Machine Tool Controller Design and Development Trend

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Outline

- CNC Controller’s Hardware Design
- CNC Controller’s Software Design
- CNC Controller’s Current Status
CNC Controller System

FAGRO 8070

System configuration

1. Numerical Control (CNC)
2. Sercos digital interface
3. Axis motors
4. Spindle motors
5. Feedback Systems
6. Tool magazine
7. Kinematics management
8. Ethernet
9. Simulator on PC
10. Distributed inputs and outputs

Photo Taken From: Internet
Controller Hardware Design

一、Hardware Classification

1. Printed-circuit Board
   1. Large PCB
   2. Module

2. Microprocessor Number
   1. Single
   2. Multi

3. Hardware Manufacturing
   1. Dedicated
   2. Universal

4. Openness
   1. Closed
   2. PC Embedded NC
   3. NC Embedded PC
   4. Pure-soft Open CNC
Printed-circuit Board Type

1. Large PCB
   - Configuration: main PCB, position control board, PLC board, graphic control board and power unit.
   - Feature: Big circuit board for main board slotted by small circuit boards for other boards.
   - Representative: FANUC 6MB series

2. Module
   - Function Module: CPU, extended memory, position control, PLC board, graphic, and communication boards.
   - Communication Interface: industry standard architecture bus (PCI, STD Bus).
   - Representative: FANUC 15 series
Microprocessor Number

1. Single
   - Single CPU: centralized control and management of the entire system’s resources

2. Multi
   - Master-slave: master CPU for host management, slave CPU for client motion control
   - Distributed: exchange information and share resources by external communication link
   - Multi-master: common bus, shared memory
Multi Master Microprocessors

- **Feature:**
  - **Configuration:** two or more CPUs and their function modules.
  - **Handshake Mechanism:** common bus arbiter for solving priority and shared memory for exchanging information between multi-master CPUs.

- **Function Module:**
  - **CNC Management:** CNC device management, such as initialization, interrupt management, and system software/hardware diagnosis.
  - **CNC Interpolation:** pretreatment interpolation and real-time interpolation calculation.
  - **Position Control:** motion control and position/velocity control.
  - **PLC(PMC):** single logic processing for NC file command(S、M、T), operation panel control and limit switch on machine.
  - **Input/Output and Display:** display for NC file, path, parameter and operation I/O.
  - **Memory:** Data transfer for NC file and data storage between function modules.
Hardware Manufacturing

1. Dedicated
   - Feature: closed architecture that designed and manufactured by manufacturer, with advantages of high reliability, compact and dedicated
   - Representative: FANUC, SIEMENS

2. Universal
   - Feature: IPC as a hardware platform with dedicated control card and CNC control software, with advantages of high openness and good maintenance
   - Representative: Power Automation PA8000
Openness

1. Closed
   - Feature: user cannot add, change and maintain any function
   - Representative: FANUC 0, MITSUBISHIM 50, SIEMENS 810

2. PC Embedded NC
   - Feature: PC installed in CNC, with certain openness but system kernel modified is allowed
   - Representative: FANUC 18i/16i, SIEMENS 840D, NUM 1060

3. NC Embedded PC
   - Feature: composition of motion control card and PC, motion control card is used for CNC system and usually a high speed DSP is used as CPU
   - Representative: American Delta Tau company PMAC CNC system based on PMAC multi-axis motion control card, Japan MAZAK company MAZATROL 640 CNC system based on Mitsubishi Electric’s MELDAS MAGIC 64

4. Pure-soft Open CNC
   - Feature: RTLinux software development platform as a pure software CNC system
   - Representative: American MDSI company Open CNC, German PA company PA8000
PC Embedded CNC

![Diagram showing PC installed inside CNC, with a dedicated bus for connection between PC and CNC.]

- **Operation Panel**
- **Dedicated Bus**
- **General PC Exchanger**

**Text:**
- PC installed inside CNC, bus connection between PC and CNC

Photo Taken From: Internet
NC Embedded PC

Non real-time process for system monitor management, fault diagnosis, interface display and interpreter.

Real-time process for interpolation calculation, tool compensation, position control and velocity control.

