IE360: CAD/CAM

Computer Aided Design and Computer Aided Manufacturing

Lecture (9)

Introduction to Numerical Control (NC)

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CAM Part Outline

- Introduction to Numerical Control (NC) (one lecture)
  - Basic definitions and historical developments
  - Hardware configuration of NC machine tools
  - Classification of NC machine tools
  - Fundamentals of NC machine tools
  - Advantages and limitations of NC machine tools
  - Applications
- Part Programming (four lectures)
  - Basic concepts of part programming
  - Manual part programming
  - Computer-assisted part programming
  - Part programming from CAD database
- Group Technology (one lecture)
  - Group technology techniques

Basic definitions:

- Numerical control (NC) refers to the use of a prepared program (called a part program) consisting of coded alphanumeric data to automatically control the functions and motions of a machine tool.

- The program is a set of statements that can be interpreted by the machine control system and converted into signals that move the spindles and drives of the machine tool.

- It contains geometric information about the part and motion information to move the cutting tool with respect to the workpiece.

- Cutting speed, feed rate, and auxiliary functions such as coolant on/off and spindle direction are also specified in the part program to meet the required surface finishes and tolerances.

Historical Developments:

- The first successful electronically programmed automatic machine was a joint project between Massachusetts Institute of Technology (MIT) and the US Air Force in the mid 1950's. It was a three axis milling machine controlled by a room full of vacuum tube electronics. Even though it was unreliable, it set the stage for modern machines. The controller was called NC.

- In the 1960's, computer numerical control (CNC) machines became available with timesharing on mainframe computers. True NC machines continued to be built.

- By the 1970's, specialized computers were being manufactured for CNC controls. By the late 1970's, no true NC machines were being made, only CNC.

- During the 1980's, many machine manufactures took advantage of PC technology to increase the reliability and decrease the cost of CNC controls.

- Today, all machines are CNC although the term NC is still used, but not in its original definition.

Hardware configuration of NC machine tools:

In general, there are three basic components of an operational NC machine tool (as illustrated in Figure 2):

- Programme of instruction.
- Machine control unit.
- Machine tool.

