

Using R to Cut Triangles

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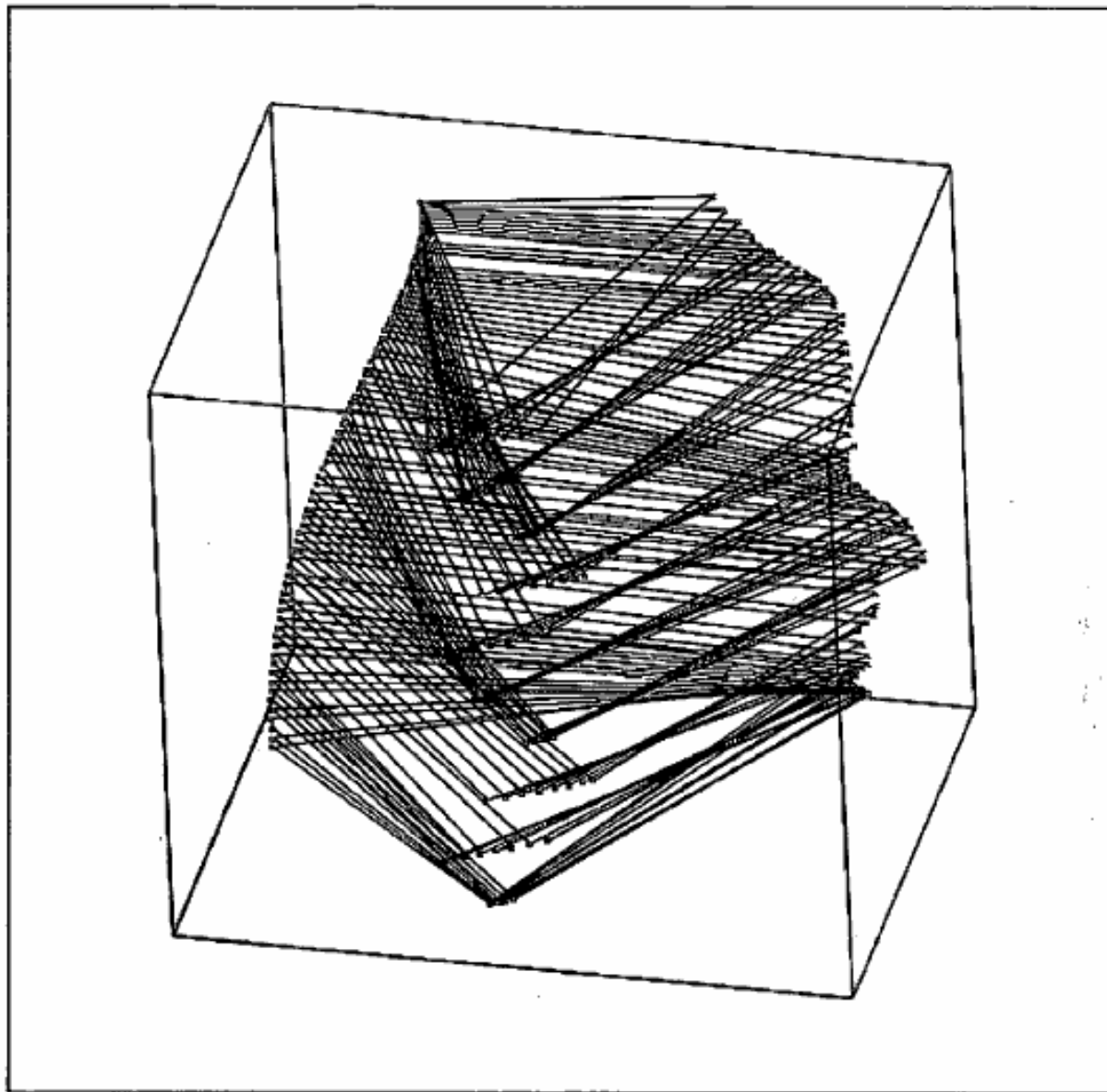
8/25/2010

Why Cut Triangles?