Photo Taken From: Internet
Universal Controller

- NC Kernel and Motion Control Card

Diagram:
- RT-Linux
- DSP
- Multi-axis Motion Control Card
- Servo Drive/Motor

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Universal Controller

IPC

HMI, OS: Windows

RS232

COM2

DSP

Multi-axis Mechanism
Control Process Design

- **Control Classification**
  1. **NC Control**: Numerical control for each axis coordinate
  2. **Auxiliary Control**: Sequence control for each responder action

- **Control Flow**
  1. Control Command, Parameters, Machining Data → Input Unit → CNC Storage Unit
  2. NC File Opened → Blocks Interpretation

![Diagram of Control Process Design](image-url)
Control Process Design

- **Low Speed Auxiliary Information:** Output and process by PLC to realize auxiliary control
  1. **Auxiliary Function (M):** Spindle start/stop, coolant on/off, tool change...
  2. **Spindle Speed Function (S):** Spindle speed controlled
  3. **Tool Function (T):** Tool selection

- **High Speed Auxiliary Information:** Preprocess, interpolation and position control; simultaneously moving coordinate axes
  1. **Tool Compensation Process:** Part trajectory convers to tool center trajectory.
  2. **Feedrate Process:** Component velocity calculation and speed limit process.
Software System Design

Software Classification

1. CNC Device Operating Characteristics

   1. Real-time:
      - Strong real-time
      - Weak real-time
      - Periodic: Interpolation, motion control
      - Sudden: Emergency stop, alarm fault
      - Display: Trajectory, coordinate
      - Editor: Parameter, NC file

2. Parallel Processing: Display, machining, I/O processing, troubleshooting

3. Multi Processing
   - Control: Interpreter, tool compensation, path planning, motion control
   - Management: Input, I/O processing, display, diagnosis
Software System Design

- Software Classification

3. CNC Software Architecture
Tool Compensation

Compensation Kind

- **Tool radius compensation**: Cutter radius compensation for machining centers, tool nose radius compensation for turning centers
  - G40(Cancel tool radius comp. G41 and G42)
  - G41(Left tool radius compensation)
  - G42(Right tool radius compensation)

- **Tool length compensation**: Adjust for differences in length between different tools
  - G43(Tool length compensation plus)
  - G44(Tool length compensation minus)
  - G49(Cancel tool length comp. G43 and G44)

- **Tool center offset compensation**
Tool Radius Compensation

- Linear radius compensation

\[\begin{align*}
  x' &= x + \Delta x \\
  y' &= y + \Delta y
\end{align*}\]

\[\angle XOAO = \angle A'AK = \alpha\]

\[\Delta x = r \sin \alpha = r \cdot \frac{y}{\sqrt{x^2 + y^2}}\]

\[\Delta y = r \cos \alpha = r \cdot \frac{x}{\sqrt{x^2 + y^2}}\]

- Circular radius compensation

\[\begin{align*}
  x_e' &= x_e + \Delta x \\
  y_e' &= y_e + \Delta y
\end{align*}\]

\[\angle BOX = \angle B'BK = \alpha\]

\[\Delta x = r \cos \alpha = r \cdot \frac{x_e}{R}\]

\[\Delta y = r \sin \alpha = r \cdot \frac{y_e}{R}\]

\[\begin{align*}
  x_e' &= x_e \pm \frac{r x_e}{R} \\
  y_e' &= y_e + \frac{r y_e}{R}
\end{align*}\]
Tool Length Compensation

Tool length compensation

- **G43**: tool length compensation in a positive direction
  \[ Z_{Act} = Z_{Cmd} + (H_{xx}) \]

- **G44**: tool length compensation in a negative direction
  \[ Z_{Act} = Z_{Cmd} - (H_{xx}) \]
Die and Mold Machining

Feature

- NC Files:
  - Lots of small line segments (CAM software) ⇒ curves ⇒ surfaces

Effect of surface accuracy

1. CNC system delay

- For high speed machining, low workpiece precision from servo delay caused by deviation between command and actual trajectory

![Diagram of command and actual trajectory](Photo Taken From: Internet)
Die and Mold Machining

- **Feature**
  - **Effect of surface accuracy**
  - **CAM system output distortion**
    - Un-smoothing machining velocity of adjacent trajectories caused by irregular small line segments of adjacent
    - Unsmooth surface of surface blemishes caused by servo delay.

