

Computational Design + Fabrication: CNC

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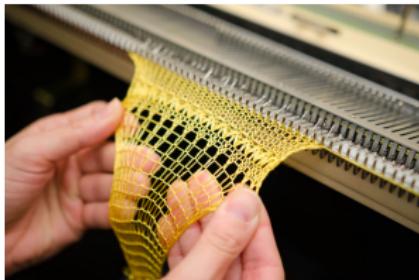
September 4, 2015

- Computerized
- Numeric
- Control

Benefits

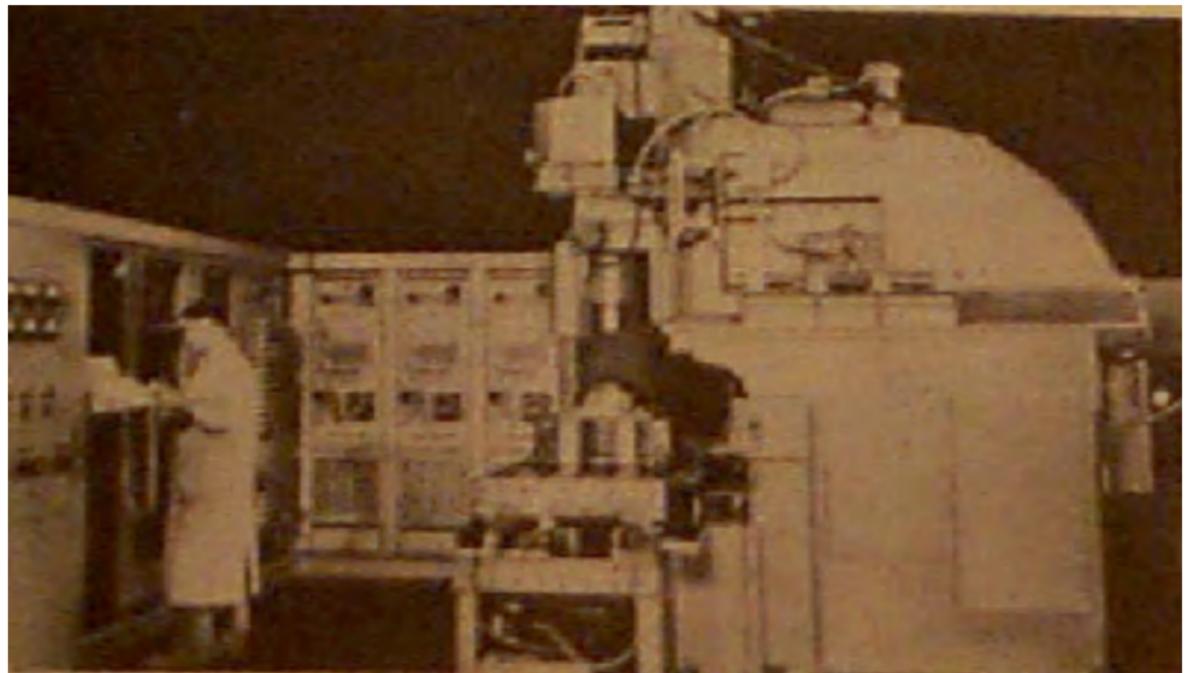
- Automation
- Precision
- Repeatability
- Flexibility

- Cutters
- Mills
- 3D Printers
- Lathes
- Knitting



stoll cnc knitting machine

CNC History



John T Parsons + MIT 1949

- Additive
- Subtractive



additive



subtractive

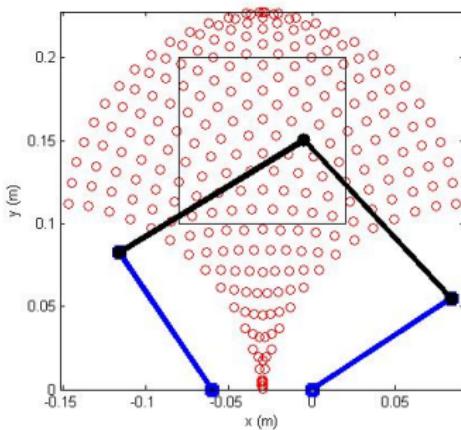
- How Many?

- 1D
- 2D
- 2.5D
- 3D
- 5D
- linear

- What Kind?