- Sculpture – As stack of triangles is rotated, six silhouettes appear (each set of vertices takes part in two silhouettes)
- Patent Application -

<http://www.google.com/patents/about?id=d-WaAAAAEBAJ&dq=stacked+polygons>

Figure 4



Cutting by Hand

- Tedious, time-consuming, sometimes inaccurate.
- Want to use a machine to do the cutting.

Patent Application Publication Mar. 23, 2006 Sheet 5 of 8 US 2006/0061565 A1

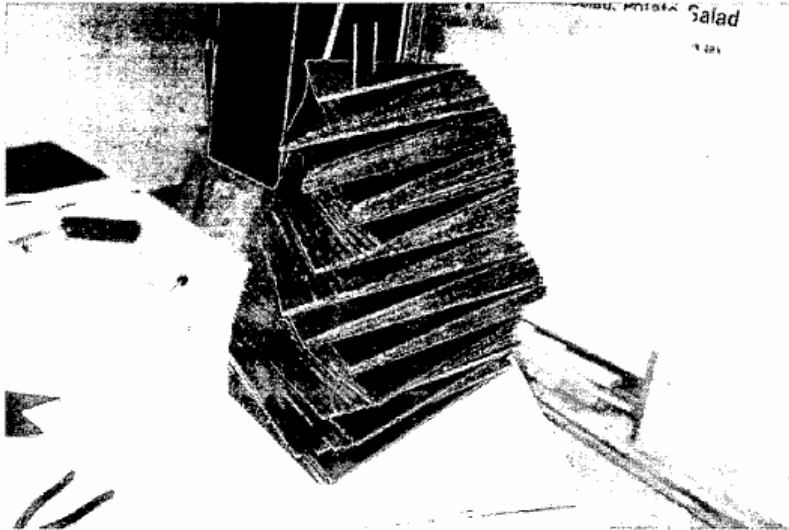
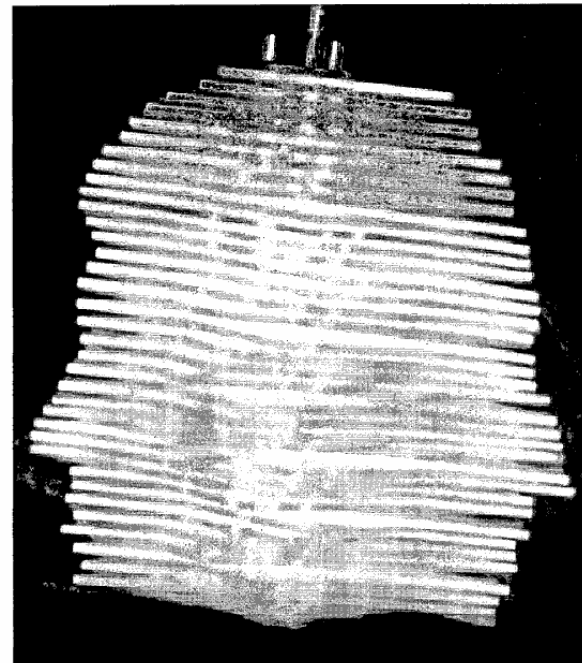


Figure 5

Figure 8



The Machine

- <http://mikescnc.blogspot.com/>
- Computer sends signals through printer cable.
- Each signal moves X, Y, or Z direction only 0.0008 mm.
- Use special software, “Mach3” (<http://www.machsupport.com/>) to interpret “G-code” and send the signals to stepper motor controller.
- Use R to automate writing G-code in txt files.

But First

- Want to minimize wasted aluminum, so need good idea of where triangle will be cut.
 - Select as origin ($X=Y=0$) one vertex of triangle
 - Make one cut horizontal (move in Y direction only)
- Allow for thickness of aluminum, so need proper scaling of triangle.
- Account for bit radius, so cut along a path outside the triangle.
- Determine where to begin and end each straight cut and how to direct the machine for circular cut at vertices.
- Use R to work through the above (trig)

