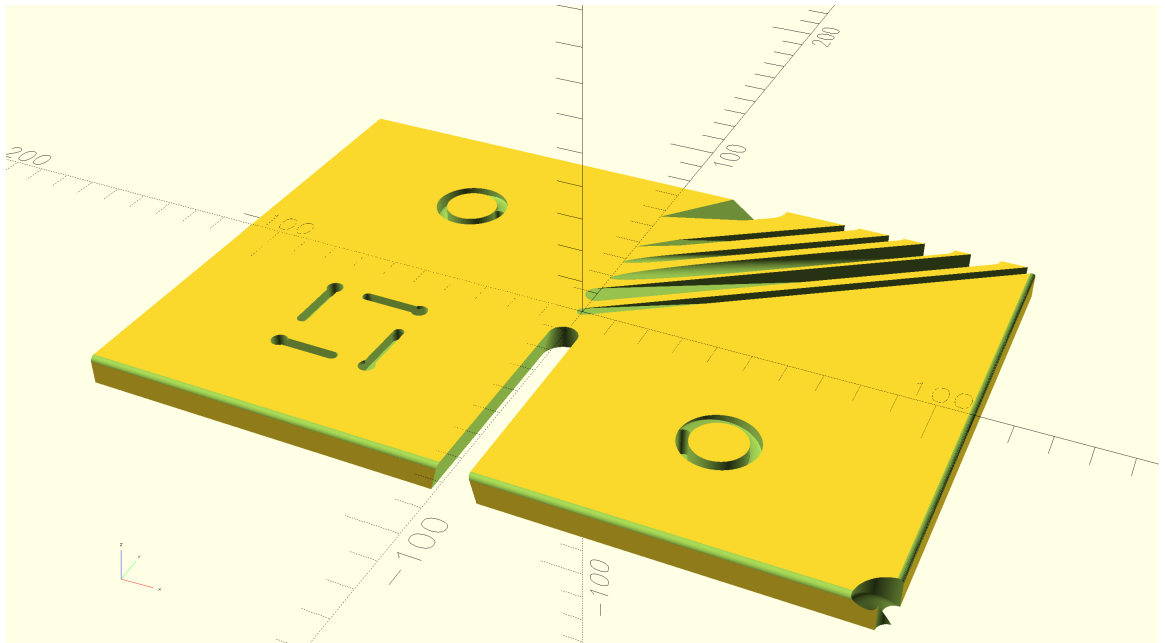
```

```

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()

```

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



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/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 R0_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 opendxxfile(Base_filename);
92 gcptmpl opendxxfiles(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,
        stockzero);
105 gcptmpl
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 toolchange(374, 10000);
211 gcptmpl rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4+
    stockYheight/16))
212 gcptmpl //rapidXY(-(stockXwidth/4 - stockXwidth /16), -(stockYheight/4 +
    stockYheight/16))
213 gcptmpl rapidZ(0);
214 gcptmpl
215 gcptmpl cutline(xpos(), ypos(), (stockZthickness/2) * -1);
216 gcptmpl cutlinedxfgc(xpos() + stockYheight /9, ypos(), zpos());
217 gcptmpl cutline(xpos() - stockYheight /9, ypos(), zpos());
218 gcptmpl cutline(xpos(), ypos(), 0);
219 gcptmpl
220 gcptmpl rapidZ(retractheight);
221 gcptmpl rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4+
    stockYheight/16));
222 gcptmpl rapidZ(0);
223 gcptmpl cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
224 gcptmpl cutlinedxfgc(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos());
225 gcptmpl cutline(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos());
226 gcptmpl cutline(gcp.xpos(), gcp.ypos(), 0);
227 gcptmpl
228 gcptmpl rapidZ(retractheight);
229 gcptmpl rapidXY(-stockXwidth/4+stockXwidth/16, -(stockYheight/4-

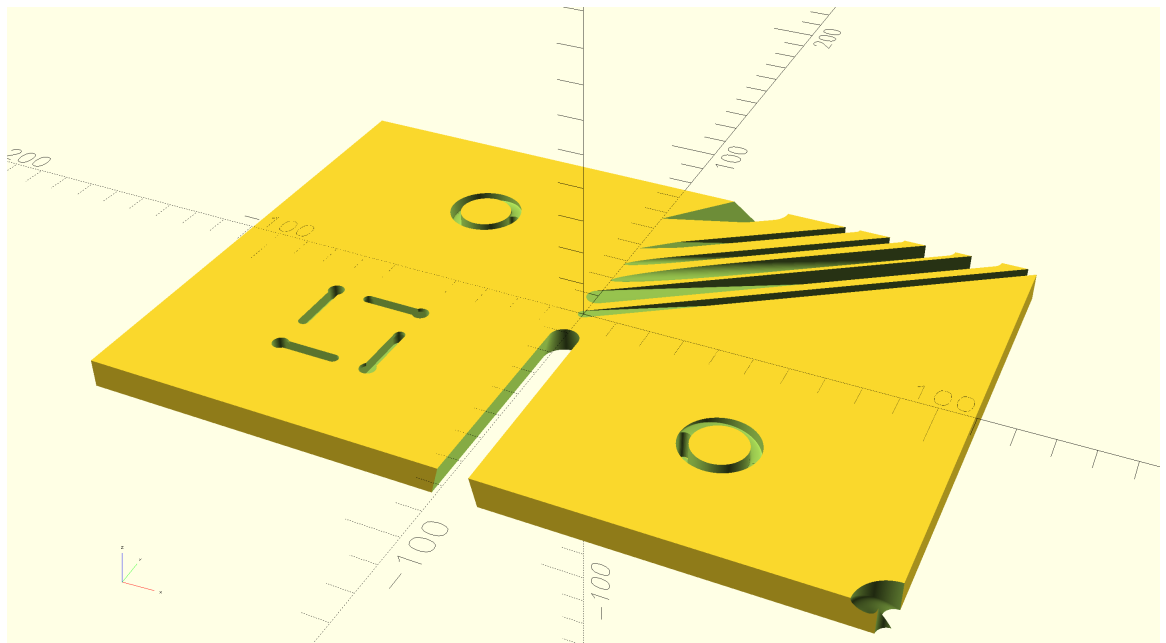
```

```

        stockYheight/8));
230 gcptmpl rapidZ(0);
231 gcptmpl cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
232 gcptmpl cutlinedxfgc(gcp.xpos()-stockYheight/9, gcp.ypos(), gcp.zpos());
233 gcptmpl cutline(gcp.xpos()+stockYheight/9, gcp.ypos(), gcp.zpos());
234 gcptmpl cutline(gcp.xpos(), gcp.ypos(), 0);
235 gcptmpl
236 gcptmpl rapidZ(retractheight);
237 gcptmpl rapidXY(-stockXwidth/4-stockXwidth/16, -(stockYheight/4-
        stockYheight/8));
238 gcptmpl rapidZ(0);
239 gcptmpl cutline(gcp.xpos(), gcp.ypos(), -stockZthickness/2);
240 gcptmpl cutlinedxfgc(gcp.xpos(), gcp.ypos()-stockYheight/9, gcp.zpos());
241 gcptmpl cutline(gcp.xpos(), gcp.ypos()+stockYheight/9, gcp.zpos());
242 gcptmpl cutline(gcp.xpos(), gcp.ypos(), 0);
243 gcptmpl
244 gcptmpl stockandtoolpaths();
245 gcptmpl //stockwotoolpaths();
246 gcptmpl //outputtoolpaths();
247 gcptmpl
248 gcptmpl //makecube(3, 2, 1);
249 gcptmpl
250 gcptmpl //instantiatecube();
251 gcptmpl
252 gcptmpl closegcodefile();
253 gcptmpl closedxffiles();
254 gcptmpl closedxffile();

```

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



Obviously, the use of OpenSCAD to make use of roundover tooling remains to be implemented. Similarly, generate keyhole dxfs needs to be updated to function as expected.

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 versions of commands which will share the same name.

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 be the first argument where possible — this makes it obvious if they are not used — the negative consideration, 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 straightforward to ensure that functions and variables have different names for purposes of scope

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

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

	line			arc		
	cut	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. See `stepsizearc` and `stepsizeroundover`.

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 gpcscad //
22 gpcscad // module placecube(){
23 gpcscad // gcp.placecube();
24 gpcscad //}
25 gpcscad //
26 gpcscad // module instantiatecube(){
27 gpcscad // gcp.instantiatecube();
28 gpcscad //}
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 begins with the `init` method which allows passing in and defining the variables which will be used by the other methods in this class. Part of this includes handling various definitions for Boolean values.

```

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.

Similarly, a 3D model of the tool will be available as `currenttool` itself and used where appropriate.

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

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

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

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

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

```
114 gcpy      def setxpos(self, newxpos):
115 gcpy #          global mpx
116 gcpy      self.mpx = newxpos
117 gcpy
118 gcpy      def setypos(self, newypos):
119 gcpy #          global mpy
120 gcpy      self.mpy = newypos
121 gcpy
122 gcpy      def setzpos(self, newzpos):
123 gcpy #          global mpz
124 gcpy      self.mpz = newzpos
125 gcpy
126 gcpy #      def settpzinc(self, newtpzinc):
127 gcpy #          global tpzinc
128 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

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.

```
130 gcpy      def setupstock(self, stockXwidth,
131 gcpy          stockYheight,
132 gcpy          stockZthickness,
133 gcpy          zeroheight,
134 gcpy          stockzero,
135 gcpy          retractheight):
136 gcpy      self.stockXwidth = stockXwidth
137 gcpy      self.stockYheight = stockYheight
138 gcpy      self.stockZthickness = stockZthickness
139 gcpy      self.zeroheight = zeroheight
140 gcpy      self.stockzero = stockzero
```

```

141 gcpy          self.retractheight = retractheight
142 gcpy #          global mpx
143 gcpy          self.mpx = float(0)
144 gcpy #          global mpy
145 gcpy          self.mpy = float(0)
146 gcpy #          global mpz
147 gcpy          self.mpz = float(0)
148 gcpy #          global tpz
149 gcpy #          self.tpzinc = float(0)
150 gcpy #          global currenttoolnum
151 gcpy          self.currenttoolnum = 102
152 gcpy #          global currenttoolshape
153 gcpy          self.currenttoolshape = cylinder(12.7, 1.5875)
154 gcpy          self.rapids = self.currenttoolshape
155 gcpy #          global stock
156 gcpy          self.stock = cube([stockXwidth, stockYheight,
                                   stockZthickness])
157 gcpy %%WRITEGC          if self.generategcode == True:
158 gcpy %%WRITEGC          self.writegc("(Design File: " + self.
                                   basefilename + ")")
159 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.

```

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

```

```

183 gcpy          /2),"mm,␣-",str(self.stockZthickness),"mm")
                self.writegc("(stockMax:",str(self.stockXwidth
184 gcpy          /2),"mm,␣",str(self.stockYheight/2),"mm,␣
                0.00mm)")
                self.writegc("(STOCK/BLOCK,␣",str(self.
                stockXwidth),"␣",str(self.stockYheight),"␣
                ",str(self.stockZthickness),"␣",str(self.
                stockXwidth/2),"␣", str(self.stockYheight
                /2),"␣",str(self.stockZthickness),")")
185 gcpy          if self.zeroheight == "Bottom":
186 gcpy              if self.stockzero == "Lower-Left":
187 gcpy                  self.stock = self.stock.translate([0,0,0])
188 gcpy                  if self.generategcode == True:
189 gcpy                      self.writegc("(stockMin:0.00mm,␣0.00mm,␣0.00mm
                )")
190 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth
                ),"mm,␣",str(self.stockYheight),"mm,␣␣",str
                (self.stockZthickness),"mm")")
191 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                stockXwidth),"␣",str(self.stockYheight),"
                ␣",str(self.stockZthickness),"␣0.00,␣0.00,
                ␣0.00)")
192 gcpy              if self.stockzero == "Center-Left":
193 gcpy                  self.stock = self.stock.translate([0,-self.
                stockYheight / 2,0])
194 gcpy                  if self.generategcode == True:
195 gcpy                      self.writegc("(stockMin:0.00mm,␣-",str(self.
                stockYheight/2),"mm,␣0.00mm)")
196 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth
                ),"mm,␣",str(self.stockYheight/2),"mm,␣-",str
                (self.stockZthickness),"mm")")
197 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                stockXwidth),"␣",str(self.stockYheight),"␣
                ",str(self.stockZthickness),"␣0.00,␣",str(
                self.stockYheight/2),"␣0.00mm));
198 gcpy              if self.stockzero == "Top-Left":
199 gcpy                  self.stock = self.stock.translate([0,-self.
                stockYheight,0])
200 gcpy                  if self.generategcode == True:
201 gcpy                      self.writegc("(stockMin:0.00mm,␣-",str(self.
                stockYheight),"mm,␣0.00mm)")
202 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth
                ),"mm,␣0.00mm,␣",str(self.stockZthickness),"
                mm)")
203 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                stockXwidth),"␣",str(self.stockYheight),"␣
                ",str(self.stockZthickness),"␣0.00,␣",str(
                self.stockYheight),"␣0.00)")
204 gcpy              if self.stockzero == "Center":
205 gcpy                  self.stock = self.stock.translate([-self.
                stockXwidth / 2,-self.stockYheight / 2,0])
206 gcpy                  if self.generategcode == True:
207 gcpy                      self.writegc("(stockMin:␣-",str(self.
                stockXwidth/2),"␣-",str(self.stockYheight
                /2),"mm,␣0.00mm)")
208 gcpy                      self.writegc("(stockMax:",str(self.stockXwidth
                /2),"mm,␣",str(self.stockYheight/2),"mm,␣",
                str(self.stockZthickness),"mm")")
209 gcpy                      self.writegc("(STOCK/BLOCK,␣",str(self.
                stockXwidth),"␣",str(self.stockYheight),"␣
                ",str(self.stockZthickness),"␣",str(self.
                stockXwidth/2),"␣", str(self.stockYheight
                /2),"␣0.00)")
210 gcpy          if self.generategcode == True:
211 gcpy              self.writegc("G90");
212 gcpy              self.writegc("G21");
```

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