- rotary
- linear

- how big
- shape
- constraints

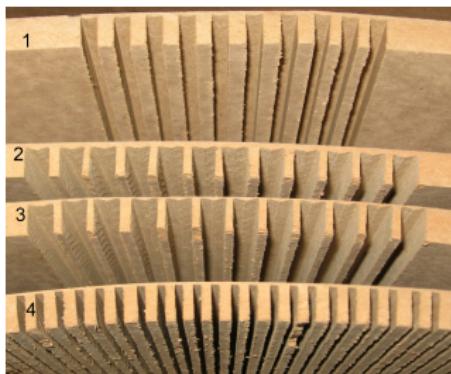


by xiyang yeh @ stanford

- how fast to do cut
- up to speed of breaking end mill
- more but slower cuts

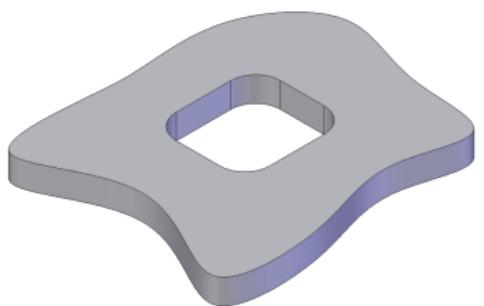
- open loop
 - crash
- closed loop
 - limit switch
 - rotary encoder
 - camera

- width of saw blade
- cut radius
- must compensate in code

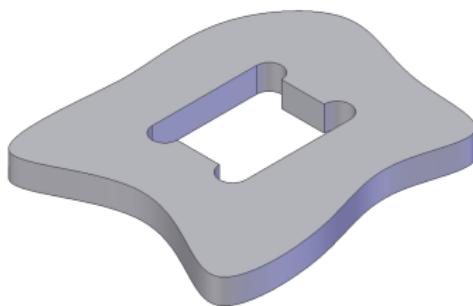


by parts express

- extra cut to compensate for mill radius



NO UNDERCUT



UNDERCUT

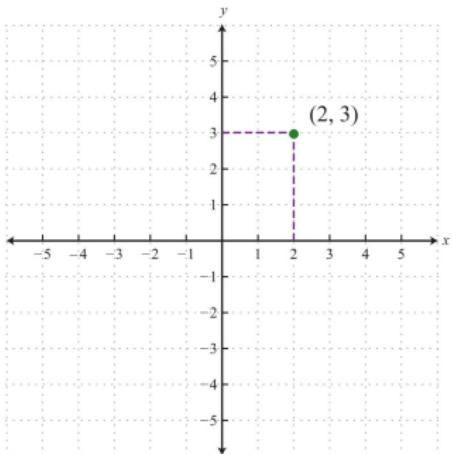
by wizard191

- extra cut during start or finish of cut
- usually need to plan for this



by big blue saw

- Rectangular
- Precision – increments
- Origin – Zeroing
- Absolute and Relative



- different cutters
- thicker mill cuts faster but less precise
- switch between them under program control



- word addressed format for programming
- sentence like commands: letter followed by numeric argument
- command is made up of words often one letter with intuitive interpretations
- step by step commands
- read interpret execute each command

X10

Y20

O	Program number (Used for program identification)
N	Sequence number (Used for line identification)
G	Preparatory function (See below)
X	X-axis designation
Y	Y-axis designation
Z	Z-axis designation
R	Radius designation
F	Feedrate designation
S	Spindle speed designation
H	Tool length offset designation
D	Tool radius offset designation
T	Tool Designation
M	Miscellaneous function

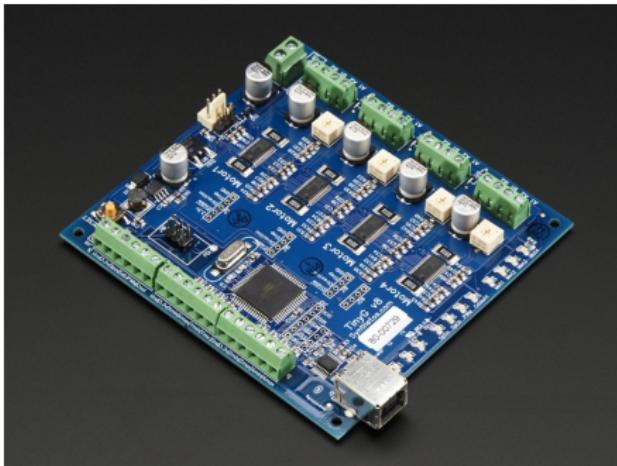
Example GCode Program

```
G1 X5 Y-5 Z6 F3300.0 (Move to position <x,y,z>=<5,-5,6> at speed 3300.0)
G21 (set units to mm)
G90 (set positioning to absolute)
G92 X0 Y0 Z0 (set current position to <x,y,z>=<0,0,0>)
```