Move to Origin

Create G to be the coordinates, repositioned so $X1=Y1=0$

G\$X1 <- 0

G\$Y1 <- 0

G\$X2 <- X2-X1

G\$Y2 <- Y2-Y1

G\$X3 <- X3-X1

G\$Y3 <- Y3-Y1

G\$HX1 <- HX1-X1

G\$HX2 <- HX2-X1

G\$HX3 <- HX3-X1

G\$HY1 <- HY1-Y1

G\$HY2 <- HY2-Y1

G\$HY3 <- HY3-Y1

Rotate (get horizontal edge)

```
# Rotate the triangles so Y2=0 for all
```

```
H <- G # Update H
```

```
theta <- numeric(length(X1))
```

```
for (i in 1:length(X2))
```

```
{
```

```
theta[i] <- -atan(G$Y2[i]/G$X2[i])
```

```
H$X2[i] <- cos(theta[i])*G$X2[i]-sin(theta[i])*G$Y2[i]
```

```
H$Y2[i] <- sin(theta[i])*G$X2[i]+cos(theta[i])*G$Y2[i]
```

```
H$X3[i] <- cos(theta[i])*G$X3[i]-sin(theta[i])*G$Y3[i]
```

```
H$Y3[i] <- sin(theta[i])*G$X3[i]+cos(theta[i])*G$Y3[i]
```

```
H$HX1[i] <- cos(theta[i])*G$HX1[i]-sin(theta[i])*G$HY1[i]
```

```
H$HY1[i] <- sin(theta[i])*G$HX1[i]+cos(theta[i])*G$HY1[i]
```

```
H$HX2[i] <- cos(theta[i])*G$HX2[i]-sin(theta[i])*G$HY2[i]
```

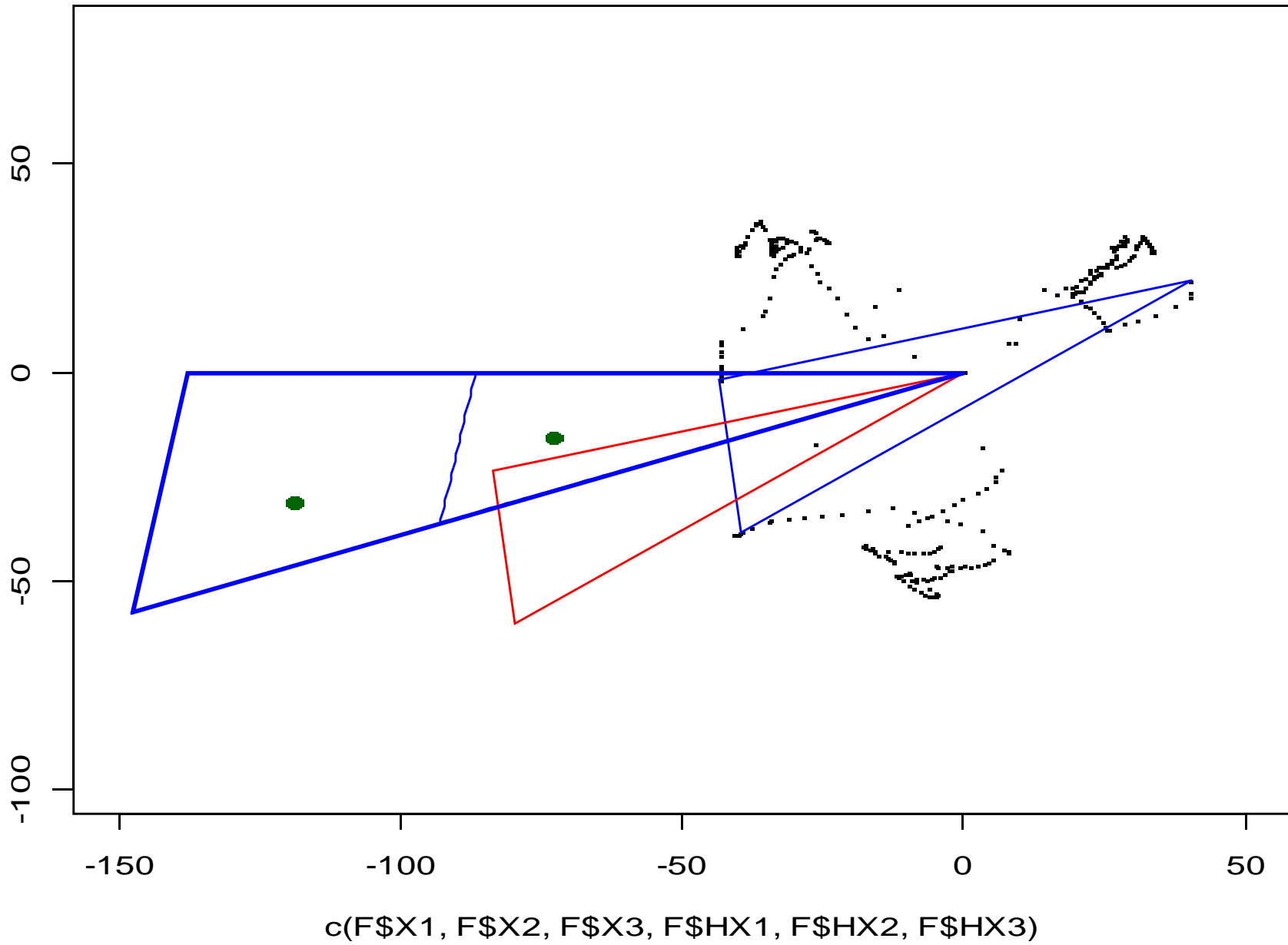
```
H$HY2[i] <- sin(theta[i])*G$HX2[i]+cos(theta[i])*G$HY2[i]
```

```
H$HX3[i] <- cos(theta[i])*G$HX3[i]-sin(theta[i])*G$HY3[i]
```

```
H$HY3[i] <- sin(theta[i])*G$HX3[i]+cos(theta[i])*G$HY3[i]
```

```
}
```