```

36 gcpyscad module setupstock(stockXwidth, stockYheight, stockZthickness,
                zeroheight, stockzero, retractheight) {
37 gcpyscad     gcp.setupstock(stockXwidth, stockYheight, stockZthickness,
                zeroheight, stockzero, retractheight);
38 gcpyscad }
```



```
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

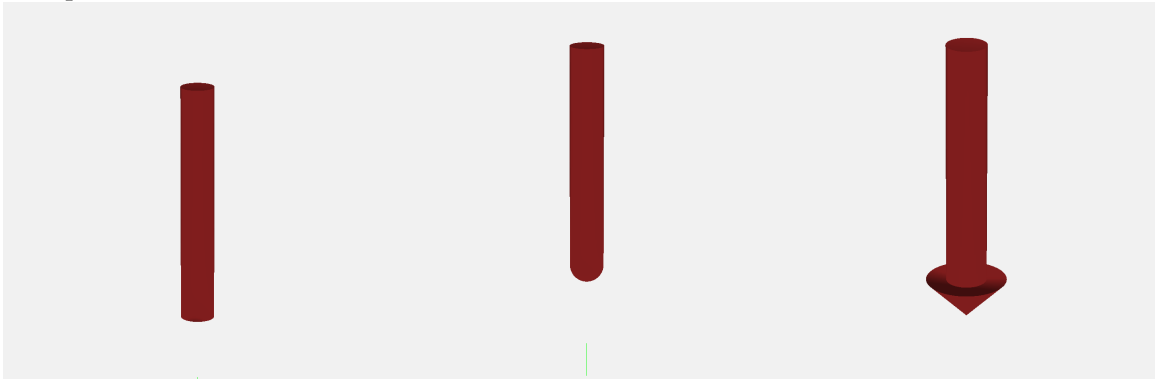
Similarly Python functions and variables will be used in: currenttoolnumber (note that it is important to use a different name than the variable currenttoolnum and settool to track and set and return the current tool:

```
214 gcpy def settool(self,tn):
215 gcpy # global currenttoolnum
216 gcpy self.currenttoolnum = tn
217 gcpy
218 gcpy def currenttoolnumber(self):
219 gcpy # global currenttoolnum
220 gcpy return self.currenttoolnum
221 gcpy
222 gcpy # def currentroundovertoolnumber(self):
223 gcpy # global Roundover_tool_num
224 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:

```
226 gcpy def endmill_square(self, es_diameter, es_flute_length):
227 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:

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

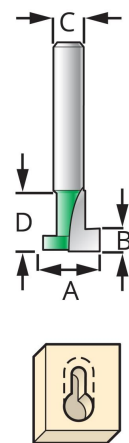
endmill v The endmill v is modeled as a cylinder with a zero width base and a second cylinder for the shaft (note that Python’s math defaults to radians, hence the need to convert from degrees):

```
235 gcpy      def endmill_v(self, es_v_angle, es_diameter):
236 gcpy          es_v_angle = math.radians(es_v_angle)
237 gcpy          v = cylinder(r1=0, r2=(es_diameter / 2), h=((es_diameter /
238 gcpy              2) / math.tan((es_v_angle / 2))), center=False)
239 gcpy          s = cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2), h
240 gcpy              =((es_diameter * 8) ), center=False)
241 gcpy          sh = s.translate([0, 0, ((es_diameter / 2) / math.tan((
242 gcpy              es_v_angle / 2)))]])
243 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:

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

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

```
245 gcpy      def keyhole_shaft(self, es_diameter, es_flute_length):
246 gcpy          return cylinder(r1=(es_diameter / 2), r2=(es_diameter / 2),
247 gcpy              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>.

```
248 gcpy      def threadmill(self, minor_diameter, major_diameter, cut_height
249 gcpy          ):
```

```
249 gcpy          btm = cylinder(r1=(minor_diameter / 2), r2=(major_diameter
                    / 2), h=cut_height, center = False)
250 gcpy          top = cylinder(r1=(major_diameter / 2), r2=(minor_diameter
                    / 2), h=cut_height, center = False)
251 gcpy          top = top.translate([0, 0, cut_height/2])
252 gcpy          tm = btm.union(top)
253 gcpy          return tm
254 gcpy
255 gcpy          def threadmill_shaft(self, diameter, cut_height, height):
256 gcpy          shaft = cylinder(r1=(diameter / 2), r2=(diameter / 2), h=
                    height, center = False)
257 gcpy          shaft = shaft.translate([0, 0, cut_height/2])
258 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)

```
260 gcpy          def dovetail(self, dt_bottomdiameter, dt_topdiameter, dt_height
                    , dt_angle):
261 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.

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

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

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 pre-viewing 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

currenttoolshape

cutline module and handle the tooling in a separate module as is currently done for roundover tooling.

```
263 gcpy      def currenttool(self):
264 gcpy #          global currenttoolshape
265 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.

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

```
311 gcpy          elif (tool_number == 374):
312 gcpy              self.writegc("(TOOL/MILL,9.53,␣0.00,␣3.17,␣0.00)")
313 gcpy          elif (tool_number == 375):
314 gcpy              self.writegc("(TOOL/MILL,9.53,␣0.00,␣3.17,␣0.00)")
315 gcpy          elif (tool_number == 376):
316 gcpy              self.writegc("(TOOL/MILL,12.7,␣0.00,␣4.77,␣0.00)")
317 gcpy          elif (tool_number == 378):
318 gcpy              self.writegc("(TOOL/MILL,12.7,␣0.00,␣4.77,␣0.00)")
319 gcpy          elif (tool_number == 814):
320 gcpy              self.writegc("(TOOL/MILL,12.7,␣6.367,␣12.7,␣0.00)")
321 gcpy              #dt_bottomdiameter, dt_topdiameter, dt_height, dt_angle
322 gcpy              )
323 gcpy              #https://www.leevalley.com/en-us/shop/tools/power-tool-
324 gcpy              accessories/router-bits/30172-dovetail-bits?item=18
325 gcpy              J1607
326 gcpy              self.currenttoolshape = self.dovetail(12.7, 6.367,
327 gcpy                  12.7, 14)
328 gcpy          elif (tool_number == 56125):#0.508/2, 1.531
329 gcpy              self.writegc("(TOOL/CRMILL,␣0.508,␣6.35,␣3.175,␣7.9375,
330 gcpy                  ␣3.175)")
331 gcpy          elif (tool_number == 56142):#0.508/2, 2.921
332 gcpy              self.writegc("(TOOL/CRMILL,␣0.508,␣3.571875,␣1.5875,␣
333 gcpy                  5.55625,␣1.5875)")
334 gcpy          elif (tool_number == 312):#1.524/2, 3.175
335 gcpy              self.writegc("(TOOL/CRMILL, Diameter1, Diameter2,
336 gcpy                  Radius, Height, Length)")
337 gcpy          elif (tool_number == 1570):#0.507/2, 4.509
338 gcpy              self.writegc("(TOOL/CRMILL,␣0.17018,␣9.525,␣4.7625,␣
339 gcpy                  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.

```
332 gcpy          self.writegc("M6T",str(tool_number))
333 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:

```
52 gpcpscad module toolchange(tool_number,speed){
53 gpcpscad     gcp.toolchange(tool_number,speed);
54 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,
57 gpcpscad     td_depth);
```

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

```
335 gcpy          def tool_diameter(self, ptd_tool, ptd_depth):
336 gcpy          # Square 122,112,102,201
337 gcpy              if ptd_tool == 122:
338 gcpy                  return 0.79375
```

```
339 gcpy          if ptd_tool == 112:
340 gcpy              return 1.5875
341 gcpy          if ptd_tool == 102:
342 gcpy              return 3.175
343 gcpy          if ptd_tool == 201:
344 gcpy              return 6.35
345 gcpy # Ball 121,111,101,202
346 gcpy          if ptd_tool == 122:
347 gcpy              if ptd_depth > 0.396875:
348 gcpy                  return 0.79375
349 gcpy              else:
350 gcpy                  return ptd_tool
351 gcpy          if ptd_tool == 112:
352 gcpy              if ptd_depth > 0.79375:
353 gcpy                  return 1.5875
354 gcpy              else:
355 gcpy                  return ptd_tool
356 gcpy          if ptd_tool == 101:
357 gcpy              if ptd_depth > 1.5875:
358 gcpy                  return 3.175
359 gcpy              else:
360 gcpy                  return ptd_tool
361 gcpy          if ptd_tool == 202:
362 gcpy              if ptd_depth > 3.175:
363 gcpy                  return 6.35
364 gcpy              else:
365 gcpy                  return ptd_tool
366 gcpy # V 301, 302, 390
367 gcpy          if ptd_tool == 301:
368 gcpy              return ptd_tool
369 gcpy          if ptd_tool == 302:
370 gcpy              return ptd_tool
371 gcpy          if ptd_tool == 390:
372 gcpy              return ptd_tool
373 gcpy # Keyhole
374 gcpy          if ptd_tool == 374:
375 gcpy              if ptd_depth < 3.175:
376 gcpy                  return 9.525
377 gcpy              else:
378 gcpy                  return 6.35
379 gcpy          if ptd_tool == 375:
380 gcpy              if ptd_depth < 3.175:
381 gcpy                  return 9.525
382 gcpy              else:
383 gcpy                  return 8
384 gcpy          if ptd_tool == 376:
385 gcpy              if ptd_depth < 4.7625:
386 gcpy                  return 12.7
387 gcpy              else:
388 gcpy                  return 6.35
389 gcpy          if ptd_tool == 378:
390 gcpy              if ptd_depth < 4.7625:
391 gcpy                  return 12.7
392 gcpy              else:
393 gcpy                  return 8
394 gcpy # Dovetail
395 gcpy          if ptd_tool == 814:
396 gcpy              if ptd_depth > 12.7:
397 gcpy                  return 6.35
398 gcpy              else:
399 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:

```
401 gcpy          def tool_radius(self, ptd_tool, ptd_depth):
402 gcpy              tr = self.tool_diameter(ptd_tool, ptd_depth)/2
403 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.

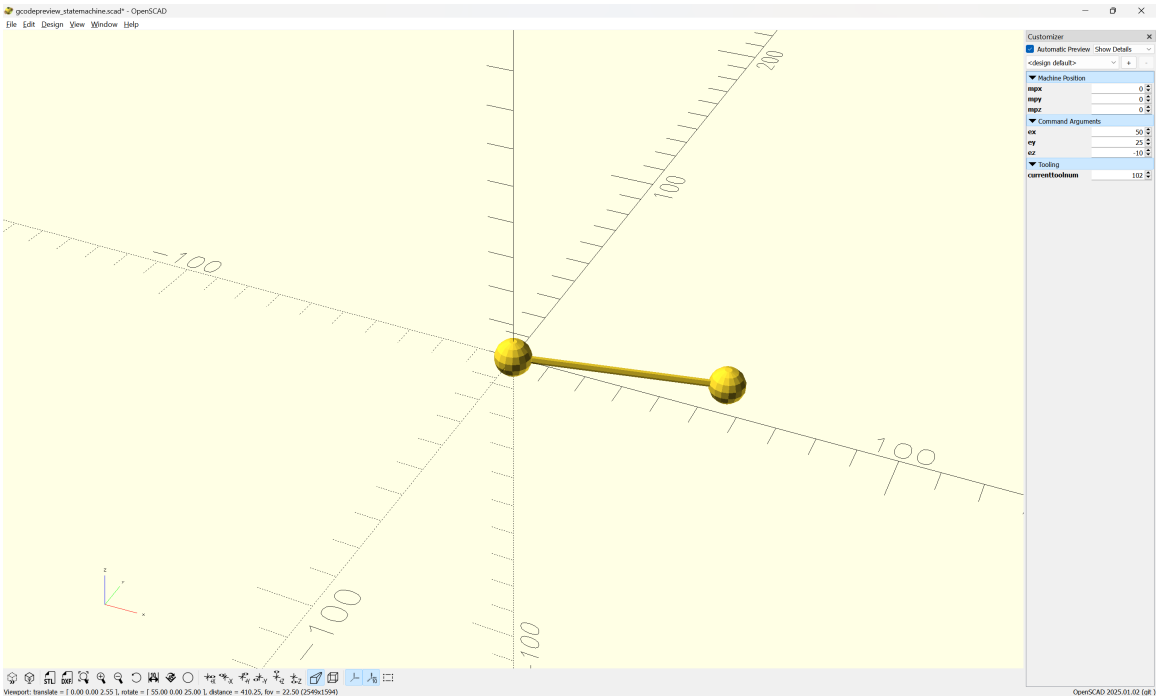
rapid... Note that the variables self.rapids and self.toolpaths are used to hold the accumulated (unioned) 3D models of the rapid motions and cuts so that they may be differenced from the stock when the value generatepaths is set to True.

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:

```
405 gcpy      def rcs(self,ex, ey, ez, shape):
406 gcpy          start = shape
407 gcpy          end = shape
408 gcpy          toolpath = hull(start.translate([self.xpos(), self.ypos(),
409 gcpy                                     self.zpos()]),
410 gcpy                                     end.translate([ex,ey,ez]))
411 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.

```
412 gcpy      def rapid(self,ex, ey, ez):
413 gcpy          cts = self.currenttoolshape
414 gcpy          toolpath = self.rcs(ex, ey, ez, cts)
415 gcpy          self.setxpos(ex)
416 gcpy          self.setypos(ey)
417 gcpy          self.setzpos(ez)
418 gcpy          if self.generatepaths == True:
419 gcpy              self.rapids = self.rapids.union(toolpath)
420 gcpy #              return cylinder(0.01, 0, 0.01, center = False, fn = 3)
421 gcpy              return cube([0.001,0.001,0.001])
422 gcpy          else:
423 gcpy              return toolpath
424 gcpy
425 gcpy      def cutshape(self,ex, ey, ez):
426 gcpy          cts = self.currenttoolshape
427 gcpy          toolpath = self.rcs(ex, ey, ez, cts)
428 gcpy          if self.generatepaths == True:
429 gcpy              self.toolpaths = self.toolpaths.union(toolpath)
430 gcpy              return cube([0.001,0.001,0.001])
431 gcpy          else:
432 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:

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

```

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

```

```
513 gcpy          for i in range(1, 90, stepsizeroundover):
514 gcpy              angle = i
515 gcpy              dx = tool_radius_width*math.cos(math.radians(angle))
516 gcpy              dxx = tool_radius_width*math.cos(math.radians(angle+1))
517 gcpy              dzz = tool_radius_width*math.sin(math.radians(angle))
518 gcpy              dz = tool_radius_width*math.sin(math.radians(angle+1))
519 gcpy              dh = abs(dzz-dz)+0.0001
520 gcpy              slice = cylinder(dh,tool_radius_tip+tool_radius_width-
                                   dx,tool_radius_tip+tool_radius_width-dxx)
521 gcpy              toolpath = toolpath.union(hull(slice.translate([bx,by,
                                   bz+dz]), slice.translate([ex,ey,ez+dz])))
522 gcpy          if self.generatepaths == True:
523 gcpy              self.toolpaths = self.toolpaths.union(toolpath)
524 gcpy          else:
525 gcpy              return toolpath
```

The matching OpenSCAD command is a descriptor:

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

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

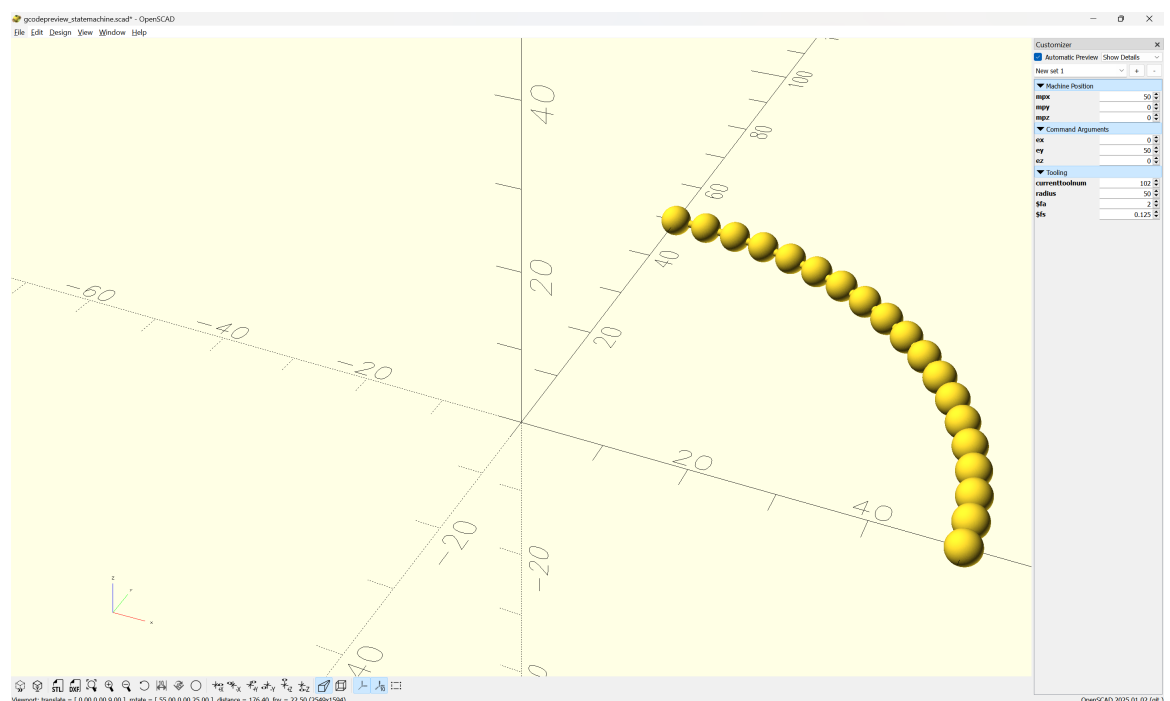
Cutting the quadrant arcs greatly simplifies the calculation and interface for the modules. A full set of 8 will be necessary, then circles will have a pair of modules (one for each cut direction) made for them.

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 `cutarcCW` loop: `cutarcCW` (clockwise) or `cutarcCC` (counterclockwise) to handle the drawing and processing `cutarcCC` 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.)

```

527 gcpy      def cutarcCC(self, barc, earc, xcenter, ycenter, radius,
                    tpzreldim, stepsizearc=1):
528 gcpy #          tpzinc = ez - self.zpos() / (earc - barc)
529 gcpy          tpzinc = tpzreldim / (earc - barc)
530 gcpy          cts = self.currenttoolshape
531 gcpy          toolpath = cts
532 gcpy          toolpath = toolpath.translate([self.xpos(),self.ypos(),self
                    .zpos()])
533 gcpy          i = barc
534 gcpy          while i < earc:
535 gcpy              toolpath = toolpath.union(self.cutline(xcenter + radius

```

```

        * math.cos(math.radians(i)), ycenter + radius *
        math.sin(math.radians(i)), self.zpos()+tpzinc))
536 gcpy          i += stepsizearc
537 gcpy          if self.generatepaths == False:
538 gcpy              return toolpath
539 gcpy          else:
540 gcpy              return cube([0.01,0.01,0.01])
541 gcpy
542 gcpy          def cutarcCW(self, barc,earc, xcenter, ycenter, radius,
tpzreldim, stepsizearc=1):
543 gcpy #              print(str(self.zpos()))
544 gcpy #              print(str(ez))
545 gcpy #              print(str(barc - earc))
546 gcpy #              tpzinc = ez - self.zpos() / (barc - earc)
547 gcpy #              print(str(tzinc))
548 gcpy #              global toolpath
549 gcpy #              print("Entering n toolpath")
550 gcpy              tpzinc = tpzreldim / (barc - earc)
551 gcpy              cts = self.currenttoolshape
552 gcpy              toolpath = cts
553 gcpy              toolpath = toolpath.translate([self.xpos(),self.ypos(),self
.zpos()])
554 gcpy              i = barc
555 gcpy              while i > earc:
556 gcpy                  toolpath = toolpath.union(self.cutline(xcenter + radius
* math.cos(math.radians(i)), ycenter + radius *
* math.sin(math.radians(i)), self.zpos()+tpzinc))
557 gcpy #                  self.setxpos(xcenter + radius * math.cos(math.radians(
i)))
558 gcpy #                  self.setypos(ycenter + radius * math.sin(math.radians(
i)))
559 gcpy #                  print(str(self.xpos()), str(self.ypos()), str(self.zpos
()))
560 gcpy #                  self.setzpos(self.zpos()+tpzinc)
561 gcpy                  i += abs(stepsizearc) * -1
562 gcpy #                  self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
radius, barc, earc)
563 gcpy #                  if self.generatepaths == True:
564 gcpy #                      print("Unioning n toolpath")
565 gcpy #                      self.toolpaths = self.toolpaths.union(toolpath)
566 gcpy #                  else:
567 gcpy                  if self.generatepaths == False:
568 gcpy                      return toolpath
569 gcpy                  else:
570 gcpy                      return cube([0.01,0.01,0.01])
```

Matching OpenSCAD modules are easily made:

```

82 gcpscad module cutarcCC(barc, earc, xcenter, ycenter, radius, tpzreldim){
83 gcpscad     gcp.cutarcCC(barc, earc, xcenter, ycenter, radius, tpzreldim);
84 gcpscad }
85 gcpscad
86 gcpscad module cutarcCW(barc, earc, xcenter, ycenter, radius, tpzreldim){
87 gcpscad     gcp.cutarcCW(barc, earc, xcenter, ycenter, radius, tpzreldim);
88 gcpscad }
```

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 — dxfarcs

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.

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

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

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

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:

```
572 gcpy      def dxfcircle(self, tool_num, xcenter, ycenter, radius):
573 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 0, 90)
574 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 90, 180)
575 gcpy          self.dxfarc(tool_num, xcenter, ycenter, radius, 180, 270)
576 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:

```
578 gcpy      def dxfrectangle(self, tool_num, xorigin, yorigin, xwidth,
579 gcpy          yheight, corners = "Square", radius = 6):
580 gcpy          if corners == "Square":
581 gcpy              self.dxfline(tool_num, xorigin, yorigin, xorigin +
582 gcpy                  xwidth, yorigin)
583 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin,
584 gcpy                  xorigin + xwidth, yorigin + yheight)
585 gcpy              self.dxfline(tool_num, xorigin + xwidth, yorigin +
586 gcpy                  yheight, xorigin + xwidth, yorigin + yheight)
587 gcpy              self.dxfline(tool_num, xorigin, yorigin + yheight,
588 gcpy                  xorigin, yorigin)
589 gcpy          elif corners == "Fillet":
590 gcpy              self.dxfrectangleround(tool_num, xorigin, yorigin,
591 gcpy                  xwidth, yheight, radius)
592 gcpy          elif corners == "Chamfer":
593 gcpy              self.dxfrectanglechamfer(tool_num, xorigin, yorigin,
594 gcpy                  xwidth, yheight, radius)
595 gcpy          elif corners == "Flipped_Fillet":
596 gcpy              self.dxfrectangleflippedfillet(tool_num, xorigin,
597 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.

