Chapter 1:
Introduction to
Computer Numerical Control

Computer Numerical Control (CNC)
Learning objectives

- **CNC Overview**
- **Flow of CNC Processing**
- **CNC Concepts**

Computer Numerical Control (CNC)

Intro

- **Computer Numerical Control (CNC)**
  - **Process of manufacturing machined parts that utilizes a computerized controller to drive motors that control the movement of each axis of the tool in a production environment**
  - **Computerized Controller controls the production**
    - **Drive each axis of a machine using motors**
    - **Regulate speed, direction and time of rotation for each motor**
  - **Characteristics of Computerized Controller Program**
    - **Specialized Commands to control the machine**
    - **Function codes**
    - **Numeric point data (Cartesian coordinates)**

Computer Numerical Control (CNC) Production Environment

CNC Applications include:

- **Milling**
  - Process of using rotating cutter to scope materials from a work piece that may result in
  - 2-D patterns, 3-D patterns or other profiles/shapes
- **Turning**
  - A cutter that moves perpendicular thru' the center plane of a rotating work piece to produce a shape:
  - Depending on the shape of the tool and operations performed
- **Industrial Robots and CNC**
  - To perform repetitive tasks
    - Examples include, handling heavy and hazardous materials

Our focus will be on CNC Milling and CNC Turning machine tools

Computer Numerical Control (CNC)

Machine Tool

Three Major Components:

- **Machine Tool**
  - Could be one of many
- **Motors and Feedback Mechanism**
  - Provide link between machine tool and the controller
  - Type, size and resolution vary based on machine application
- **Controller**
  - Heart of the CNC machine

CNC Process

Typical Steps

1. Develop or obtain the three dimensional geometric model of the part (Part Drawing)
   - May use CAD
2. Decide which machine will produce the part
   - Machining operation and cutter path directions required to produce the part
   - Using Computer software
   - Reviewing Engineering drawings/Specifications
3. Choose tooling to be used
4. Decide on Machining sequence
   - Flow chart
   - Run a CAM software to generate
     - The CNC program for the part
     - Setup sheets
     - List of tools
5. If Flow chart is used:
   - Calculate the speed and feeds required for tooling and part material
   - Write the NC program

If A CAM software is used:

   - Verify the program using a simulator (e.g., CNCez)
   - Edit program if necessary

CNC Process

Typical Steps contd.

6. Download part program to appropriate machine(s)
   - Machine the prototype
7. Verify program on actual machine
   - Edit program if necessary
8. Run program and produce parts

Guidelines for using the Hurco CNC (Courtesy of Prof Michael Dragomier):
http://www.personal.kent.edu/~asamba/Hurco.zip

CNC Program Overview

- A CNC program is a sequential list of machining instructions
- Program consists of blocks (or lines) each of which contains an individual command for a movement or specific action
- Each block is numbered

Commands are comprised of Codes

- **G-codes** used for preparatory functions which involve actual tool moves –
  - rapid moves, feed moves, radial feed moves, dwells, roughing and profiling cycles.
    - Dwell – intentional time delay during which the spindle (rotating tool) maintains contact with the work piece
    - Roughing – cuts used to remove large amounts of materials from the workpiece rapidly at the start of the cutting. Subsequently, Finishing cuts are employed at much slower speeds for the final product
    - Profiling – An operation that feeds a cutting tool along a non-linear path to create curved features in a workpiece
- **M-codes** miscellaneous functions
  - spindle on and off, tool changes, coolant on and off, program stops, etc.
- N – Block number
- X, Y, Z – coordinates
- I, J, K – X, Y, Z in disguise
- S – spindle speed
- F – feedrate

Sample CNC Program

The following code instructs a CNC milling machine that on executing line (or block) 100, the tool is to cut relative to the original point at a feed rate of 20 in/min along the X axis 1.25 in and the Y-axis 1.75 in

%	Program start flag
: 100(Sample program)	**Program #100; comment**
N95 G90 G20	Block number 95, Absolute in inches
N100 G01 X1.25 Y1.75 F20.0	

CNC Sample Program

```
%                                          Program start flag
:10 (PLANES  T9=1/4 END MILL  WORKPIECE = 4X4X0.75)      Program number and comments
N100 G90 G20 G40 G80                       Absolute, Inch, Cancel Cutter Comp, Cancel canned cycles
N105 M06 T9
N110 M03 S4800
Material Removal
N115 G00 X1 Y0.5
N120 Z0.125
N125 G01 Z-0.25 F5
N130 X1.0318
N135 G18 G03 X1.5159 Z-0.375 I0 K-1
N140 G02 X2.4841 Z-0.375 I0.4841 K0.875
N145 G03 X2.9682 Z-0.250 I0.4841 K-0.875
N150 G01 X3
N155 G17 G03  X3.5 Y1 I0 J0.5
N160 G01 Y1.0318
N165 G19 G02 Y1.5159 Z-0.375 J0 K-1
N170 G03 Y2.4841 Z-0.375 J0.4841 K0.875
N175 G02 Y2.9682 Z-0.250 J0.4841 K-0.875
N180 G01 Y3
N185 G17 G03 X3 Y3.5 I-0.5 J0
N190 G01 X2.9682
N195 G18 G02 X2.4841 Z-0.375 I0 K-1
N200 G03 X1.5159 Z-0.375 I-0.4841 K0.875
N205 G02 X1.0318 Z-0.250 I-0.4841 K-0.875
N210 G01 X1
N215 G17 G03 X0.5 Y3 I0 J-0.5
N220 G01 Y2.9682
```

CNC
Concepts

Our goal:

- Learn how to "drive" a CNC machine – The concepts
  - With that knowledge, you should be able to operate any CNC machine once you learn the particulars of that machine.

The Concepts

- There are four concepts you need to thoroughly understand to be successful
  1. The Cartesian co-ordinate system
  2. Planes of operation
  3. Reference points, absolute and incremental positioning measurements
  4. Programming syntax

Basic idea:

If you learn how to drive, you can drive almost any car:

- All you need is to be familiar with the particulars of that car
- Location of the ignition switch or light switch, fuel tank latch
- How to adjust the rear-view mirrors or the seats etc