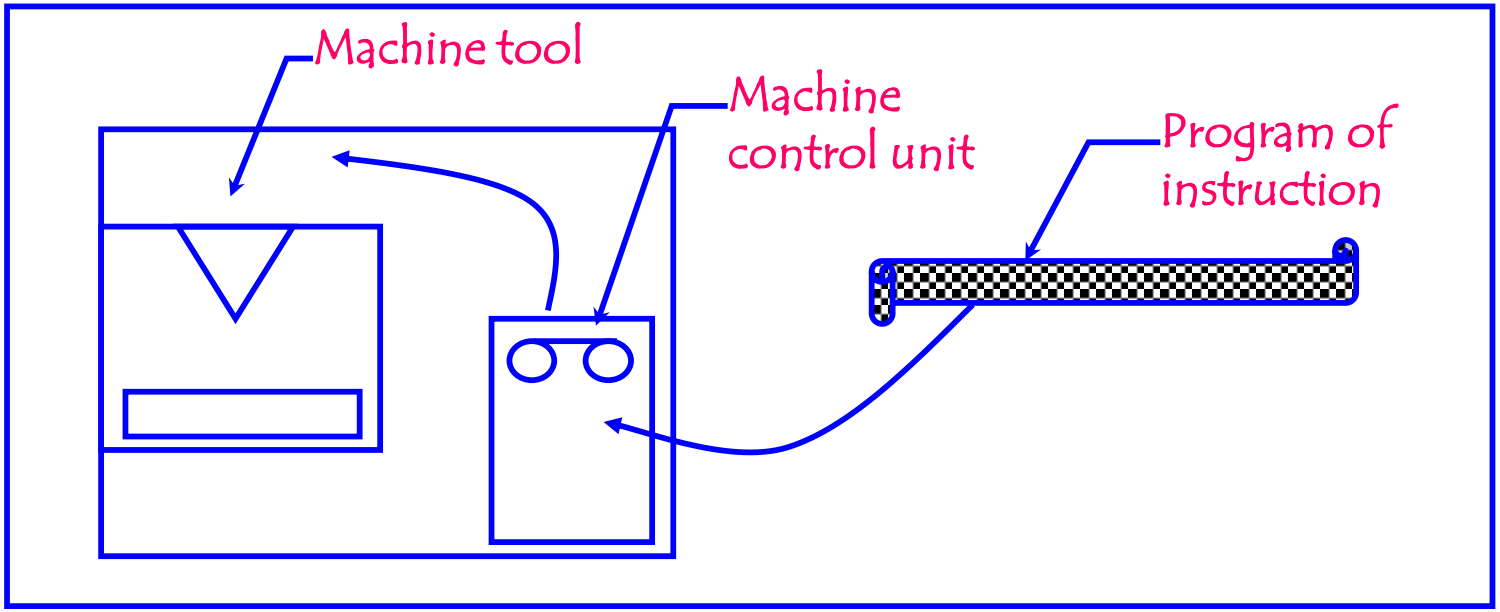


Figure 2: Schematic of a NC machine tool.

The program of instruction is a numerical or symbolic code that is detailed step-by-step to tell the machine tool what to do.

The Machine Control unit (MCU) consists of two units: the *data processing unit* (DPU) and the *control loop unit* (CLU). The DPU reads and decodes the programme of instructions and provides data to the CLU which converts it to signals to control the real movement of a machine tool. Two basic types of MCU are used with NC machines: open-loop control and closed-loop control.

The machine tool performs the mechanical work and deals directly with the part being machined.

Classification of NC machine tools :

- Classification according to type of machining:
  - Point-to-point (PTP) NC machining: In PTP machining, the cutting tool performs operations on the workpiece at specific points. The tool is not always in contact with the workpiece throughout its motion or its path. An obvious example is a drilling operation.

  - Continuous-path (contouring) machining: Unlike PTP machining, the cutting tool is always in contact with workpiece in continuous-path machining. The entire travel of the cutting tool must be controlled to close accuracy both as to position and velocity. As a result, the control unit for a continuous path machine is more complicated and expensive than for a PTP machine. Milling operations provide an example of continuous machining.

Classification of NC machine tools :

- Classification according to the structure of the machine control unit (MCU):
  - NC machine tools: In a NC machine tool, the DPU is a tape reader. Each time the NC program needs to be executed to machine a new part, the punched tape must be read via the tape reader.
  - CNC machine tools: In a CNC machine tool, a computer is joined to the NC machine to make it versatile. Information can be stored in a memory unit and, therefore, a part program needs to be loaded into the MCU only once. Some CNC machines have display monitors to facilitate visual editing of part programs by the operator and provide diagnostic analysis. More sophisticated machines can also display the tool path for graphical verifications. Figure 3 illustrates the general configuration of CNC.