- **Inconsistent path lengths or angles**
- **Irregular corner**
- **Tiny segment deviation, retrograde, ‘S’ mark**
Precision Motion Command

- Coordinate movement for desired motion Axes
- Generation and interpolation

**Interpolator**: trajectory planning

- Continuous machining path converted to coordinate movement
- Output approximate coordinate movement every fixed time interval

Motor rotation amount $\theta(t)$

The target trajectory is assumed to be piecewise linear with some
Interpolation

Feature of CNC Motion

- **Move in pulses**
  - Tool’s basic motion unit (BMU): **Pulse**
  - Tool’s displacement magnitude along each coordinate direction: integer multiple of pulses.
  - Machine Tool’s motion space: a discretized grid-area which a mesh size represents a pulse; tool only can be moved a grid node location.

- **Tiny linear segments to be machined**
  - Tool is moved to approximate the original curves or surfaces by a series of broken line;

NC Programming

- **G00** for Rapid Positioning
  - Tool is moved along the shortest route to programmed X,Y,Z position
- **G01** for Linear interpolation
  - Tool is moved along a line
- **G02** for Circular Interpolation Clockwise
  - Tool is moved along an arc from the starting point to an end point
- **G03** for Circular Interpolation Counterclockwise
Interpolation

◆ Classification

☐ Hardware interpolation
  • High-speed algorithm but lack of flexibility, difficulty with adaptations and modifications
  • Early NC system: hardware interpolator consists of digital logic circuit
  • It is used for fine interpolation

☐ Software interpolation
  • Low-speed algorithm but high flexibility, ease with adaptations and modifications
  • CNC system: interpolation by pure software or software/hardware combination
  • It is used for rough interpolation.

◆ CNC’s Common Interpolation
  • Basic interpolation: linear, circular
  • Parametric interpolation: helical, parabolic, cubic…
Point by Point Comparison

**Flow**

1. **Deviation Judgment:** According to deviation symbol to determine positional deviation between tool’s current position and part contour.

2. **Coordinate Feed:** According to deviation judgment to control responding coordinate axis to move one step for approaching workpiece.

3. **Deviation Calculation:** After moving one step, recalculate new positional deviation for new tool’s position.

4. **End Discrimination:** If the end point is reached, stop interpolating; else, return step 1.
**Point by Point Comparison**

- **Linear Interpolation**: Deviation value \( F_i \) is defined as the distance between the moving point and contouring OE.

  \[ F_i = X_e Y_i - X_i Y_e \]

1. When \( F_i \geq 0 \), the moving point is over the straight line \( \rightarrow \) moves one step along \( +X \) direction;
2. When \( F_i < 0 \), the moving point is below the straight line \( \rightarrow \) moves one step along \( +Y \) direction.

- **Circular Interpolation CCW**: Deviation value \( F_i \) is defined as the difference between the moving point \( N \) and arc radius \( R \).

  \[ F_i = X_i^2 + Y_i^2 - R^2 \]

1. When \( F_i \geq 0 \), the moving point is outside the arc \( \rightarrow \) moves one step along \( -X \) direction;
2. When \( F_i < 0 \), the moving point is inside the arc \( \rightarrow \) moves one step along \( +Y \) direction.
Extended DDA Interpolation

Feature

- Digital Differential Analyzer (DDA)
  - solves equations by numerical methods
  - a kind of increment algorithm
  - the value of x, y, and z in the next step will be figured out after x, y, and z in the previous step add a small increment simultaneously and respectively.
  - high precision machining but simple algorithm
  - calculation of tool’s displacement along with coordinates to make the tool is moved along the machining trajectory.
  - computing speed fast
  - the distribution of the controller pulse overflow is more uniform
  - easy to implement multi-axis moving simultaneously and complex multi-axis independent variable space curve interpolation
  - the most commonly used in numerical contouring control system
Extended DDA Interpolation

- **Principle**
  - Velocity components of \( V \)
  - Incremental coordinates required to move

Moves from start point \( P_s(X_s, Y_s, Z_s) \) to reach the end point \( P_e(X_e, Y_e, Z_e) \) at time \( t = T_i \). \( T \) is the sampling time.

The grid density (number of subintervals \( N \)): \( N \) is rounded to the nearest integer, equal to or greater than \( T_i / T \).

- \( V \)—Programmed feedrate (mm/min)
- \( T \)—Interpolation period (ms)
- \( \lambda t \)—time constant after interpolation, \( \lambda t = T \times 10^{-3} / 60 \)
Extended DDA Interpolation

- **Principle**
  - **Number of feedrate**
  - **Coordinate values for moving point**

\[ \lambda_d = FRN \lambda_t \]
Velocity Design for Linear IPO

**Velocity Calculation**

- Determine contouring’s step length and each coordinate axis’s feed length at a sampling time.