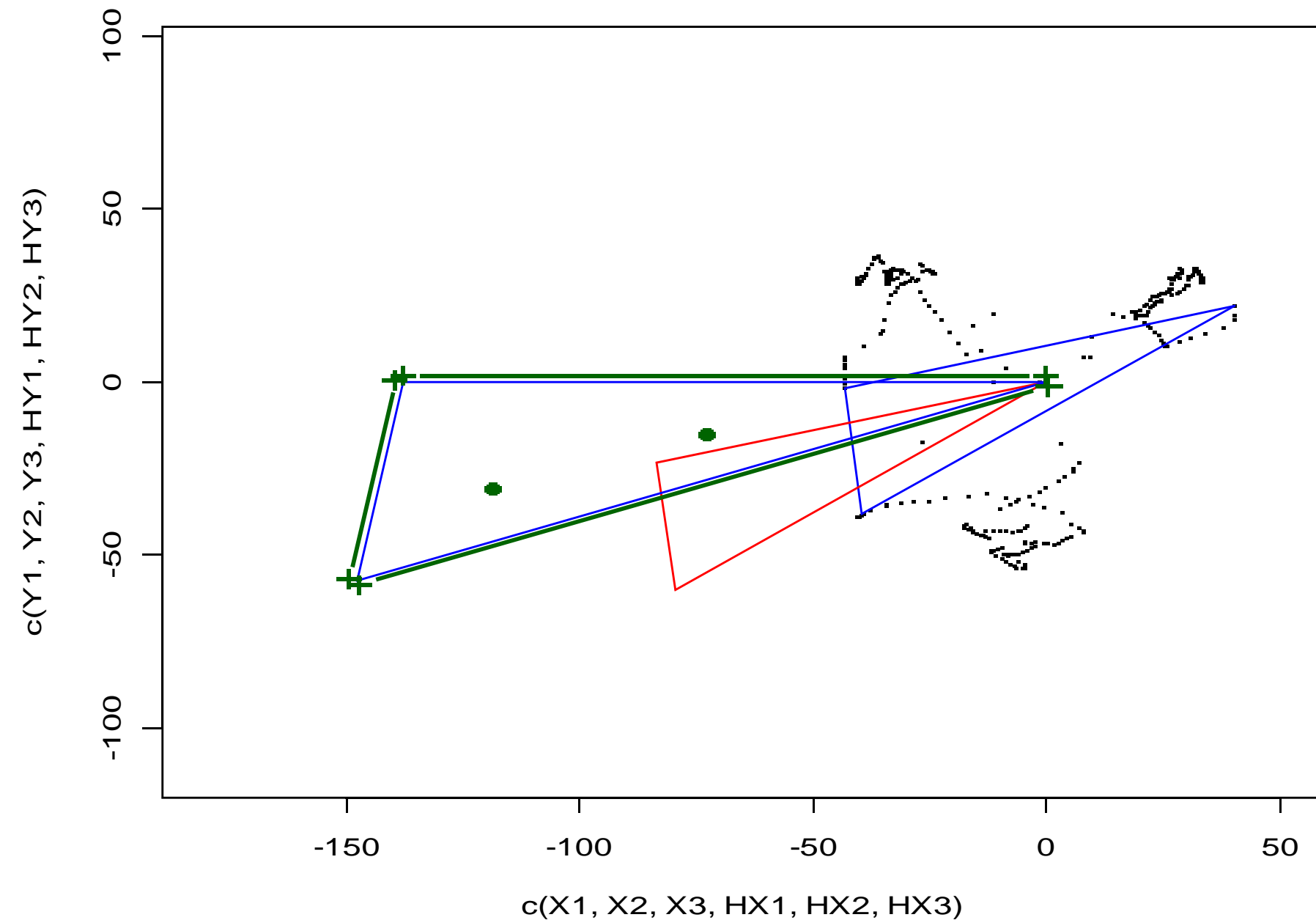

c(F\$Y1, F\$Y2, F\$Y3, F\$HY1, F\$HY2, F\$HY3)



Rescale & Calculate Tool Path

```
H <- Scale*H
J <- matrix(nrow=length(X1),ncol=12) # This new matrix will have final
coordinates, account for tool radius
m1 <- -(H$X3-H$X2)/(H$Y3-H$Y2) # Slope of perpendicular to leg BC
m2 <- -(H$X3)/(H$Y3) # Slope of perpendicular to leg CA
z1 <- sqrt(r^2/(1+m1^2)) # X-distance to tool center from B
z2 <- sqrt(r^2/(1+m2^2)) # X-distance to tool center from A
J[,1] <- 0 # X-coord of starting point
J[,7] <- r # Y-coord of starting point
J[,2] <- H$X2 # X-coord after first linear cut (G1)
J[,8] <- r
J[,3] <- H$X2 - z1
J[,9] <- H$Y2 - m1*z1
J[,4] <- H$X3 - z1
J[,10] <- H$Y3 - m1*z1
J[,5] <- H$X3 + z2
J[,11] <- H$Y3 + m2*z2
J[,6] <- H$X1 + z2
J[,12] <- H$Y1 + m2*z2
H <- round(H,digits=5)
J <- round(J,digits=5)
```

Triangle 1



Drilling Steps

- Drill two holes. Start with small bit.
 - Move to first location
 - Drill
 - Lift
 - Move to second location
 - Drill
 - Lift
- Change to 1/8" bit
 - Move, drill, lift, move, drill, lift.

```

WriteSmallHoles <- function(TRI)