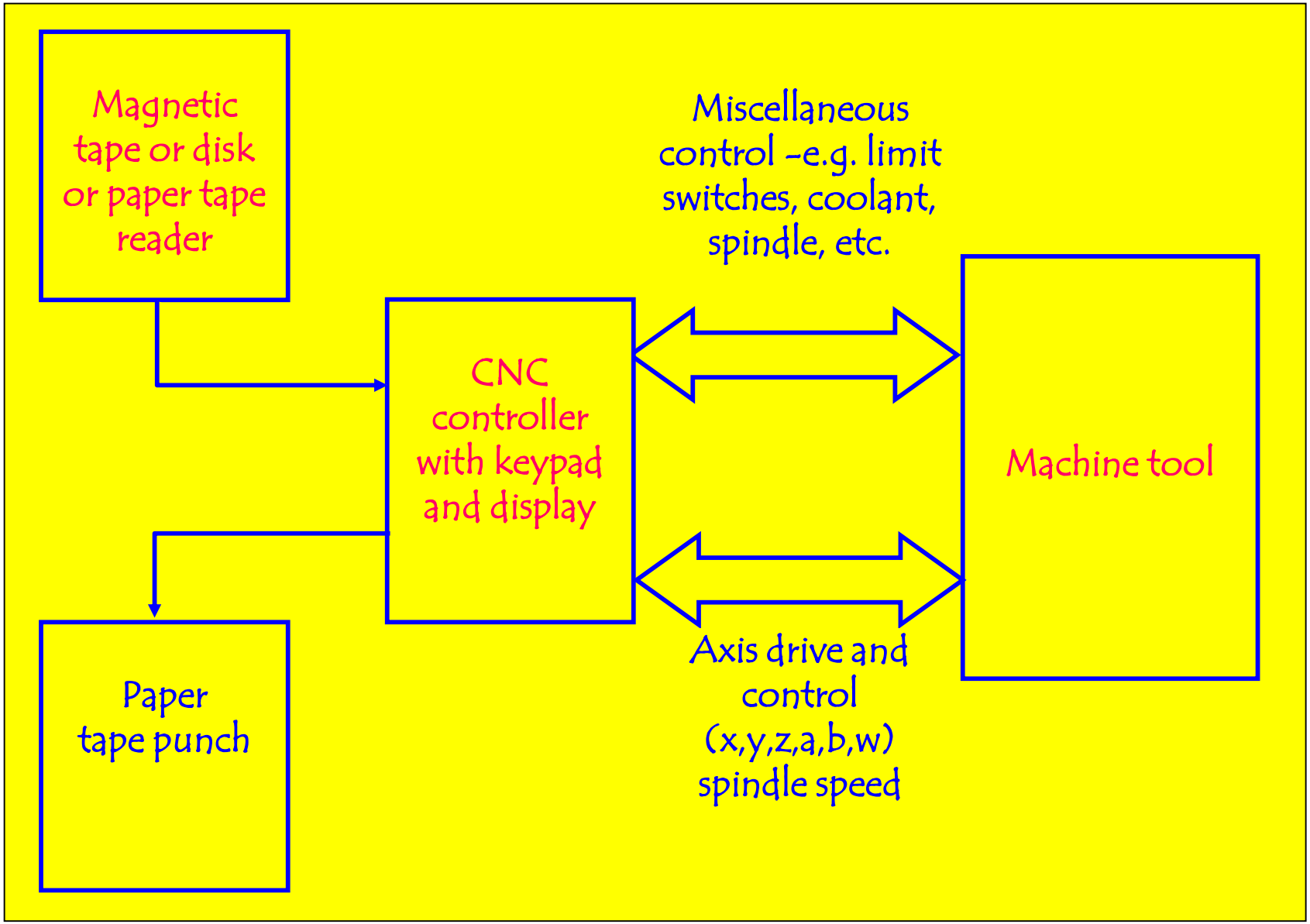


Figure 3: The general configuration of CNC machine tools.

- Direct numerical control (DNC) machine tools: DNC refers to a manufacturing system that uses a central computer to simultaneously control several machines that are connected via a communication network, as illustrated in Figure 4. In DNC, the host computer stores the NC part programs and downloads these programs to the CNC machine tools to produce the desired part. This technique relies on the central computer to serve the machine tools.