```
591 gcpy      def dxfrectangleround(self, tool_num, xorigin, yorigin, xwidth,
592 gcpy          yheight, radius):
593 gcpy          self.dxfarc(tool_num, xorigin + xwidth - radius, yorigin +
594 gcpy              yheight - radius, radius, 0, 90)
595 gcpy          self.dxfarc(tool_num, xorigin + radius, yorigin + yheight -
596 gcpy              radius, radius, 90, 180)
597 gcpy          self.dxfarc(tool_num, xorigin + radius, yorigin + radius,
598 gcpy              radius, 180, 270)
599 gcpy          self.dxfarc(tool_num, xorigin + xwidth - radius, yorigin +
600 gcpy              radius, radius, 270, 360)

596 gcpy          self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
597 gcpy              xwidth - radius, yorigin)
598 gcpy          self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
599 gcpy              xorigin + xwidth, yorigin + yheight - radius)
600 gcpy          self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
601 gcpy              yheight, xorigin + radius, yorigin + yheight)
602 gcpy          self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
603 gcpy              xorigin, yorigin + radius)
```

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

```
602 gcpy      def dxfrectanglechamfer(self, tool_num, xorigin, yorigin,
603 gcpy          xwidth, yheight, radius):
604 gcpy          self.dxfline(tool_num, xorigin + radius, yorigin, xorigin,
605 gcpy              yorigin + radius)
606 gcpy          self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
607 gcpy              xorigin + radius, yorigin + yheight)
608 gcpy          self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
609 gcpy              yheight, xorigin + xwidth, yorigin + yheight - radius)
610 gcpy          self.dxfline(tool_num, xorigin + xwidth - radius, yorigin,
611 gcpy              xorigin + xwidth, yorigin + radius)

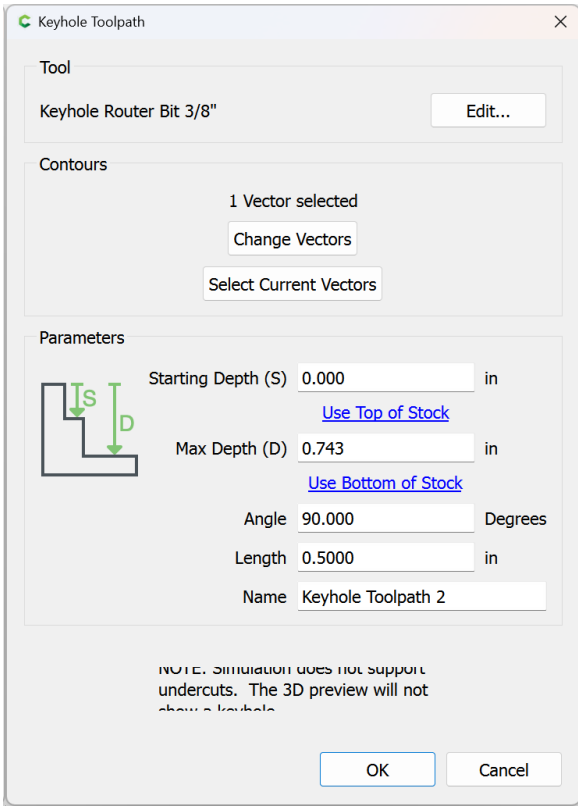
607 gcpy          self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
608 gcpy              xwidth - radius, yorigin)
609 gcpy          self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
610 gcpy              xorigin + xwidth, yorigin + yheight - radius)
611 gcpy          self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
612 gcpy              yheight, xorigin + radius, yorigin + yheight)
613 gcpy          self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
614 gcpy              xorigin, yorigin + radius)
```

Flipped Fillet:

```
613 gcpy      def dxfrectangleflippedfillet(self, tool_num, xorigin, yorigin,
614 gcpy          xwidth, yheight, radius):
615 gcpy          self.dxfarc(tool_num, xorigin, yorigin, radius, 0, 90)
616 gcpy          self.dxfarc(tool_num, xorigin + xwidth, yorigin, radius,
617 gcpy              90, 180)
618 gcpy          self.dxfarc(tool_num, xorigin + xwidth, yorigin + yheight,
619 gcpy              radius, 180, 270)
620 gcpy          self.dxfarc(tool_num, xorigin, yorigin + yheight, radius,
621 gcpy              270, 360)

618 gcpy          self.dxfline(tool_num, xorigin + radius, yorigin, xorigin +
619 gcpy              xwidth - radius, yorigin)
620 gcpy          self.dxfline(tool_num, xorigin + xwidth, yorigin + radius,
621 gcpy              xorigin + xwidth, yorigin + yheight - radius)
622 gcpy          self.dxfline(tool_num, xorigin + xwidth - radius, yorigin +
623 gcpy              yheight, xorigin + radius, yorigin + yheight)
624 gcpy          self.dxfline(tool_num, xorigin, yorigin + yheight - radius,
625 gcpy              xorigin, yorigin + radius)
```

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:

```
624 gcpy      def cutkeyholegdcxf(self, kh_tool_num, kh_start_depth,
625 gcpy          kh_max_depth, kht_direction, kh_distance):
626 gcpy          toolpath = self.cutKHgdcxf(kh_tool_num, kh_start_depth,
627 gcpy              kh_max_depth, 90, kh_distance)
628 gcpy          elif (kht_direction == "S"):
629 gcpy              toolpath = self.cutKHgdcxf(kh_tool_num, kh_start_depth,
630 gcpy                  kh_max_depth, 270, kh_distance)
631 gcpy          elif (kht_direction == "E"):
632 gcpy              toolpath = self.cutKHgdcxf(kh_tool_num, kh_start_depth,
633 gcpy                  kh_max_depth, 0, kh_distance)
634 gcpy          elif (kht_direction == "W"):
635 gcpy              toolpath = self.cutKHgdcxf(kh_tool_num, kh_start_depth,
636 gcpy                  kh_max_depth, 180, kh_distance)
637 gcpy          if self.generatepaths == True:
638 gcpy              self.toolpaths = union([self.toolpaths, toolpath])
639 gcpy              return toolpath
640 gcpy          else:
641 gcpy              return cube([0.01,0.01,0.01])
```

```
90 gcpscad module cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
    kht_direction, kh_distance){
91 gcpscad     gcp.cutkeyholegcdxf(kh_tool_num, kh_start_depth, kh_max_depth,
        kht_direction, kh_distance);
92 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:

```
639 gcpy      def cutKHgcdxf(self, kh_tool_num, kh_start_depth, kh_max_depth,
    kh_angle, kh_distance):
640 gcpy      oXpos = self.xpos()
641 gcpy      oYpos = self.ypos()
642 gcpy      self.dxfKH(kh_tool_num, self.xpos(), self.ypos(),
        kh_start_depth, kh_max_depth, kh_angle, kh_distance)
643 gcpy      toolpath = self.cutline(self.xpos(), self.ypos(), -
        kh_max_depth)
644 gcpy      self.setxpos(oXpos)
645 gcpy      self.setypos(oYpos)
646 gcpy      if self.generatepaths == False:
647 gcpy          return toolpath
648 gcpy      else:
649 gcpy          return cube([0.001,0.001,0.001])

651 gcpy      def dxfKH(self, kh_tool_num, oXpos, oYpos, kh_start_depth,
    kh_max_depth, kh_angle, kh_distance):
652 gcpy      #     oXpos = self.xpos()
653 gcpy      #     oYpos = self.ypos()
654 gcpy      #Circle at entry hole
655 gcpy      self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7), 0, 90)
656 gcpy      self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7), 90,180)
657 gcpy      self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 7),180,270)
658 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:

```
660 gcpy #pre-calculate needed values
661 gcpy      r = self.tool_radius(kh_tool_num, 7)
662 gcpy      #     print(r)
663 gcpy      rt = self.tool_radius(kh_tool_num, 1)
664 gcpy      #     print(rt)
665 gcpy      ro = math.sqrt((self.tool_radius(kh_tool_num, 1))**2-(self.
        tool_radius(kh_tool_num, 7))**2)
666 gcpy      #     print(ro)
667 gcpy      angle = math.degrees(math.acos(ro/rt))
668 gcpy      #Outlines of entry hole and slot
669 gcpy      if (kh_angle == 0):
670 gcpy      #Lower left of entry hole
671 gcpy          self.dxfarc(kh_tool_num, self.xpos(),self.ypos(),self.
            tool_radius(kh_tool_num, 1),180,270)
672 gcpy      #Upper left of entry hole
673 gcpy          self.dxfarc(kh_tool_num, self.xpos(),self.ypos(),self.
            tool_radius(kh_tool_num, 1),90,180)
674 gcpy      #Upper right of entry hole
675 gcpy      #     self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
        41.810, 90)
676 gcpy          self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
            angle, 90)
677 gcpy      #Lower right of entry hole
678 gcpy          self.dxfarc(kh_tool_num, self.xpos(), self.ypos(), rt,
            270, 360-angle)
679 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))))
680 gcpy      #Actual line of cut
681 gcpy      #     self.dxfline(kh_tool_num, self.xpos(),self.ypos(),self
        .xpos()+kh_distance,self.ypos())
```