- G90, G91
- spindle speed
- coolant
- tool changing

- like turtle graphics
 - move
 - pen up/down
- no loops
- no subroutines

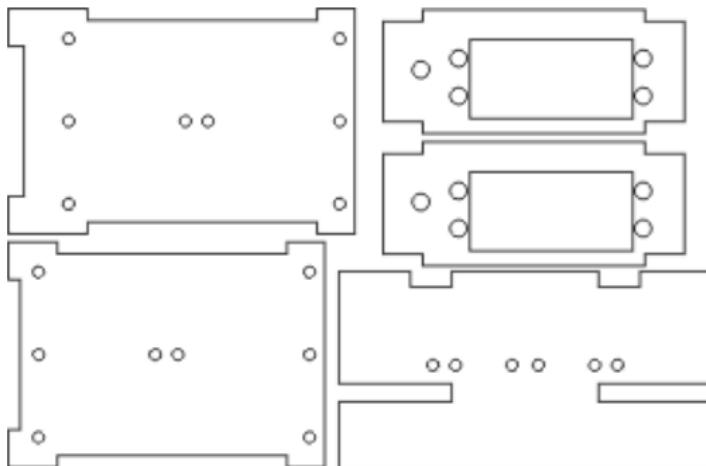
- send gcode to CNC machine
- machine interprets one command at a time
- usually microcontroller which is interpreting and executing



tinyG microcontroller board

- organize cuts efficiently
- plan motions according to dynamics
- change speeds
- bang-bang control

- need to plan cuts so parts are cut correctly
- cut holes out first
- much more involved for 5 axis machines

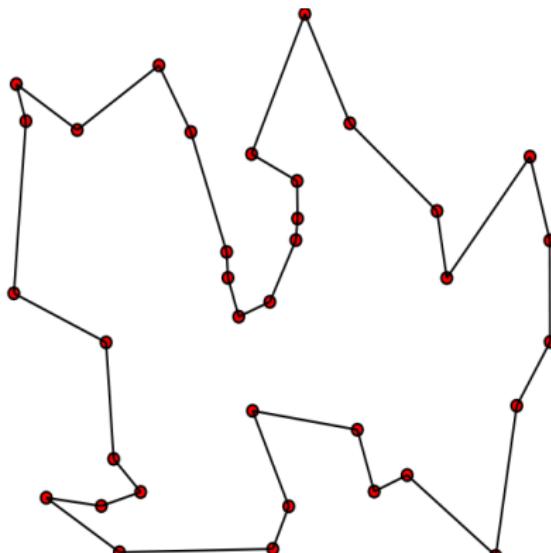


by customlasercutters

Traveling Salesman Problem

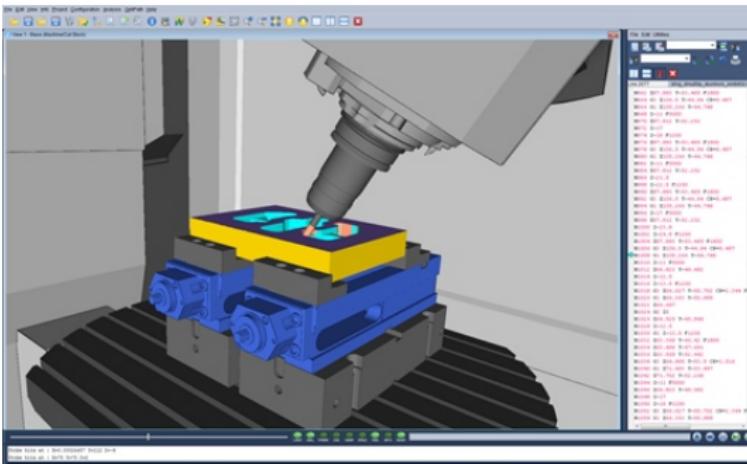
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- salesman has to visit n city in minimum time



GLPK solution by xypron

- show planned out motions
- actually interpret gcode
- validate that plan works



by modern machine shop

- show feedback during execution
- communicate to user for manual intervention
- WYSIWYG



by othermachine co

- DXF,SVG,PDF – polylines
- STL,OBJ – meshes
- AMF – materials, frep

```
solid name
facet normal ni nj nk
    outer loop
        vertex v1x v1y v1z
        vertex v2x v2y v2z
        vertex v3x v3y v3z
    endloop
endfacet
endsolid name
```

- AMF – <http://www.astm.org/Standards/ISOASTM52915.htm>