**Algorithm**

1. **Projection on NC program segment**
   \[ L_x = x_e' - x_0', \quad L_y = y_e' - y_0' \]

2. **Cosine on line direction**
   \[ \cos \alpha = \frac{L_x}{L}; \quad \cos \beta = \frac{L_y}{L} \]

3. **Contouring’s step length (ΔL) for one IPO period**
   \[ \Delta L = \frac{1}{60} F \cdot \Delta t, \quad \text{Feedrate} \ F = [\text{mm/min}], \ I \text{PO period} \ \Delta t = [\text{ms}] \cdot \Delta L = [\mu \text{m}] \]

4. **Each coordinate axis’s feed length (Δx, Δy) at a sampling time**
   \[ \Delta x = \Delta L \cdot \cos \alpha = F \cos \alpha \cdot \frac{\Delta t}{60} (\mu \text{m}) \]
   \[ \Delta y = \Delta L \cdot \sin \alpha = F \sin \alpha \cdot \frac{\Delta t}{60} = \Delta L \cdot \cos \beta = F \cos \beta \cdot \frac{\Delta t}{60} (\mu \text{m}) \]
Velocity Design for Circular IPO

Velocity Calculation

Algorithm

Each coordinate axis’s feed length ($\Delta x_i$, $\Delta y_i$) at a sampling time

\[
\Delta x_i = F \cos \alpha_i \Delta t / 60 = \frac{F \Delta t J_{i-1}}{60R} = \lambda_d J_{i-1}
\]

\[
\Delta y_i = F \sin \alpha_i \Delta t / 60 = \frac{F \Delta t I_{i-1}}{60R} = \lambda_d I_{i-1}
\]

\[
\lambda_d = \frac{F \Delta t}{60R} \quad \lambda_d = \frac{1}{60} \cdot FRN \cdot \Delta t
\]

$FRN = \frac{F}{R}$

$\lambda_d$: step partition coefficient (speed coefficient)
Feedrate Design for Feedrate Difference

Tangent feedrate is continuous

Feedrate difference limit

Program
N1 G01 G91 X100. F5000
N2 Y100.

Photo Taken From: FANUC
Acceleration/Deceleration Design

O0001

N10 G0 X0 Y0
N20 G01 X20 Y20 F1000
N30 X40 Y0
...
M30

Tangent feedrate

Tangent acceleration

Machine vibrates

Time

N20

(0, 0)

(20, 20)

(40, 0)

N20

Machine vibration reduces

Time

Tangent feedrate

Tangent acceleration

Machine vibrates

Machine vibration reduces

Time
Types of ACC/DEC

Three common types of ACC/DEC for commercial controllers

- Linear Acceleration/Deceleration
- Exponential Acceleration/Deceleration
- Bell-shaped Acceleration/Deceleration
Path Error Reduction with G-Code

Path error due to using after interpolation feedrate controlling could be eliminated by adding G04 or G09 between two blocks.

- **G04: Dwell For Precise Timing**
  - It keeps the axes unmoving for the period of time in seconds specified by the P number.

- **G09: Exact Stop Check**
  - It causes the machine to wait until the cutter is finished and exactly on position before continuing.
SIEMENS Exact Stop Function

- **Exact Stop Coarse and Fine**

<table>
<thead>
<tr>
<th>G function</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>G601</td>
<td>Exact stop fine</td>
</tr>
<tr>
<td>G602</td>
<td>Exact stop coarse</td>
</tr>
<tr>
<td>G603</td>
<td>Interpolation end</td>
</tr>
</tbody>
</table>

Exact stop coarse  
(MD36010) >  
Exact stop fine  
(MD36000)
Look-ahead Function

- N1
- N2
- N3
- N4
- N5
- N6
- N7
- N8

Feedrate

Time

Sharp Corners

Look-ahead ON

Look-ahead OFF

T_{traditional}

T_{look-ahead}

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Look-ahead Bell-shaped Acc./Dec.