```

682 gcpy #upper right of end of slot (kh_max_depth+4.36))/2
683 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)
684 gcpy #lower right of end of slot
685 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)
686 gcpy #upper right slot
687 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))
688 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)
689 gcpy #end position at top of slot
690 gcpy #lower right slot
691 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))
692 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)
693 gcpy #end position at top of slot
694 gcpy #          hull(){
695 gcpy #              translate([xpos(), ypos(), zpos()]){
696 gcpy #                  keyhole_shaft(6.35, 9.525);
697 gcpy #              }
698 gcpy #              translate([xpos(), ypos(), zpos()-kh_max_depth]){
699 gcpy #                  keyhole_shaft(6.35, 9.525);
700 gcpy #              }
701 gcpy #          }
702 gcpy #          hull(){
703 gcpy #              translate([xpos(), ypos(), zpos()-kh_max_depth]){
704 gcpy #                  keyhole_shaft(6.35, 9.525);
705 gcpy #              }
706 gcpy #              translate([xpos()+kh_distance, ypos(), zpos()-kh_max_depth])
707 gcpy #              {
708 gcpy #                  keyhole_shaft(6.35, 9.525);
709 gcpy #              }
710 gcpy #          cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
711 gcpy #          cutwithfeed(getxpos()+kh_distance,getypos(),-kh_max_depth,feed
712 gcpy #          );
713 gcpy #          setxpos(getxpos()-kh_distance);
714 gcpy #          } else if (kh_angle > 0 && kh_angle < 90) {
715 gcpy #          //echo(kh_angle);
716 gcpy #          dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
717 gcpy #          kh_max_depth))/2,90+kh_angle,180+kh_angle, KH_tool_num);
718 gcpy #          dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
719 gcpy #          kh_max_depth))/2,180+kh_angle,270+kh_angle, KH_tool_num);
720 gcpy #          dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
721 gcpy #          kh_max_depth+4.36))/2,kh_angle+asin((tool_diameter(KH_tool_num, (
722 gcpy #          kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth
723 gcpy #          ))/2)),90+kh_angle, KH_tool_num);
724 gcpy #          dxfarc(getxpos(),getypos(),tool_diameter(KH_tool_num, (
725 gcpy #          kh_max_depth))/2,270+kh_angle,360+kh_angle-asin((tool_diameter(
726 gcpy #          KH_tool_num, (kh_max_depth+4.36))/2)/(tool_diameter(KH_tool_num,
727 gcpy #          (kh_max_depth))/2)), KH_tool_num);
728 gcpy #          dxfarc(getxpos()+(kh_distance*cos(kh_angle)),
729 gcpy #          getypos()+(kh_distance*sin(kh_angle)),tool_diameter(KH_tool_num,
730 gcpy #          (kh_max_depth+4.36))/2,0+kh_angle,90+kh_angle, KH_tool_num);
731 gcpy #          dxfarc(getxpos()+(kh_distance*cos(kh_angle)),getypos()+(
732 gcpy #          kh_distance*sin(kh_angle)),tool_diameter(KH_tool_num, (
733 gcpy #          kh_max_depth+4.36))/2,270+kh_angle,360+kh_angle, KH_tool_num);
734 gcpy #          dxfline( getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2*
735 gcpy #          cos(kh_angle+asin((tool_diameter(KH_tool_num, (kh_max_depth
736 gcpy #          +4.36))/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2))),
737 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))),
724 gcpy # getxpos()+((kh_distance*cos(kh_angle))-((tool_diameter(KH_tool_num
        , (kh_max_depth+4.36))/2)*sin(kh_angle)),
725 gcpy # getypos()+((kh_distance*sin(kh_angle))+((tool_diameter(KH_tool_num
        , (kh_max_depth+4.36))/2)*cos(kh_angle)), KH_tool_num);
726 gcpy #//echo("a",tool_diameter(KH_tool_num, (kh_max_depth+4.36))/2);
727 gcpy #//echo("c",tool_diameter(KH_tool_num, (kh_max_depth))/2);
728 gcpy #echo("Aangle",asin((tool_diameter(KH_tool_num, (kh_max_depth+4.36)
        )/2)/(tool_diameter(KH_tool_num, (kh_max_depth))/2)));
729 gcpy #//echo(kh_angle);
730 gcpy # cutwithfeed(getxpos()+((kh_distance*cos(kh_angle)),getypos()+((
        kh_distance*sin(kh_angle)),-kh_max_depth,feed);
731 gcpy #
        toolpath = toolpath.union(self.cutline(self.xpos()+
        kh_distance, self.ypos(), -kh_max_depth))
732 gcpy
        elif (kh_angle == 90):
733 gcpy #Lower left of entry hole
734 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),180,270)
735 gcpy #Lower right of entry hole
736 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),270,360)
737 gcpy #left slot
738 gcpy
        self.dxfline(kh_tool_num, oXpos-r, oYpos+ro, oXpos-r,
        oYpos+kh_distance)
739 gcpy #right slot
740 gcpy
        self.dxfline(kh_tool_num, oXpos+r, oYpos+ro, oXpos+r,
        oYpos+kh_distance)
741 gcpy #upper left of end of slot
742 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos+kh_distance,r
        ,90,180)
743 gcpy #upper right of end of slot
744 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos+kh_distance,r
        ,0,90)
745 gcpy #Upper right of entry hole
746 gcpy
        self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 0, 90-angle)
747 gcpy #Upper left of entry hole
748 gcpy
        self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90+angle,
        180)
749 gcpy #
        toolpath = toolpath.union(self.cutline(oXpos, oYpos+
        kh_distance, -kh_max_depth))
750 gcpy
        elif (kh_angle == 180):
751 gcpy #Lower right of entry hole
752 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),270,360)
753 gcpy #Upper right of entry hole
754 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),0,90)
755 gcpy #Upper left of entry hole
756 gcpy
        self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 90, 180-
        angle)
757 gcpy #Lower left of entry hole
758 gcpy
        self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180+angle,
        270)
759 gcpy #upper slot
760 gcpy
        self.dxfline(kh_tool_num, oXpos-ro, oYpos-r, oXpos-
        kh_distance, oYpos-r)
761 gcpy #lower slot
762 gcpy
        self.dxfline(kh_tool_num, oXpos-ro, oYpos+r, oXpos-
        kh_distance, oYpos+r)
763 gcpy #upper left of end of slot
764 gcpy
        self.dxfarc(kh_tool_num, oXpos-kh_distance,oYpos,r
        ,90,180)
765 gcpy #lower left of end of slot
766 gcpy
        self.dxfarc(kh_tool_num, oXpos-kh_distance,oYpos,r
        ,180,270)
767 gcpy #
        toolpath = toolpath.union(self.cutline(oXpos-
        kh_distance, oYpos, -kh_max_depth))
768 gcpy
        elif (kh_angle == 270):
769 gcpy #Upper left of entry hole
770 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),90,180)
771 gcpy #Upper right of entry hole
772 gcpy
        self.dxfarc(kh_tool_num, oXpos,oYpos,self.tool_radius(
        kh_tool_num, 1),0,90)
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 #lower left of end of slot
778 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos-kh_distance,r
                             ,180,270)
779 gcpy #lower right of end of slot
780 gcpy          self.dxfarc(kh_tool_num, oXpos,oYpos-kh_distance,r
                             ,270,360)
781 gcpy #lower right of entry hole
782 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 180, 270-
                             angle)
783 gcpy #lower left of entry hole
784 gcpy          self.dxfarc(kh_tool_num, oXpos, oYpos, rt, 270+angle,
                             360)
785 gcpy #          toolpath = toolpath.union(self.cutline(oXpos, oYpos-
                             kh_distance, -kh_max_depth))
786 gcpy #          print(self.zpos())
787 gcpy #          self.setxpos(oXpos)
788 gcpy #          self.setypos(oYpos)
789 gcpy #          if self.generatepaths == False:
790 gcpy #              return toolpath
791 gcpy
792 gcpy # } else if (kh_angle == 90) {
793 gcpy # //Lower left of entry hole
794 gcpy # dxfarc(getxpos(),getypos(),9.525/2,180,270, KH_tool_num);
795 gcpy # //Lower right of entry hole
796 gcpy # dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
797 gcpy # //Upper right of entry hole
798 gcpy # dxfarc(getxpos(),getypos(),9.525/2,0,acos(tool_diameter(
KH_tool_num, 5)/tool_diameter(KH_tool_num, 1)), KH_tool_num);
799 gcpy # //Upper left of entry hole
800 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)
;
801 gcpy # //Actual line of cut
802 gcpy # dxfline(getxpos(),getypos(),getxpos(),getypos()+kh_distance);
803 gcpy # //upper right of slot
804 gcpy # dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,0,90, KH_tool_num);
805 gcpy # //upper left of slot
806 gcpy # dxfarc(getxpos(),getypos()+kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
807 gcpy # //right of slot
808 gcpy # dxfline(
809 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
810 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,
811 gcpy #     getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
812 gcpy #     //end position at top of slot
813 gcpy #     getypos()+kh_distance,
814 gcpy #     KH_tool_num);
815 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);
816 gcpy # hull(){
817 gcpy #     translate([xpos(), ypos(), zpos()]){
818 gcpy #         keyhole_shaft(6.35, 9.525);
819 gcpy #     }
820 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){
821 gcpy #         keyhole_shaft(6.35, 9.525);
822 gcpy #     }
823 gcpy # }
824 gcpy # hull(){
825 gcpy #     translate([xpos(), ypos(), zpos()-kh_max_depth]){
826 gcpy #         keyhole_shaft(6.35, 9.525);
827 gcpy #     }
828 gcpy #     translate([xpos(), ypos()+kh_distance, zpos()-kh_max_depth])
{
829 gcpy #         keyhole_shaft(6.35, 9.525);
830 gcpy #     }
831 gcpy # }
832 gcpy # cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
833 gcpy # cutwithfeed(getxpos(),getypos()+kh_distance,-kh_max_depth,feed
);

```

```

834 gcpy #      setypos(getypos()-kh_distance);
835 gcpy # } else if (kh_angle == 180) {
836 gcpy #      //Lower right of entry hole
837 gcpy #      dxfarc(getxpos(),getypos(),9.525/2,270,360, KH_tool_num);
838 gcpy #      //Upper right of entry hole
839 gcpy #      dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
840 gcpy #      //Upper left of entry hole
841 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);
842 gcpy #      //Lower left of entry hole
843 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
);
844 gcpy #      //upper left of slot
845 gcpy #      dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,90,180, KH_tool_num);
846 gcpy #      //lower left of slot
847 gcpy #      dxfarc(getxpos()-kh_distance,getypos(),tool_diameter(
KH_tool_num, (kh_max_depth+6.35))/2,180,270, KH_tool_num);
848 gcpy #      //Actual line of cut
849 gcpy #      dxfline(getxpos(),getypos(),getxpos()-kh_distance,getypos());
850 gcpy #      //upper left slot
851 gcpy #      dxfline(
852 gcpy #          getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
tool_diameter(KH_tool_num,5)^2))/2),
853 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,
854 gcpy #          getxpos()-kh_distance,
855 gcpy #          //end position at top of slot
856 gcpy #          getypos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
857 gcpy #          KH_tool_num);
858 gcpy #      //lower right slot
859 gcpy #      dxfline(
860 gcpy #          getxpos()-(sqrt((tool_diameter(KH_tool_num,1)^2)-(
tool_diameter(KH_tool_num,5)^2))/2),
861 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,
862 gcpy #          getxpos()-kh_distance,
863 gcpy #          //end position at top of slot
864 gcpy #          getypos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
865 gcpy #          KH_tool_num);
866 gcpy #      hull(){
867 gcpy #          translate([xpos(), ypos(), zpos()]){
868 gcpy #              keyhole_shaft(6.35, 9.525);
869 gcpy #          }
870 gcpy #          translate([xpos(), ypos(), zpos()-kh_max_depth]){
871 gcpy #              keyhole_shaft(6.35, 9.525);
872 gcpy #          }
873 gcpy #      }
874 gcpy #      hull(){
875 gcpy #          translate([xpos(), ypos(), zpos()-kh_max_depth]){
876 gcpy #              keyhole_shaft(6.35, 9.525);
877 gcpy #          }
878 gcpy #          translate([xpos()-kh_distance, ypos(), zpos()-kh_max_depth])
{
879 gcpy #              keyhole_shaft(6.35, 9.525);
880 gcpy #          }
881 gcpy #      }
882 gcpy #      cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
883 gcpy #      cutwithfeed(getxpos()-kh_distance,getypos(),-kh_max_depth,feed
);
884 gcpy #      setxpos(getxpos()+kh_distance);
885 gcpy # } else if (kh_angle == 270) {
886 gcpy #      //Upper right of entry hole
887 gcpy #      dxfarc(getxpos(),getypos(),9.525/2,0,90, KH_tool_num);
888 gcpy #      //Upper left of entry hole
889 gcpy #      dxfarc(getxpos(),getypos(),9.525/2,90,180, KH_tool_num);
890 gcpy #      //lower right of slot
891 gcpy #      dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,270,360, KH_tool_num);
892 gcpy #      //lower left of slot
893 gcpy #      dxfarc(getxpos(),getypos()-kh_distance,tool_diameter(
KH_tool_num, (kh_max_depth+4.36))/2,180,270, KH_tool_num);
894 gcpy #      //Actual line of cut
895 gcpy #      dxfline(getxpos(),getypos(),getxpos(),getypos()-kh_distance);
896 gcpy #      //right of slot

```

```

897 gcpy #         dxflines(
898 gcpy #             getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
899 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,
900 gcpy #             getxpos()+tool_diameter(KH_tool_num, (kh_max_depth))/2,
901 gcpy #             //end position at top of slot
902 gcpy #             getypos()-kh_distance,
903 gcpy #             KH_tool_num);
904 gcpy #             //left of slot
905 gcpy #             dxflines(
906 gcpy #                 getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
907 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,
908 gcpy #                 getxpos()-tool_diameter(KH_tool_num, (kh_max_depth))/2,
909 gcpy #                 //end position at top of slot
910 gcpy #                 getypos()-kh_distance,
911 gcpy #                 KH_tool_num);
912 gcpy #             //Lower right of entry hole
913 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
);
914 gcpy #             //Lower left of entry hole
915 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);
916 gcpy #             hull(){
917 gcpy #                 translate([xpos(), ypos(), zpos()]){
918 gcpy #                     keyhole_shaft(6.35, 9.525);
919 gcpy #                 }
920 gcpy #                 translate([xpos(), ypos(), zpos()-kh_max_depth]){
921 gcpy #                     keyhole_shaft(6.35, 9.525);
922 gcpy #                 }
923 gcpy #             }
924 gcpy #             hull(){
925 gcpy #                 translate([xpos(), ypos(), zpos()-kh_max_depth]){
926 gcpy #                     keyhole_shaft(6.35, 9.525);
927 gcpy #                 }
928 gcpy #                 translate([xpos(), ypos()-kh_distance, zpos()-kh_max_depth])
{
929 gcpy #                     keyhole_shaft(6.35, 9.525);
930 gcpy #                 }
931 gcpy #             }
932 gcpy #             cutwithfeed(getxpos(),getypos(),-kh_max_depth,feed);
933 gcpy #             cutwithfeed(getxpos(),getypos()-kh_distance,-kh_max_depth,feed
);
934 gcpy #             setypos(getypos()+kh_distance);
935 gcpy #         }
936 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`.

```

938 gcpy         def stockandtoolpaths(self, option = "stockandtoolpaths"):
939 gcpy             if option == "stock":
940 gcpy                 if self.generatepaths == False:
941 gcpy                     output(self.stock)
942 gcpy #                     print("Outputting stock")
943 gcpy             else:
944 gcpy                 return self.stock
945 gcpy             elif option == "toolpaths":
946 gcpy                 if self.generatepaths == False:
947 gcpy                     output(self.toolpaths)
948 gcpy             else:
949 gcpy                 return self.toolpaths
950 gcpy             elif option == "rapids":
951 gcpy                 if self.generatepaths == False:
952 gcpy                     output(self.rapids)
953 gcpy             else:
954 gcpy                 return self.rapids
955 gcpy             else:
956 gcpy                 part = self.stock.difference(self.toolpaths)
957 gcpy                 if self.generatepaths == False:
958 gcpy                     output(part)

```

```
959 gcpy                else:
960 gcpy                return part

```

```
94 gcpscad module stockandtoolpaths(){
95 gcpscad     gcp.stockandtoolpaths();
96 gcpscad }
97 gcpscad
98 gcpscad module stockwotoolpaths(){
99 gcpscad     gcp.stockandtoolpaths("stock");
100 gcpscad }
101 gcpscad
102 gcpscad module outputtoolpaths(){
103 gcpscad     gcp.stockandtoolpaths("toolpaths");
104 gcpscad }
105 gcpscad
106 gcpscad module outputrapids(){
107 gcpscad     gcp.stockandtoolpaths("rapids");
108 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.