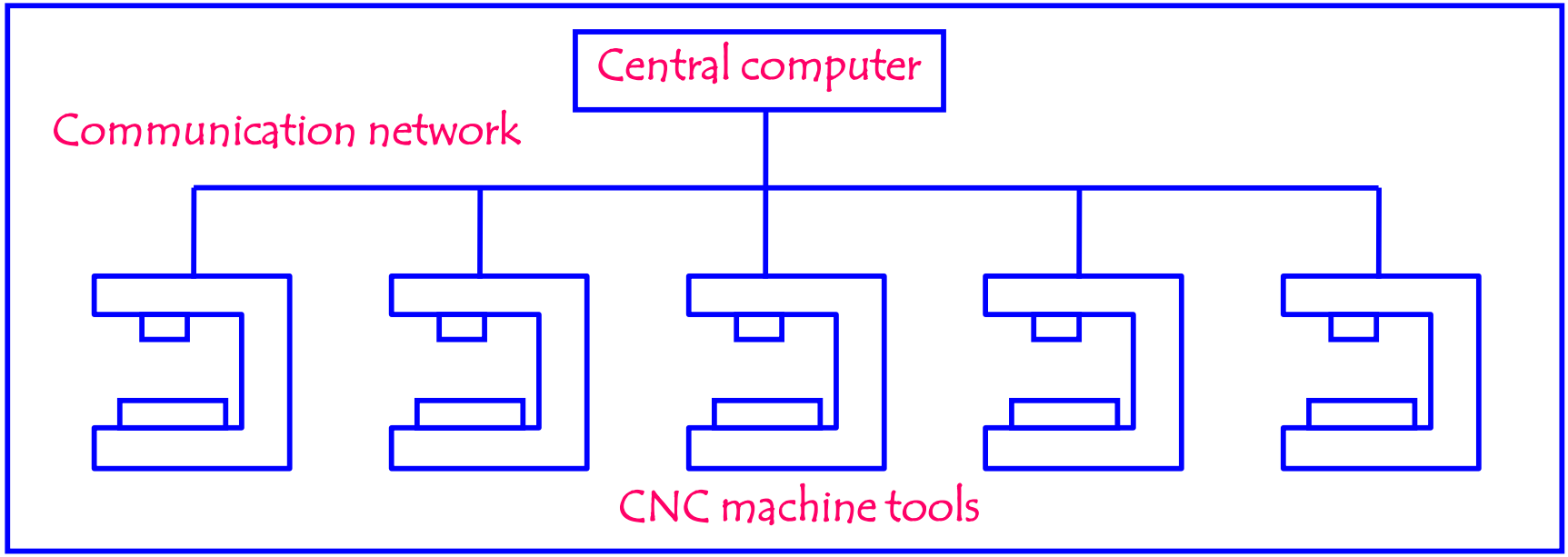


Figure 4: Schematic of DNC machine tools.

- Distributed numerical control machine tools:
  - In distributed NC, the central computer downloads complete programs to CNC machines.
  - These machines may hold one or more programs in their local storage and thus are independent of the central computer.
  - In some distributed NC systems, a satellite computer local to each NC machine can be inserted to increase the speed of the entire system, to handle laege computer files, and to expand the number of machine tools used. This configuration is illustrated in Figure 5.