Look-ahead Linear Acc./Dec. Before Interpolation

Look-ahead Bell-Shaped Acc./Dec. Before Interpolation

Substitutes bell-shaped with linear acc./dec.
Deceleration by Acceleration

- Limit for each axis’s max acceleration to reduce a machine vibration caused by large acc/dec.
Jerk Plan

- Jerk is the derivative of acceleration with respect to time.
Jerk Control

Line block(N1) connects circular block(N2)

Vibration due to acceleration change

Limit axial max. acc. variation(Jerk)

Photo Taken From: FANUC
Jerk Control

Max. acc. variation

Accelerometer change amount:
1000 mm/s²

Arc radius: 10 mm
Specified feedrate: 6000 mm/min

From straight line to arc

Jerk Limitation

Photo Taken From: FANUC & SIEMENS
Linear vs. Parametric Interpolation

1. No errors for using small line segments to approximate curves
2. Compression for part programming file’s size
3. Increasing machining feedrate
4. Do need to transfer files through DNC

• High-end CNC
  – FANUC : Nano Smoothing I & II
  – MITSUBISHI : SSS4(Super Smooth Surface4)
  – SIEMENS : Compressor
  – HEIDENHAIN : Contour Filter (M124)
Smoothing Control

- **FANUC Nano Smoothing I/II**
  - Related G-code
    - G5.1 Q3(Enable)
    - G5.1 Q0(Disable)
Smoothing Control

MITSUBISHI SSS (Super Smooth Surface)

- With look-ahead blocks by judging part program paths, unnecessary deceleration is reduced, even when fine steps in the program exist. This provides a smooth finish without deviation for die-mold machining.

It compensates uneven paths output from CAM to smoothly joint the tool center points' path. This function suppresses the vibrations of the tool by moving the rotary axis smoothly.
Smoothing Control

- MITSUBISHI SSS4(Super Smooth Surface 4)

Optimum speed control is always performed even with a program with an error, resulting smooth surface in short time.

Machining time can be shorter by 5 to 30% relative to a conventional system, especially more effective at a higher feed rate.
Smoothing Control

- **SIEMENS Compressor**
  - In accordance with the specified tolerance band, the compressor takes a sequence of G1 commands, combines them and compresses them into a spline
    - COMPON/COMPCURV
      - 10 blocks as a set for curve fitting with three or fifth order polynomial equations
    - COMPCAD
      - All blocks combined and compressed into a B-Spline
Smoothing Control

- **HEIDENHAIN Contour Filter (M124)**

  - **Shape of Contour Transitions**
    - Tangential circle \([\text{MP7415.0} = 0]\)
    - Third-degree polynomial (cubic spline) \([\text{MP7415.0} = 1]\)
    - Fifth-degree polynomial \([\text{MP7415.0} = 2]\)
    - Seventh-degree polynomial (standard setting) \([\text{MP7415.0} = 3]\)

  - **Rounding of Contour Transitions**
    - Do not round the contour transition \([\text{MP7415.1} = 0]\)
    - Round the contour transition \([\text{MP7415} = 1]\)

**Constraints:**

- Permissible contour deviation \(T\)
- Minimum length \(E\) of a contour element
General Motion Control Platform

Before

CPU Card
HMI Module
Motion Module
Motion Control Chip

Now

CPU Card
HMI Module
CPU
Motion Module
Digital Motion Control Chip

Dedicated CPU for Motion Module
Hardware Design

- **ITRI CNC Controller**
  - Before: IPC card + Motion control card
  - Now: IPC Card + Motion Control Card

- **SOC-based Precision Motion Control Card**
- **Dual-CPU Dual-OS CNC Controller**

Before:
- High cost, bulky, poor stability,

Now:
- Low cost, small size, good stability,
Software Design

- IPC’s CPU for HMI
- Motion control card’s CPU for motion control kernel

Feature:
1. Integration of motion control chip, SOC and IPC card in a SOC-based CNC control device

Feature:
2. Integration of motion control kernel, axes control with FIFO, PLC and HMI communication interface
Dual-CPU Dual-OS CNC Controller

- GMC Controller (Half-Size Rack)
  - GMC Motion Control Card
  - IPC Card
  - 3D Accelerated Graphics Card

Option: 3D simulation with 3D acceleration graphics card
Controller Hardware Architecture

- **Compact Package**
  - 15” Industrial touchscreen
  - M100Touch controller
  - Operation panel and full-key keyboard
  - Handwheel control
  - Adapter plate
  - GMC motion control card
  - Universal/Serial servo system
Machine Center Controller

1. Spindle System
2. Feed System
3. Controller Rack
4. Controller Hardware
5. Controller Software
6. Electronic Control Applications
High-speed High-precision Control