```
962 gcpy      def writegc(self, *arguments):
963 gcpy          if self.generategcode == True:
964 gcpy              line_to_write = ""
965 gcpy              for element in arguments:
966 gcpy                  line_to_write += element
967 gcpy              self.gc.write(line_to_write)
968 gcpy              self.gc.write("\n")
969 gcpy
970 gcpy      def writedxf(self, toolnumber, *arguments):
971 gcpy #          global dxfclosed
972 gcpy          line_to_write = ""
973 gcpy          for element in arguments:
974 gcpy              line_to_write += element
975 gcpy          if self.generateddxf == True:
976 gcpy              if self.dxfclosed == False:
977 gcpy                  self.dxf.write(line_to_write)
978 gcpy                  self.dxf.write("\n")
979 gcpy          if self.generateddxfs == True:
980 gcpy              self.writedxfs(toolnumber, line_to_write)
981 gcpy
982 gcpy      def writedxfs(self, toolnumber, line_to_write):
983 gcpy #          print("Processing writing toolnumber", toolnumber)
984 gcpy #          line_to_write = ""
985 gcpy #          for element in arguments:
986 gcpy #              line_to_write += element
987 gcpy          if (toolnumber == 0):
988 gcpy              return
989 gcpy          elif self.generateddxfs == True:
990 gcpy              if (self.large_square_tool_num == toolnumber):
991 gcpy                  self.dxf_lgsq.write(line_to_write)
992 gcpy                  self.dxf_lgsq.write("\n")
993 gcpy              if (self.small_square_tool_num == toolnumber):
994 gcpy                  self.dxf_smsq.write(line_to_write)
995 gcpy                  self.dxf_smsq.write("\n")
996 gcpy              if (self.large_ball_tool_num == toolnumber):
997 gcpy                  self.dxf_lgbl.write(line_to_write)
998 gcpy                  self.dxf_lgbl.write("\n")
999 gcpy              if (self.small_ball_tool_num == toolnumber):
1000 gcpy                  self.dxf_smb1.write(line_to_write)
1001 gcpy                  self.dxf_smb1.write("\n")
1002 gcpy              if (self.large_V_tool_num == toolnumber):
1003 gcpy                  self.dxf_lgV.write(line_to_write)
1004 gcpy                  self.dxf_lgV.write("\n")
1005 gcpy              if (self.small_V_tool_num == toolnumber):
1006 gcpy                  self.dxf_smV.write(line_to_write)
1007 gcpy                  self.dxf_smV.write("\n")
1008 gcpy              if (self.DT_tool_num == toolnumber):
1009 gcpy                  self.dxf_DT.write(line_to_write)
1010 gcpy                  self.dxf_DT.write("\n")
1011 gcpy              if (self.KH_tool_num == toolnumber):
1012 gcpy                  self.dxf_KH.write(line_to_write)
1013 gcpy                  self.dxf_KH.write("\n")
1014 gcpy              if (self.Roundover_tool_num == toolnumber):
1015 gcpy                  self.dxf_Rt.write(line_to_write)
1016 gcpy                  self.dxf_Rt.write("\n")
1017 gcpy              if (self.MISC_tool_num == toolnumber):
1018 gcpy                  self.dxf_Mt.write(line_to_write)
1019 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
opendxfile and opendxfile 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:

```
110 gpcscad module opendxfile(basefilename){
111 gpcscad     gcp.opendxfile(basefilename);
112 gpcscad }
113 gpcscad
114 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) {
115 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)
    ;
116 gpcscad }
```

opengcodefile With matching OpenSCAD commands: opengcodefile for OpenSCAD:

```
118 gpcscad module opengcodefile(basefilename, currenttoolnum, toolradius,
    plunge, feed, speed) {
119 gpcscad     gcp.opengcodefile(basefilename, currenttoolnum, toolradius,
    plunge, feed, speed);
120 gpcscad }
```

and Python:

```
1021 gcpy      def opengcodefile(self, basefilename = "export",
1022 gcpy          currenttoolnum = 102,
1023 gcpy          toolradius = 3.175,
1024 gcpy          plunge = 400,
1025 gcpy          feed = 1600,
1026 gcpy          speed = 10000
1027 gcpy          ):
1028 gcpy          self.basefilename = basefilename
1029 gcpy          self.currenttoolnum = currenttoolnum
1030 gcpy          self.toolradius = toolradius
1031 gcpy          self.plunge = plunge
1032 gcpy          self.feed = feed
1033 gcpy          self.speed = speed
1034 gcpy          if self.generategcode == True:
1035 gcpy              self.gcodefilename = basefilename + ".nc"
1036 gcpy              self.gc = open(self.gcodefilename, "w")
1037 gcpy
1038 gcpy      def opendxfile(self, basefilename = "export"):
1039 gcpy          self.basefilename = basefilename
1040 gcpy          # global generatedxfs
1041 gcpy          # global dxfclosed
1042 gcpy          self.dxfclosed = False
1043 gcpy          if self.generatedxif == True:
1044 gcpy              self.generatedxfs = False
1045 gcpy              self.dxfilename = basefilename + ".dxf"
1046 gcpy              self.dxf = open(self.dxfilename, "w")
1047 gcpy              self.dxfpreamble(-1)
1048 gcpy
1049 gcpy      def opendxfiles(self, basefilename = "export",
1050 gcpy          large_square_tool_num = 0,
1051 gcpy          small_square_tool_num = 0,
1052 gcpy          large_ball_tool_num = 0,
1053 gcpy          small_ball_tool_num = 0,
1054 gcpy          large_V_tool_num = 0,
1055 gcpy          small_V_tool_num = 0,
1056 gcpy          DT_tool_num = 0,
1057 gcpy          KH_tool_num = 0,
1058 gcpy          Roundover_tool_num = 0,
1059 gcpy          MISC_tool_num = 0):
1060 gcpy          # global generatedxfs
1061 gcpy          self.basefilename = basefilename
1062 gcpy          self.generatedxfs = True
1063 gcpy          self.large_square_tool_num = large_square_tool_num
1064 gcpy          self.small_square_tool_num = small_square_tool_num
1065 gcpy          self.large_ball_tool_num = large_ball_tool_num
1066 gcpy          self.small_ball_tool_num = small_ball_tool_num
1067 gcpy          self.large_V_tool_num = large_V_tool_num
1068 gcpy          self.small_V_tool_num = small_V_tool_num
```

```

1069 gcpy      self.DT_tool_num = DT_tool_num
1070 gcpy      self.KH_tool_num = KH_tool_num
1071 gcpy      self.Roundover_tool_num = Roundover_tool_num
1072 gcpy      self.MISC_tool_num = MISC_tool_num
1073 gcpy      if self.generatedxf == True:
1074 gcpy          if (large_square_tool_num > 0):
1075 gcpy              self.dxf_lgsqfilename = basefilename + str(
                    large_square_tool_num) + ".dxf"
1076 gcpy #              print("Opening ", str(self.dxf_lgsqfilename))
1077 gcpy              self.dxf_lgsq = open(self.dxf_lgsqfilename, "w")
1078 gcpy          if (small_square_tool_num > 0):
1079 gcpy #              print("Opening small square")
1080 gcpy              self.dxf_ssqfilename = basefilename + str(
                    small_square_tool_num) + ".dxf"
1081 gcpy              self.dxf_ssq = open(self.dxf_ssqfilename, "w")
1082 gcpy          if (large_ball_tool_num > 0):
1083 gcpy #              print("Opening large ball")
1084 gcpy              self.dxf_lgbfilename = basefilename + str(
                    large_ball_tool_num) + ".dxf"
1085 gcpy              self.dxf_lgb = open(self.dxf_lgbfilename, "w")
1086 gcpy          if (small_ball_tool_num > 0):
1087 gcpy #              print("Opening small ball")
1088 gcpy              self.dxf_smbfilename = basefilename + str(
                    small_ball_tool_num) + ".dxf"
1089 gcpy              self.dxf_smb = open(self.dxf_smbfilename, "w")
1090 gcpy          if (large_V_tool_num > 0):
1091 gcpy #              print("Opening large V")
1092 gcpy              self.dxf_lgVfilename = basefilename + str(
                    large_V_tool_num) + ".dxf"
1093 gcpy              self.dxf_lgV = open(self.dxf_lgVfilename, "w")
1094 gcpy          if (small_V_tool_num > 0):
1095 gcpy #              print("Opening small V")
1096 gcpy              self.dxf_smVfilename = basefilename + str(
                    small_V_tool_num) + ".dxf"
1097 gcpy              self.dxf_smV = open(self.dxf_smVfilename, "w")
1098 gcpy          if (DT_tool_num > 0):
1099 gcpy #              print("Opening DT")
1100 gcpy              self.dxf_DTfilename = basefilename + str(DT_tool_num
                    ) + ".dxf"
1101 gcpy              self.dxf_DT = open(self.dxf_DTfilename, "w")
1102 gcpy          if (KH_tool_num > 0):
1103 gcpy #              print("Opening KH")
1104 gcpy              self.dxf_KHfilename = basefilename + str(KH_tool_num
                    ) + ".dxf"
1105 gcpy              self.dxf_KH = open(self.dxf_KHfilename, "w")
1106 gcpy          if (Roundover_tool_num > 0):
1107 gcpy #              print("Opening Rt")
1108 gcpy              self.dxf_Rtfilename = basefilename + str(
                    Roundover_tool_num) + ".dxf"
1109 gcpy              self.dxf_Rt = open(self.dxf_Rtfilename, "w")
1110 gcpy          if (MISC_tool_num > 0):
1111 gcpy #              print("Opening Mt")
1112 gcpy              self.dxf_Mtfilename = basefilename + str(
                    MISC_tool_num) + ".dxf"
1113 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:

```

1114 gcpy      if (large_square_tool_num > 0):
1115 gcpy          self.dxf_preamble(large_square_tool_num)
1116 gcpy      if (small_square_tool_num > 0):
1117 gcpy          self.dxf_preamble(small_square_tool_num)
1118 gcpy      if (large_ball_tool_num > 0):
1119 gcpy          self.dxf_preamble(large_ball_tool_num)
1120 gcpy      if (small_ball_tool_num > 0):
1121 gcpy          self.dxf_preamble(small_ball_tool_num)
1122 gcpy      if (large_V_tool_num > 0):
1123 gcpy          self.dxf_preamble(large_V_tool_num)
1124 gcpy      if (small_V_tool_num > 0):
1125 gcpy          self.dxf_preamble(small_V_tool_num)
1126 gcpy      if (DT_tool_num > 0):
1127 gcpy          self.dxf_preamble(DT_tool_num)
1128 gcpy      if (KH_tool_num > 0):
1129 gcpy          self.dxf_preamble(KH_tool_num)
1130 gcpy      if (Roundover_tool_num > 0):
1131 gcpy          self.dxf_preamble(Roundover_tool_num)
1132 gcpy      if (MISC_tool_num > 0):

```

```
1133 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 • Ball nose, large (lgbl) writedxflgbl
- writedxfsmb1 • Ball nose, small (smb1) writedxfsmb1
- writedxflgsq • Square, large (lgsq) writedxflgsq
- writedxfsmsq • Square, small (smsq) writedxfsmsq
- writedxflgV • V, large (lgV) writedxflgV
- writedxfsmV • V, small (smV) writedxfsmV
- writedxfKH • Keyhole (KH) writedxfKH
- writedxfDT • Dovetail (DT) writedxfDT

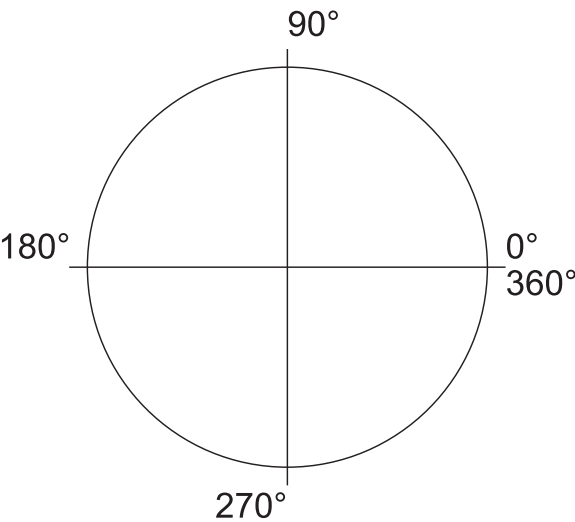
dxfpreamble This module requires that the tool number be passed in, and after writing out dxfpreamble, that value will be used to write out to the appropriate file with a series of if statements.

```
1135 gcpy def dxfpreamble(self, tn):
1136 gcpy # self.writedxf(tn,str(tn))
1137 gcpy self.writedxf(tn,"0")
1138 gcpy self.writedxf(tn,"SECTION")
1139 gcpy self.writedxf(tn,"2")
1140 gcpy self.writedxf(tn,"ENTITIES")
```

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

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

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:

```
dxfarcc(10, 10, 5, 0, 90, small_square_tool_num);
dxfarcc(10, 10, 5, 90, 180, small_square_tool_num);
dxfarcc(10, 10, 5, 180, 270, small_square_tool_num);
dxfarcc(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.