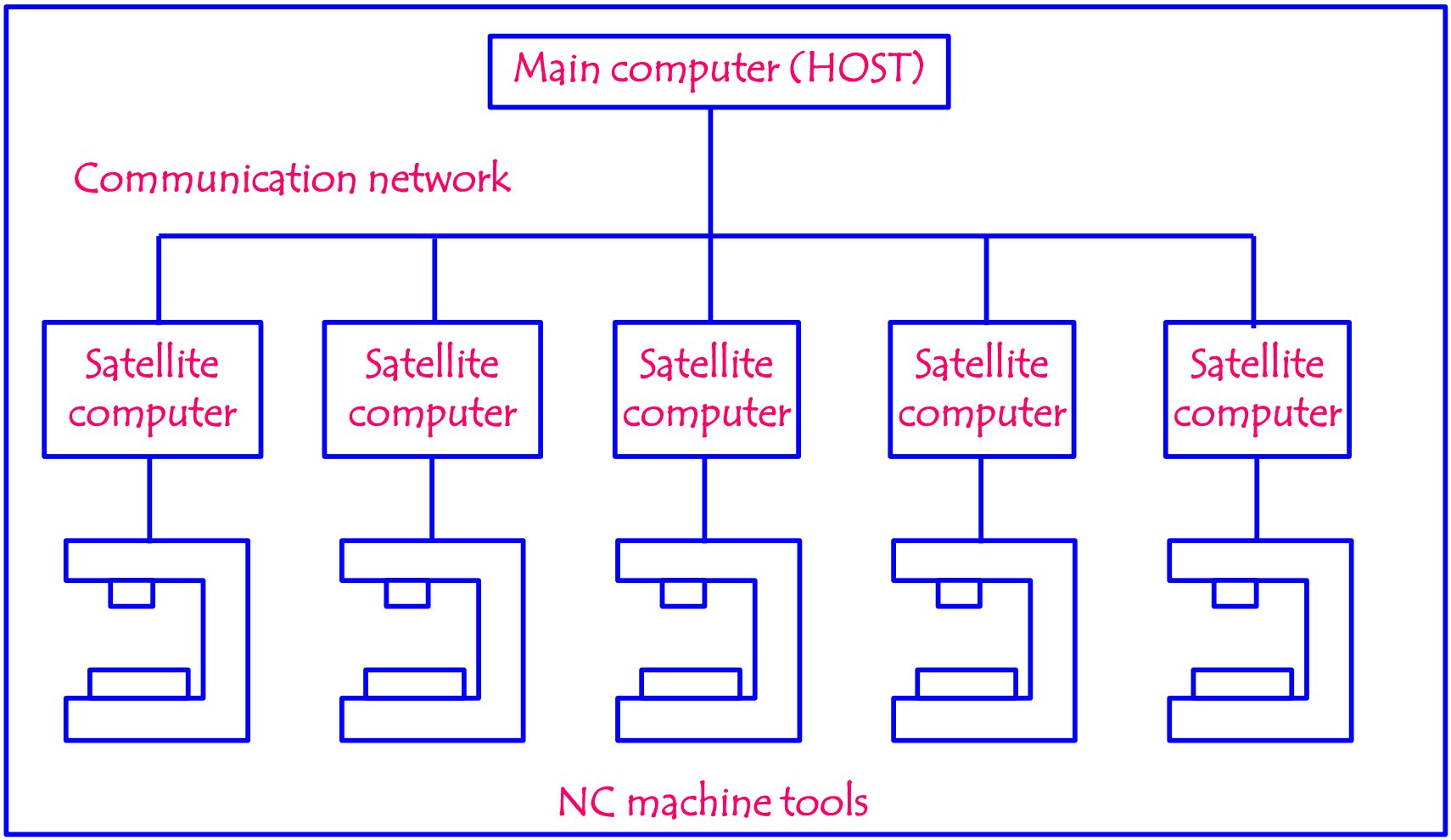


Figure 5: Distributed NC configuration, using satellite computers.

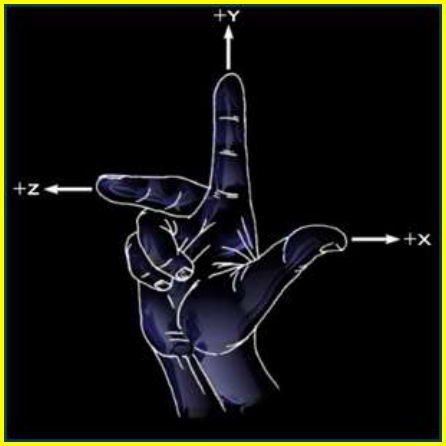
Fundamentals of NC machine tools – Motions of machine tools:

- A workpiece is machined to the finished shape by allowing a relative motion between the workpiece and the cutting tool.
  - Such relative motion can be provided by holding the workpiece stationary and moving the cutting tool as in milling and drilling, or by moving the cutting tool and the workpiece simultaneously as in turning.

  - Each motion requires its own axis of motion. An axis of motion is defined as an axis where relative motion between the cutting tool and workpiece occurs. This movement is achieved by the motion of the machine tool table (slides).