- Milling for Die and Mold
  - High-speed high-precision contouring control
  - Look-ahead 1000 Blocks
  - S-curve ACC/DEC
  - IPO time 1.0ms
  - Automatic Feedrate Control (Deceleration based on the feedrate difference at a corner)
  - B-spline and nano interpolation

- Tapping
  - Rigid tapping
  - Zero phase error tracking control

Rigid Tapping: 8000 rpm, M3
Tapping condition
Five-axis Precision Interpolation Control

Five-axis Machining
- Supported three types (TTTRR, RTTTR, RRTTT)
- Tool center point control
- Virtual tool axis retract
- Tool posture control
- Tilted working plane machining
- Rotary axes error compensation
- Workpiece setting error compensation
- 3D online anti-collision
- 3D machining simulation
Turn-mill Multi-tasking Control

- Turn-mill Machining
  - Dual-spindle simultaneous control
  - Dual system of turn-mill
  - X and C axes milling synchronously
  - Inside/outside diameter turning
  - Indexing control of the B-axis
  - Virtual Y-axis function
Industrial ROBOT Control

- Six-axis Architecture Robot
  - Kinematics and singular points estimation
  - Point to point, line/circular interpolation
  - Coordinate maintenance for Cartesian, Joint and Tool
  - All-digital series servo system and absolute coordinate
  - Modes for teach-in, programming, guidance
  - PLC embedded
  - Virtual robot-machine simulation
    - Collision warning module
    - Part set ready module
    - Fixture set ready module
    - 3D motion simulation module
Friendly, Open Man-machine Interface

- Coordinate display
- PLC ladder and IO status
- Intuitive touchscreen
- 3D machining
- Customized software
- Common Info and toolbar
- Laser measurement
- Parameter and search
FANUC Controller Architecture

- FANUC 30i
  - FSSB link servo and spindle
  - Synchronous error reduction between rigid tapping servo and spindle
  - FSSB: Fiber+ECC (Error Correction Code)
FANUC 30i Series

Feature

- 64-bit RISC micro processor chip
- AI nano contouring control
- AI high precision control
- HRV4 (High Response Vector 4) control

- CNC: 10 paths, 40 axes (32 servo axes, 8 spindles)
- PMC: dedicated processor and dedicated LSI, max. supported for five paths
- Servo: DSP-base servo processor and high-speed FSSB protocol
- Lookahead: 1000 blocks

FANUC AI nano control system
FANUC 30i Series

Feature

◆ AI nano contouring control
  - reduction position lag due to acc/dec and servo lag

◆ Smooth TCP
  - stable/high precision machining process

◆ Five-axis machining function
  - TCP/tilted work plane/TPC

◆ Adaptive predictive control (APC)

◆ SERVO GUIDE tuning software

◆ 3D interference check

◆ CIMPLICITY i CELL
  - multiple CNC network management
MITSUBISHI Controller Architecture

- M700V
MITSUBISHI M700V Series

Specification
- 64-bit CPU
- Windows Xpe OS
- 1nm system resolution
- Nano control/nano interpolation
- High gain control II
- **CNC**: 4 paths, 16 controlled axes (16 servo axes, 6 spindles)
- **Lookahead**: 2000 blocks

MITSUBISHI complete nano control system

Photo Taken From: MITSUBISHI
MITSUBISHI M700V Series

Feature

◆ Complete nano control
  - reduce speed variation
  - improving interpolation precision
◆ Super smooth surface control (SSS)
  - Stable/high-precision machining process
◆ Five-axis machining function
  - TCP/tilted work plane/TPC
◆ High-speed synchronous tapping (OMR-DD)
◆ Optimal feedforward control (OMR-FF)
◆ 3D interference check
◆ NAVI MILL/LATHE
  - user friendly programming function
    with simple operation
◆ Online teaching function
SIEMENS TIA

- Totally Integrated Automation

- SIMOTION
  - Motion Control System

- SINUMERIK
  - Computer Numerical Control

- SIMATIC Controllers
  - Modular/Embedded/PC-based
SIEMENS Sinumerik System

- **SINUMERIK CNC**
  1. CNC HMI
  2. CNC controls
  3. CNC Operate
     - ShopMill
     - ShopTurn
  4. SINUMERIK Safety Integrated