```
1142 gcpy      def dxfline(self, tn, xbegin,ybegin,xend,yend):
1143 gcpy          self.writedxf(tn,"0")
1144 gcpy          self.writedxf(tn,"LWPOLYLINE")
1145 gcpy          self.writedxf(tn,"90")
1146 gcpy          self.writedxf(tn,"2")
1147 gcpy          self.writedxf(tn,"70")
1148 gcpy          self.writedxf(tn,"0")
1149 gcpy          self.writedxf(tn,"43")
1150 gcpy          self.writedxf(tn,"0")
1151 gcpy          self.writedxf(tn,"10")
1152 gcpy          self.writedxf(tn,str(xbegin))
1153 gcpy          self.writedxf(tn,"20")
1154 gcpy          self.writedxf(tn,str(ybegin))
1155 gcpy          self.writedxf(tn,"10")
1156 gcpy          self.writedxf(tn,str(xend))
1157 gcpy          self.writedxf(tn,"20")
1158 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).

```
1160 gcpy      def dxfarc(self, tn, xcenter, ycenter, radius, anglebegin,
                        endangle):
1161 gcpy          if (self.generatedxf == True):
1162 gcpy              self.writedxf(tn, "0")
1163 gcpy              self.writedxf(tn, "ARC")
1164 gcpy              self.writedxf(tn, "10")
1165 gcpy              self.writedxf(tn, str(xcenter))
1166 gcpy              self.writedxf(tn, "20")
1167 gcpy              self.writedxf(tn, str(ycenter))
1168 gcpy              self.writedxf(tn, "40")
1169 gcpy              self.writedxf(tn, str(radius))
1170 gcpy              self.writedxf(tn, "50")
1171 gcpy              self.writedxf(tn, str(anglebegin))
1172 gcpy              self.writedxf(tn, "51")
1173 gcpy              self.writedxf(tn, str(endangle))
1174 gcpy
1175 gcpy      def gcdearc(self, tn, xcenter, ycenter, radius, anglebegin,
                        endangle):
1176 gcpy          if (self.generategcode == True):
1177 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.

```
1179 gcpy      def cutarcNECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1180 gcpy      #      global toolpath
1181 gcpy      #      toolpath = self.currenttool()
1182 gcpy      #      toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1183 gcpy          self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,0,90)
1184 gcpy          if (self.zpos == ez):
1185 gcpy              self.settzpos(0)
1186 gcpy          else:
1187 gcpy              self.settzpos((self.zpos()-ez)/90)
1188 gcpy      #      self.setxpos(ex)
1189 gcpy      #      self.setypos(ey)
1190 gcpy      #      self.setzpos(ez)
1191 gcpy          if self.generatepaths == True:
```

```

1192 gcpy                print("Unioning cutarcNECCdxf toolpath")
1193 gcpy                self.arcloop(1,90, xcenter, ycenter, radius)
1194 gcpy #                self.toolpaths = self.toolpaths.union(toolpath)
1195 gcpy                else:
1196 gcpy                    toolpath = self.arcloop(1,90, xcenter, ycenter, radius)
1197 gcpy #                print("Returning cutarcNECCdxf toolpath")
1198 gcpy                return toolpath
1199 gcpy
1200 gcpy                def cutarcNWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1201 gcpy #                    global toolpath
1202 gcpy #                    toolpath = self.currenttool()
1203 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1204 gcpy                self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,90,180)
1205 gcpy                if (self.zpos == ez):
1206 gcpy                    self.settzpos(0)
1207 gcpy                else:
1208 gcpy                    self.settzpos((self.zpos()-ez)/90)
1209 gcpy #                self.setxpos(ex)
1210 gcpy #                self.setypos(ey)
1211 gcpy #                self.setzpos(ez)
1212 gcpy                if self.generatepaths == True:
1213 gcpy                    self.arcloop(91,180, xcenter, ycenter, radius)
1214 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1215 gcpy                else:
1216 gcpy                    toolpath = self.arcloop(91,180, xcenter, ycenter,
radius)
1217 gcpy                    return toolpath
1218 gcpy
1219 gcpy                def cutarcSWCCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1220 gcpy #                    global toolpath
1221 gcpy #                    toolpath = self.currenttool()
1222 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1223 gcpy                self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,180,270)
1224 gcpy                if (self.zpos == ez):
1225 gcpy                    self.settzpos(0)
1226 gcpy                else:
1227 gcpy                    self.settzpos((self.zpos()-ez)/90)
1228 gcpy #                self.setxpos(ex)
1229 gcpy #                self.setypos(ey)
1230 gcpy #                self.setzpos(ez)
1231 gcpy                if self.generatepaths == True:
1232 gcpy                    self.arcloop(181,270, xcenter, ycenter, radius)
1233 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1234 gcpy                else:
1235 gcpy                    toolpath = self.arcloop(181,270, xcenter, ycenter,
radius)
1236 gcpy                    return toolpath
1237 gcpy
1238 gcpy                def cutarcSECCdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1239 gcpy #                    global toolpath
1240 gcpy #                    toolpath = self.currenttool()
1241 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),
self.zpos()])
1242 gcpy                self.dxfarc(self.currenttoolnumber(), xcenter,ycenter,
radius,270,360)
1243 gcpy                if (self.zpos == ez):
1244 gcpy                    self.settzpos(0)
1245 gcpy                else:
1246 gcpy                    self.settzpos((self.zpos()-ez)/90)
1247 gcpy #                self.setxpos(ex)
1248 gcpy #                self.setypos(ey)
1249 gcpy #                self.setzpos(ez)
1250 gcpy                if self.generatepaths == True:
1251 gcpy                    self.arcloop(271,360, xcenter, ycenter, radius)
1252 gcpy #                    self.toolpaths = self.toolpaths.union(toolpath)
1253 gcpy                else:
1254 gcpy                    toolpath = self.arcloop(271,360, xcenter, ycenter,
radius)
1255 gcpy                    return toolpath
1256 gcpy
1257 gcpy                def cutarcNECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1258 gcpy #                    global toolpath
1259 gcpy #                    toolpath = self.currenttool()
1260 gcpy #                    toolpath = toolpath.translate([self.xpos(),self.ypos(),

```

```

        self.zpos())
1261 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 0, 90)
1262 gcpy        if (self.zpos == ez):
1263 gcpy            self.settzpos(0)
1264 gcpy        else:
1265 gcpy            self.settzpos((self.zpos()-ez)/90)
1266 gcpy #        self.setxpos(ex)
1267 gcpy #        self.setypos(ey)
1268 gcpy #        self.setzpos(ez)
1269 gcpy        if self.generatepaths == True:
1270 gcpy            self.narcloop(89, 0, xcenter, ycenter, radius)
1271 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1272 gcpy        else:
1273 gcpy            toolpath = self.narcloop(89, 0, xcenter, ycenter, radius
                )
1274 gcpy            return toolpath
1275 gcpy
1276 gcpy        def cutarcSECWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1277 gcpy #            global toolpath
1278 gcpy #            toolpath = self.currenttool()
1279 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1280 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 270, 360)
1281 gcpy        if (self.zpos == ez):
1282 gcpy            self.settzpos(0)
1283 gcpy        else:
1284 gcpy            self.settzpos((self.zpos()-ez)/90)
1285 gcpy #        self.setxpos(ex)
1286 gcpy #        self.setypos(ey)
1287 gcpy #        self.setzpos(ez)
1288 gcpy        if self.generatepaths == True:
1289 gcpy            self.narcloop(359, 270, xcenter, ycenter, radius)
1290 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1291 gcpy        else:
1292 gcpy            toolpath = self.narcloop(359, 270, xcenter, ycenter,
                radius)
1293 gcpy            return toolpath
1294 gcpy
1295 gcpy        def cutarcSWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1296 gcpy #            global toolpath
1297 gcpy #            toolpath = self.currenttool()
1298 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1299 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 180, 270)
1300 gcpy        if (self.zpos == ez):
1301 gcpy            self.settzpos(0)
1302 gcpy        else:
1303 gcpy            self.settzpos((self.zpos()-ez)/90)
1304 gcpy #        self.setxpos(ex)
1305 gcpy #        self.setypos(ey)
1306 gcpy #        self.setzpos(ez)
1307 gcpy        if self.generatepaths == True:
1308 gcpy            self.narcloop(269, 180, xcenter, ycenter, radius)
1309 gcpy #        self.toolpaths = self.toolpaths.union(toolpath)
1310 gcpy        else:
1311 gcpy            toolpath = self.narcloop(269, 180, xcenter, ycenter,
                radius)
1312 gcpy            return toolpath
1313 gcpy
1314 gcpy        def cutarcNWCWdxf(self, ex, ey, ez, xcenter, ycenter, radius):
1315 gcpy #            global toolpath
1316 gcpy #            toolpath = self.currenttool()
1317 gcpy #            toolpath = toolpath.translate([self.xpos(), self.ypos(),
self.zpos()])
1318 gcpy        self.dxfarc(self.currenttoolnumber(), xcenter, ycenter,
                        radius, 90, 180)
1319 gcpy        if (self.zpos == ez):
1320 gcpy            self.settzpos(0)
1321 gcpy        else:
1322 gcpy            self.settzpos((self.zpos()-ez)/90)
1323 gcpy #        self.setxpos(ex)
1324 gcpy #        self.setypos(ey)
1325 gcpy #        self.setzpos(ez)
1326 gcpy        if self.generatepaths == True:
1327 gcpy            self.narcloop(179, 90, xcenter, ycenter, radius)

```



```
1328 gcpy #             self.toolpaths = self.toolpaths.union(toolpath)
1329 gcpy         else:
1330 gcpy             toolpath = self.narclloop(179,90, xcenter, ycenter,
1331 gcpy                                     radius)
1331 gcpy             return toolpath
```

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

cutarcNECCdx(-stockXwidth/4, stockYheight/4+stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcNWCCdx(-stockXwidth/4+stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock
cutarcSWCCdx(-stockXwidth/4, stockYheight/4-stockYheight/16, -stockZthickness, -stockXwidth/4, stockYh
cutarcSECCdx(-stockXwidth/4-stockYheight/16), stockYheight/4, -stockZthickness, -stockXwidth/4, stock

```
1333 gcpy         def arcCCgc(self, ex, ey, ez, xcenter, ycenter, radius):
1334 gcpy             self.writegc("G03_X", str(ex), "Y", str(ey), "Z", str(ez)
1335 gcpy                 , "R", str(radius))
1336 gcpy         def arcCWgc(self, ex, ey, ez, xcenter, ycenter, radius):
1337 gcpy             self.writegc("G02_X", str(ex), "Y", str(ey), "Z", str(ez)
1338 gcpy                 , "R", str(radius))
```

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