Fundamentals of NC machine tools – Motions of machine tools:

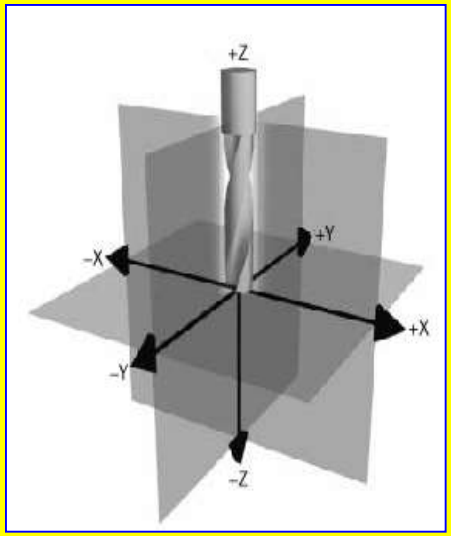
- The primary three axes of motions are referred to as the *x*, *y* and *z* axes, which form a **right-hand coordinate system**.



- The positive directions of the axes are usually defined by the manufacturer of the machine tool.
- However, it is a convention that the positive direction of the *z* axis moves the cutting tool away from the workpiece.

Fundamentals of NC machine tools – Coordinate system:

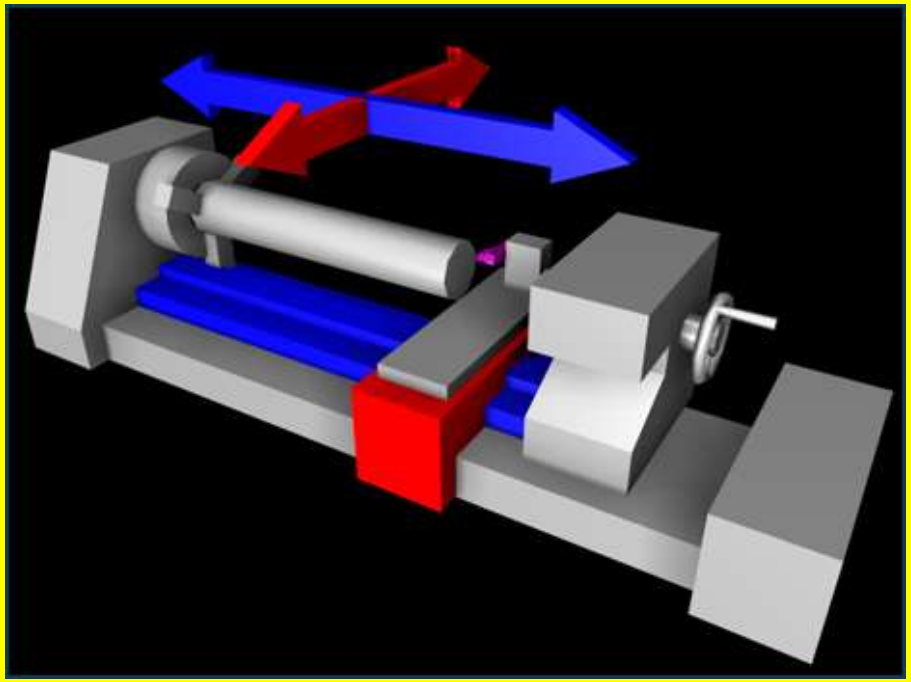
- Most of the existing machine tools use **Cartesian coordinate systems**.

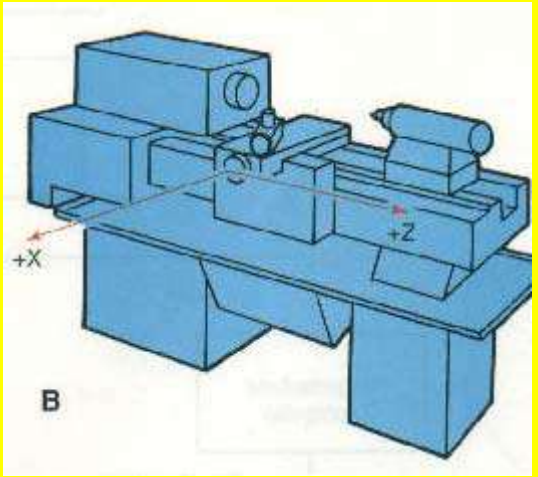


- The origin and orientation of these systems are usually provided by the manufacturer of the machine tool.