{
  File <- paste("Holes_",TRI,"_small.txt",sep="")      # Like "Holes_1_small.txt"
  Text <- paste("G00 X",HX1[TRI]," Y",HY1[TRI], " Z",upZSm," F",DrillSpeed, sep="")
  write(Text, file=File, append=FALSE)
  Text <- paste("G1 X",HX1[TRI]," Y",HY1[TRI], " Z", dnZSm, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX1[TRI]," Y",HY1[TRI], " Z",upZSm, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX2[TRI]," Y",HY2[TRI], " Z",upZSm, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G1 X",HX2[TRI]," Y",HY2[TRI], " Z",dnZSm, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX2[TRI]," Y",HY2[TRI], " Z",upZSm, sep="")
  write(Text, file=File, append=TRUE)
  if(NHoles[TRI]==3)
  {
    Text <- paste("G00 X",HX3[TRI]," Y",HY3[TRI], " Z",upZSm, sep="")
    write(Text, file=File, append=TRUE)
    Text <- paste("G1 X",HX3[TRI]," Y",HY3[TRI], " Z",dnZSm, sep="")
    write(Text, file=File, append=TRUE)
    Text <- paste("G00 X",HX3[TRI]," Y",HY3[TRI], " Z",upZSm, sep="")
    write(Text, file=File, append=TRUE)
  }
  write("G00 X0 Y0 Z0", file=File, append=TRUE)
}