Photo Taken From: SIEMENS
SIEMENS CNC Controls Architecture

1. HMI(MMC)
2. NCU
3. PLC

Numerical control unit
Drive unit

Photo Taken From: SIEMENS
SIEMENS 840D Architecture

Three CPUs:
1. MMC-CPU
2. NC-CPU
3. PLC-CPU

Four software:
1. MMC
2. NC
3. PLC
4. communication/drive interface
SIEMENS NC Control and Servo

- **840D + 611D**

- System control and display module
- Power module I/R
- Control module
- Servo drive module 611D

- PCU50
- Windows
- Operator panel/keyboard/handwheel
- NC+PLC

- Drives
- Spindle motor
- Feed motors

Photo Taken From: SIEMENS
SIEMENS Controller Structure

840D + 611D

- Reference position
- Reference speed
- Position feedback
- Calculation speed
- Current feedback
- Input of the measuring system
- Motor and SM
- Power section
- Regulator speed
- Interpolator
- Position loop
- Pret / Prif
- Nret / Nrif
- Iret / Irif
- Risp. in freq. reg. position
- Risp. in freq. reg. speed
- Risp. in freq. of the system
- Risp. in freq. reg. corr.
SIEMENS 840 Series

Specification

- 32-bit micro processor (828D: 80 bits nano precision floating operation)
- High-speed and high-precision
- NC file compressor
- Acc/dec feedforward control for contouring error suppression
- Jerk limit control for surface quality
- Active vibration control
- CNC: 10 paths, 31 controlled axes (12 servo axes, 12 spindles)
- Lookahead: 500 blocks

SIEMENS SINUMERIK control system
SIEMENS 840D sl Series

Feature

- Advanced surface control
  - high order surface + Look-ahead
  - High contouring precision
- ShopMill/ShopTurn sequence programming editor
  - Flexible readability editor language
  - Flexible machining combined cycle
- Five-axis machining function
  - TRAORI/ CYCLE996/CYCLE800
- High-speed machining function (CYCLE832)
  - Speed/accuracy/surface auto adjustment
- Dynamic Stiffness Control (DSC)
SIEMENS Simulation and Validation

- **Virtual NC Kernel (VNCK)**
  - Machining process graphic simulation/verification

- **Mechatronic Support**
  - Mechatronics design and development
  - Dynamic response analysis
  - Optimal control parameters
  - Shorten process development
HEIDENHAIN Controls Architecture

 iTNC 530

Photo Taken From: HEIDENHAIN
HEIDENHAIN iTNC530 HSCI Series

- Specification
  - 32-bit micro processor
  - MC 6341 main CPU - Pentium Dual Core with 2.2GHz processor
    - Machine Controlled: HEIDENHAIN dedicated real-time OS(HeROS 5)
    - Man-machine interface: Windows 7 OS
  - CC 6110 control unit - DSP
  - CNC: 1 path, 20 controlled axes (3 rotary axes, 2 spindles)
  - Lookahead: 1024 blocks

HEIDENHAIN contouring control system
Feature

- SmarT.NC programming editor
  - dialogue without remembering G-code

- DXF converter
  - DXF files imported to direct generate NC file

- Five-axis machining function
  - tool center point management/tilted plane/five-axis errors measurement and compensation

- Dynamic collision monitoring technology (DCM)
  - real-time multi-axis machining interference collision inspection

- Adaptive feedrate control (AFC)
  - machining time reduction
  - tool monitoring
  - machine failure rate reduction
FIDIA Controller Architecture

- C20/C40

Photo Taken From: FIDIA
FIDIA C40 Vision Series

- **Specification**
  - 32-bit micro processor
  - Two independent processors
  - 400 MHz RISC Power CPU
  - Real-time motion control
  - 3.4GHz Intel Core i7 Quad core CPU, Window 7 Ultimate 64bit
  - Man-machine interface management
    - **CNC**: 1 path, 32 controlled axes
    - **Lookahead**: 1000 blocks

FIDIA new age control system
FIDIA C40 Vision Series

Feature

◆ LookAhead(L.A. FIVE) auto tuning function
  - machine types, workpiece types, machining demand (rough, semi-finishing, finishing)

◆ Five-axis machining function
  - RTCP/tilted plane/virtual tool axis

◆ Look Ahead Virtual Milling Simulation

◆ HI-MILL - 3D CAM

◆ PLP – copying function

◆ HMS rotary axes measurement system
Thank You for Your Attention!

The End