- The coordinates systems are used to instruct the machine tool where to move on the workpiece.

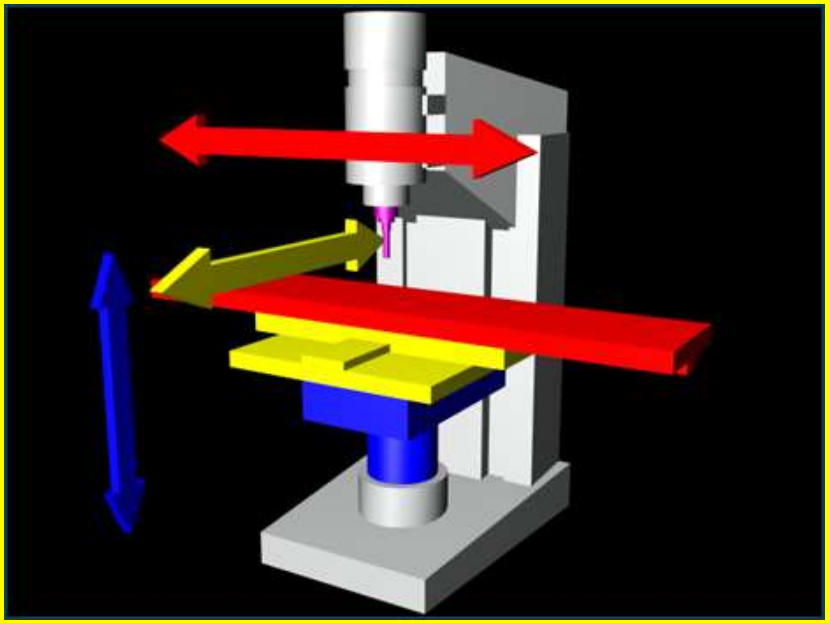
Fundamentals of NC machine tools – Axis and motion nomenclature :

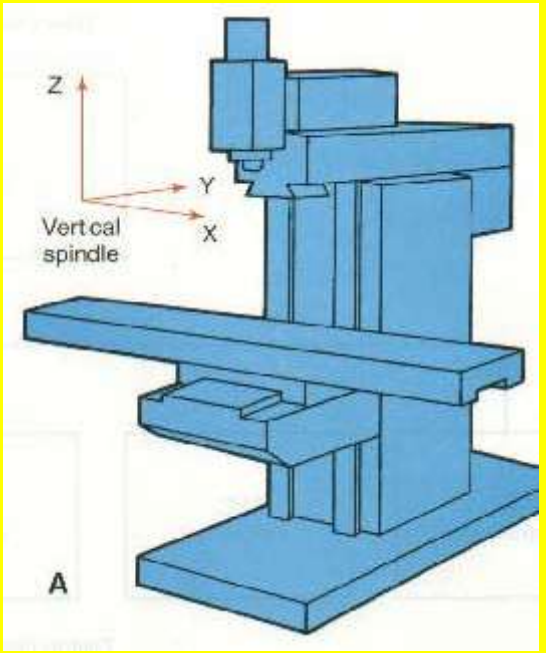




- On most *CNC lathes* the ***z* axis** is parallel to the spindle and the ***x* axis** is in the direction of tool movement. Motions in the positive ***z*** and ***x*** directions move the tool away from the workpiece.

Fundamentals of NC machine tools – Axis and motion nomenclature :





- On a vertical milling CNC machine, ***z* axis** is parallel to the tool axis and a motion in the positive ***z*** direction moves the tool away from the workpiece. The positive ***x* axis** points to the right when facing the machine. The *y* axis is determined from the ***x*** and ***z*** axes such that the ***xyz*** coordinate system forms a right-hand coordinate system.