```

```

WriteHoles <- function(TRI)
{
  File <- paste("Holes_",TRI,"large.txt",sep="")    # Like "Holes_1_large.txt"
  Text <- paste("G00 X",HX1[TRI]," Y",HY1[TRI], " Z",upZLg," F",DrillSpeed, sep="")
  write(Text, file=File, append=FALSE)
  Text <- paste("G1 X",HX1[TRI]," Y",HY1[TRI], " Z", dnZLg, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX1[TRI]," Y",HY1[TRI], " Z",upZLg, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX2[TRI]," Y",HY2[TRI], " Z",upZLg, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G1 X",HX2[TRI]," Y",HY2[TRI], " Z",dnZLg, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 X",HX2[TRI]," Y",HY2[TRI], " Z",upZLg, sep="")
  write(Text, file=File, append=TRUE)
  if(NHoles[TRI]==3)
  {
    Text <- paste("G00 X",HX3[TRI]," Y",HY3[TRI], " Z",upZLg, sep="")
    write(Text, file=File, append=TRUE)
    Text <- paste("G1 X",HX3[TRI]," Y",HY3[TRI], " Z",dnZLg, sep="")
    write(Text, file=File, append=TRUE)
    Text <- paste("G00 X",HX3[TRI]," Y",HY3[TRI], " Z",upZLg, sep="")
    write(Text, file=File, append=TRUE)
  }
  write("G00 X0 Y0 Z0", file=File, append=TRUE)
}

```

G-code for Drilling

```
G00 X-26.75622 Y-6.12709 Z-44 F15  
G1 X-26.75622 Y-6.12709 Z-56  
G00 X-26.75622 Y-6.12709 Z-44  
G00 X-14.70292 Y-11.7965 Z-44  
G1 X-14.70292 Y-11.7965 Z-56  
G00 X-14.70292 Y-11.7965 Z-44  
G00 X0 Y0 Z0
```

```
-----  
G00 X-26.75622 Y-6.12709 Z-33 F15  
G1 X-26.75622 Y-6.12709 Z-41  
G00 X-26.75622 Y-6.12709 Z-33  
G00 X-14.70292 Y-11.7965 Z-33  
G1 X-14.70292 Y-11.7965 Z-41  
G00 X-14.70292 Y-11.7965 Z-33  
G00 X0 Y0 Z0
```

Cutting Steps

- Move near (0,0).
- Lower the bit.
- Move to X= -2.4 mm (for first pass)
- Move to end of first line
- Move in arc to start of second line
- Move to end of second line
- Move in arc to start of third line
- Move to end of third line
- Move away from triangle
- Lift the bit.


```
WriteTri <- function(TRI)
{
  File <- paste("Triangle_",TRI, ".txt", sep="") # like "Triangle_3.txt"
  Text <- paste("G00 X",TriX0," Y", Y1a[TRI]," Z",upZTri," F", CutSpeed, sep="")
  write(Text, file=File, append=FALSE)
  Text <- paste("G1 Z", dnZTri, sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G1 X",X1b[TRI]," Y",Y1b[TRI],sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G3 X",X2a[TRI]," Y",Y2a[TRI]," I",X2[TRI]," J",Y2[TRI],sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G1 X",X2b[TRI]," Y",Y2b[TRI],sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G3 X",X3a[TRI]," Y",Y3a[TRI]," I",X3[TRI]," J",Y3[TRI],sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G1 X",X3b[TRI]," Y",Y3b[TRI],sep="")
  write(Text, file=File, append=TRUE)
  Text <- paste("G00 Z",upZTri,sep="")
  write(Text, file=File, append=TRUE)
  write("G00 X0 Y0 Z0", file=File, append=TRUE)
}
```

G-code for Cutting (#100)