```
1339 gcpy         def cutarcNECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1340 gcpy             :
1341 gcpy             self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1342 gcpy             if self.generatepaths == True:
1343 gcpy                 self.cutarcNECCdx(ex, ey, ez, xcenter, ycenter, radius
1344 gcpy                     )
1345 gcpy             else:
1346 gcpy                 return self.cutarcNECCdx(ex, ey, ez, xcenter, ycenter,
1347 gcpy                     radius)
1348 gcpy         def cutarcNWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1349 gcpy             :
1350 gcpy             self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1351 gcpy             if self.generatepaths == False:
1352 gcpy                 return self.cutarcNWCCdx(ex, ey, ez, xcenter, ycenter,
1353 gcpy                     radius)
1354 gcpy         def cutarcSWCCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1355 gcpy             :
1356 gcpy             self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1357 gcpy             if self.generatepaths == False:
1358 gcpy                 return self.cutarcSWCCdx(ex, ey, ez, xcenter, ycenter,
1359 gcpy                     radius)
1360 gcpy         def cutarcSECCdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1361 gcpy             :
1362 gcpy             self.arcCCgc(ex, ey, ez, xcenter, ycenter, radius)
1363 gcpy             if self.generatepaths == False:
1364 gcpy                 return self.cutarcSECCdx(ex, ey, ez, xcenter, ycenter,
1365 gcpy                     radius)
1366 gcpy         def cutarcNECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1367 gcpy             :
1368 gcpy             self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1369 gcpy             if self.generatepaths == False:
1370 gcpy                 return self.cutarcNECWdx(ex, ey, ez, xcenter, ycenter,
1371 gcpy                     radius)
1372 gcpy         def cutarcSECWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1373 gcpy             :
1374 gcpy             self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1375 gcpy             if self.generatepaths == False:
1376 gcpy                 return self.cutarcSECWdx(ex, ey, ez, xcenter, ycenter,
1377 gcpy                     radius)
1378 gcpy         def cutarcSWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1379 gcpy             :
1380 gcpy             self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1381 gcpy             if self.generatepaths == False:
1382 gcpy                 return self.cutarcSWCWdx(ex, ey, ez, xcenter, ycenter,
1383 gcpy                     radius)
1384 gcpy         def cutarcSEWCWdxfgc(self, ex, ey, ez, xcenter, ycenter, radius)
1385 gcpy             :
1386 gcpy             self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1387 gcpy             if self.generatepaths == False:
1388 gcpy                 return self.cutarcSEWCWdx(ex, ey, ez, xcenter, ycenter,
1389 gcpy                     radius)
```

```
1377 gcpy          self.arcCWgc(ex, ey, ez, xcenter, ycenter, radius)
1378 gcpy          if self.generatepaths == False:
1379 gcpy              return self.cutarcNWCWdxg(ex, ey, ez, xcenter, ycenter,
                    radius)
```

```
122 gpcscad module cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
123 gpcscad     gcp.cutarcNECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
124 gpcscad }
125 gpcscad
126 gpcscad module cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
127 gpcscad     gcp.cutarcNWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
128 gpcscad }
129 gpcscad
130 gpcscad module cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
131 gpcscad     gcp.cutarcSWCCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
132 gpcscad }
133 gpcscad
134 gpcscad module cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius){
135 gpcscad     gcp.cutarcSECCdxfgc(ex, ey, ez, xcenter, ycenter, radius);
136 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.

```
1381 gcpy          def dxfpreamble(self,tn):
1382 gcpy          #          self.writedxf(tn,str(tn))
1383 gcpy          self.writedxf(tn,"0")
1384 gcpy          self.writedxf(tn,"ENDSEC")
1385 gcpy          self.writedxf(tn,"0")
1386 gcpy          self.writedxf(tn,"EOF")
```

```
1388 gcpy          def gcodepreamble(self):
1389 gcpy          self.writegc("Z12.700")
1390 gcpy          self.writegc("M05")
1391 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.

```
1393 gcpy          def closegcodefile(self):
1394 gcpy          self.gcodepreamble()
1395 gcpy          self.gc.close()
1396 gcpy
1397 gcpy          def closedxxfile(self):
1398 gcpy          if self.generatedxg == True:
1399 gcpy          #          global dxgclosed
1400 gcpy          self.dxfpreamble(-1)
1401 gcpy          #          self.dxgclosed = True
1402 gcpy          self.dxf.close()
1403 gcpy
1404 gcpy          def closedxxfiles(self):
1405 gcpy          if self.generatedxfs == True:
1406 gcpy              if (self.large_square_tool_num > 0):
1407 gcpy                  self.dxfpreamble(self.large_square_tool_num)
1408 gcpy              if (self.small_square_tool_num > 0):
1409 gcpy                  self.dxfpreamble(self.small_square_tool_num)
1410 gcpy              if (self.large_ball_tool_num > 0):
1411 gcpy                  self.dxfpreamble(self.large_ball_tool_num)
1412 gcpy              if (self.small_ball_tool_num > 0):
1413 gcpy                  self.dxfpreamble(self.small_ball_tool_num)
1414 gcpy              if (self.large_V_tool_num > 0):
1415 gcpy                  self.dxfpreamble(self.large_V_tool_num)
1416 gcpy              if (self.small_V_tool_num > 0):
1417 gcpy                  self.dxfpreamble(self.small_V_tool_num)
1418 gcpy              if (self.DT_tool_num > 0):
1419 gcpy                  self.dxfpreamble(self.DT_tool_num)
1420 gcpy              if (self.KH_tool_num > 0):
1421 gcpy                  self.dxfpreamble(self.KH_tool_num)
1422 gcpy              if (self.Roundover_tool_num > 0):
1423 gcpy                  self.dxfpreamble(self.Roundover_tool_num)
1424 gcpy              if (self.MISC_tool_num > 0):
```

```
1425 gcpy                self.dxfpostamble(self.MISC_tool_num)
1426 gcpy
1427 gcpy                if (self.large_square_tool_num > 0):
1428 gcpy                    self.dxf_lsq.close()
1429 gcpy                if (self.small_square_tool_num > 0):
1430 gcpy                    self.dxf_ssq.close()
1431 gcpy                if (self.large_ball_tool_num > 0):
1432 gcpy                    self.dxf_lgb.close()
1433 gcpy                if (self.small_ball_tool_num > 0):
1434 gcpy                    self.dxf_smb.close()
1435 gcpy                if (self.large_V_tool_num > 0):
1436 gcpy                    self.dxf_lgv.close()
1437 gcpy                if (self.small_V_tool_num > 0):
1438 gcpy                    self.dxf_svm.close()
1439 gcpy                if (self.DT_tool_num > 0):
1440 gcpy                    self.dxf_DT.close()
1441 gcpy                if (self.KH_tool_num > 0):
1442 gcpy                    self.dxf_KH.close()
1443 gcpy                if (self.Roundover_tool_num > 0):
1444 gcpy                    self.dxf_Rt.close()
1445 gcpy                if (self.MISC_tool_num > 0):
1446 gcpy                    self.dxf_Mt.close()
```

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

```
138 gcpscad module closegcodefile(){
139 gcpscad     gcp.closegcodefile();
140 gcpscad }
141 gcpscad
142 gcpscad module closedxfiles(){
143 gcpscad     gcp.closedxfiles();
144 gcpscad }
145 gcpscad
146 gcpscad module closedxfile(){
147 gcpscad     gcp.closedxfile();
148 gcpscad }
```

4 Notes

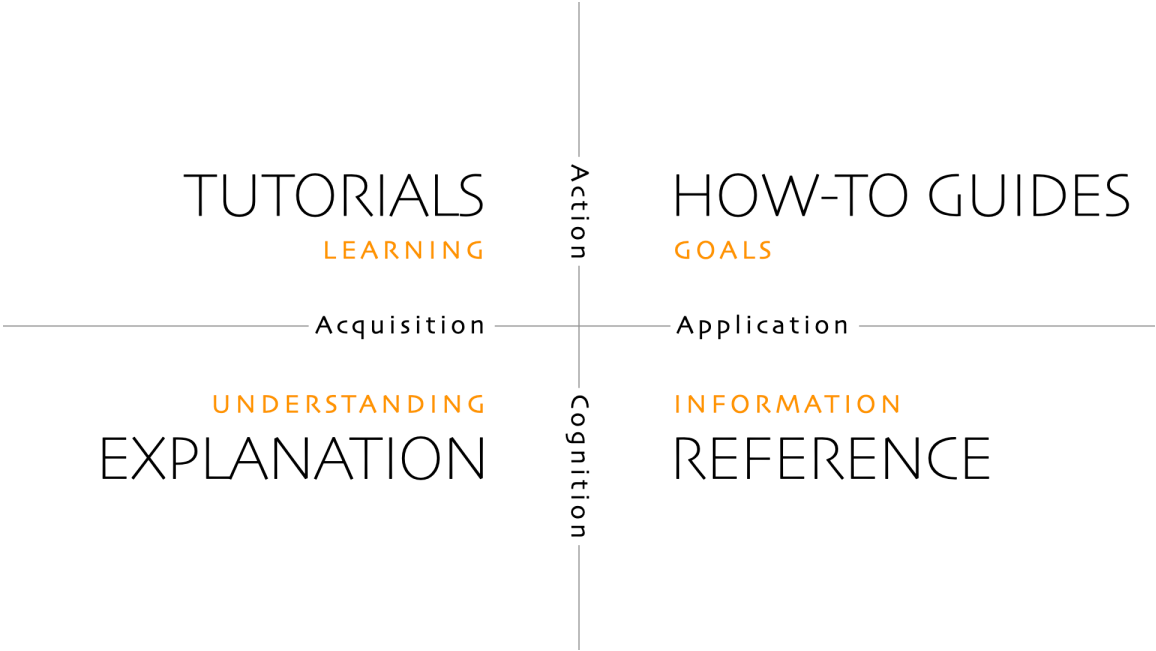
Other Resources

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:

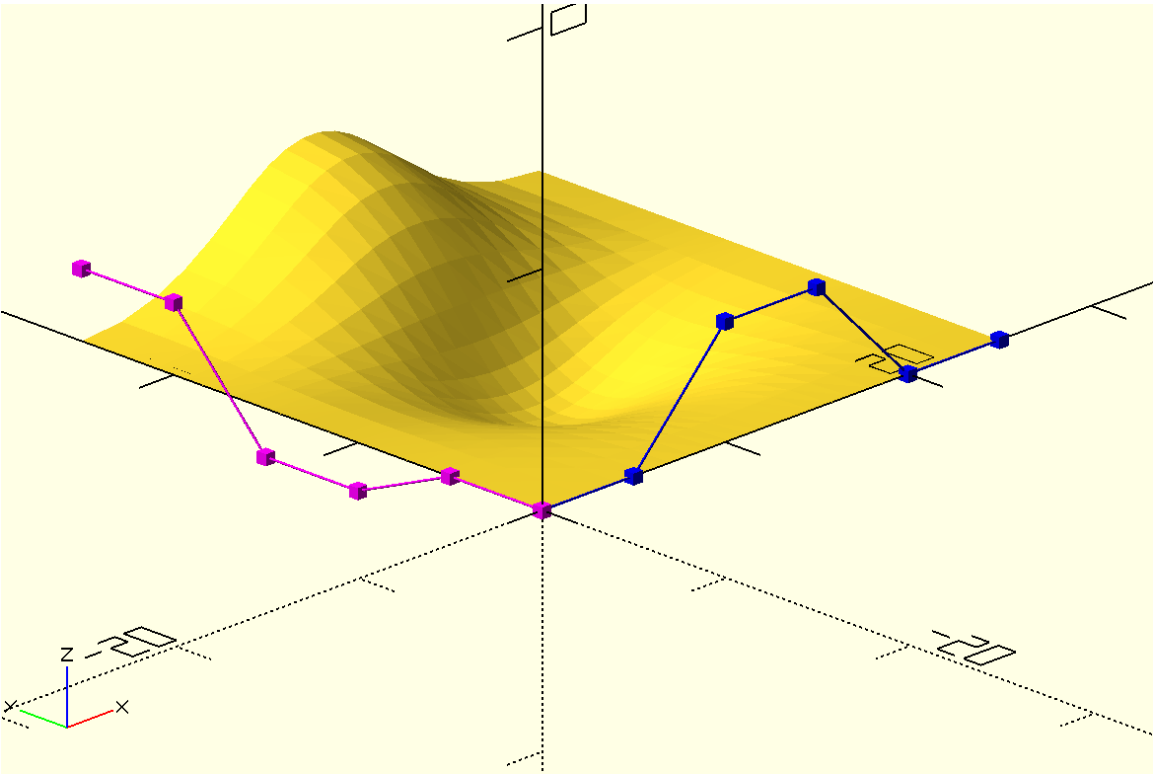
- XY
- XZ
- ZY

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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