G00 X5 Y2.4 Z-43 F50

G1 Z-50.5

G1 X-40.12981 Y2.4

G3 X-41.97668 Y-1.53267 I-40.12981 J0

G1 X-1.83212 Y-49.9071

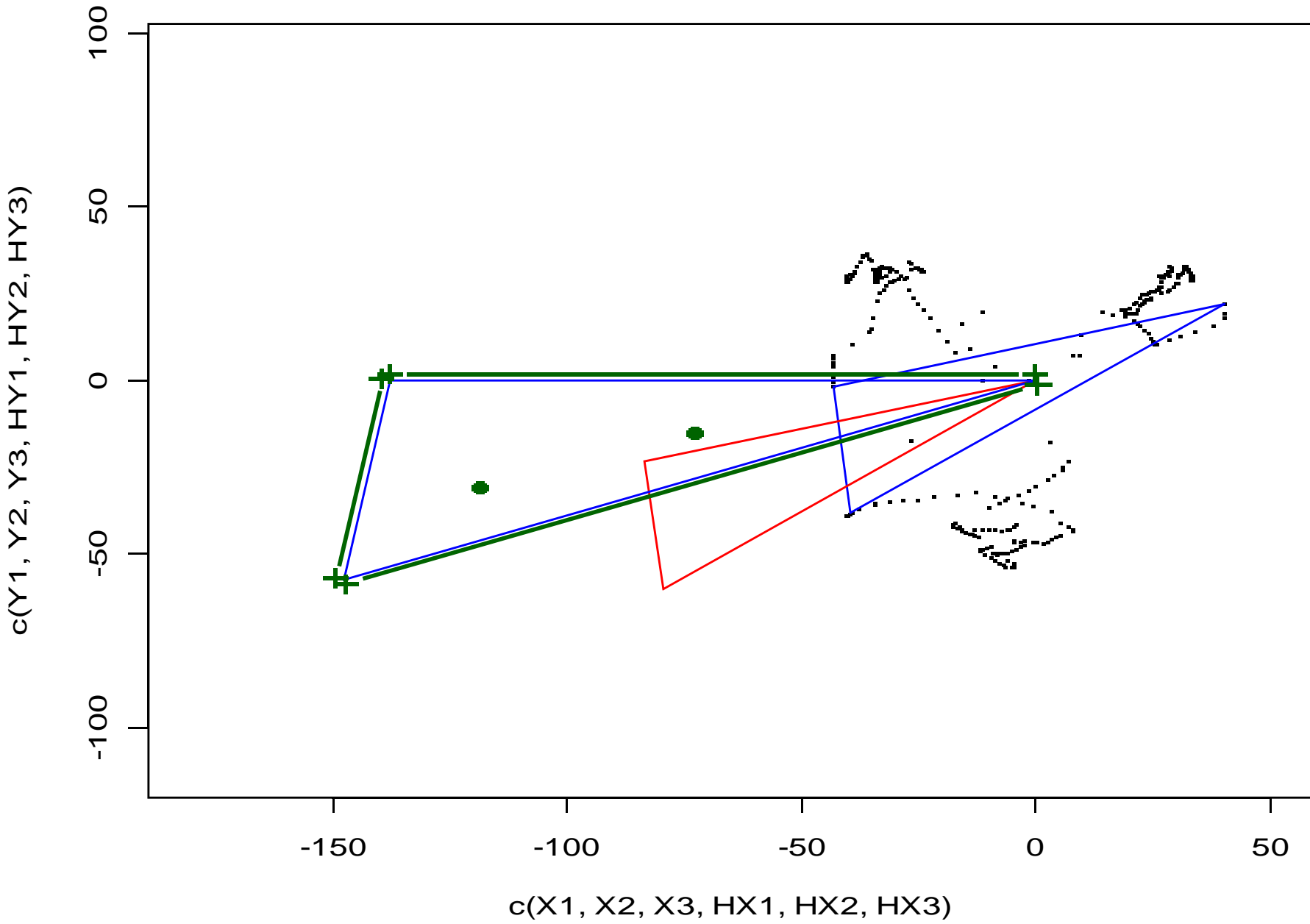
G3 X2.41475 Y-48.3737 I0.01475 J-48.37444

G1 X2.4 Y0.00073

G00 Z-43

G00 X0 Y0 Z0

Triangle 1





QC & Final Product

- Calculate desired final lengths of edges
- Sand and check with digital calipers
- Most edges are within 0.4 mm.
- Stack on 1/8" aluminum rods – excellent alignment!
- The finished sculpture!

Benn & Sally Forsyth



Benn & Sally - Silhouettes