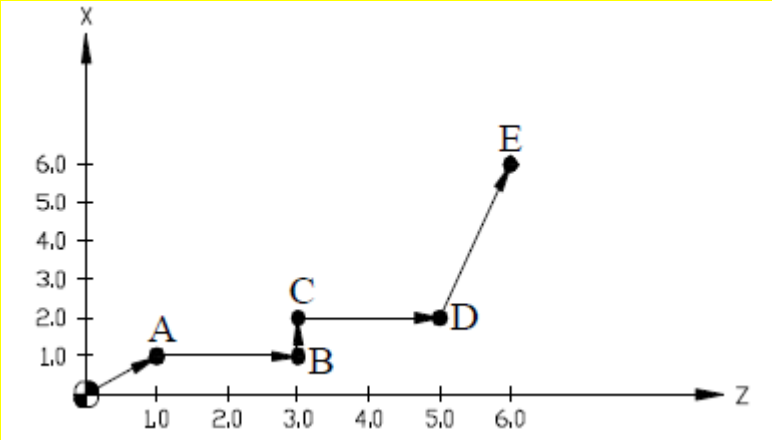
Fundamentals of NC machine tools – Incremental vs. absolute coordinates:

- Suppose we want to move from the origin through points *A*, *B*, *C*, *D*, and *E*. We can move:

• incrementally – each move is the distance from the previous point, or

• absolutely – each move is the distance from the origin.

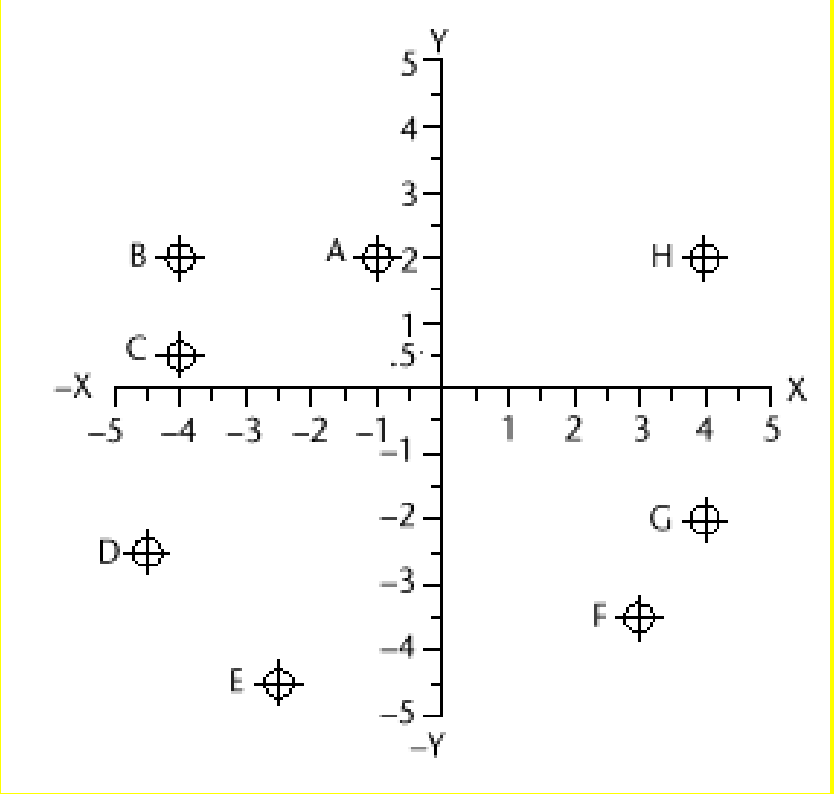
	Incremental		Absolute	
Point	Z	X	Z	X
Origin	0	0	0	0
A	1	1	1	1
B	2	0	3	1
C	0	1	3	2
D	2	0	5	2
E	1	4	6	6



Fundamentals of NC machine tools – Incremental vs. absolute coordinates:

- EXERCISE 1: Fill in the X and Y blanks with the appropriate **absolute coordinates** for points A through H.

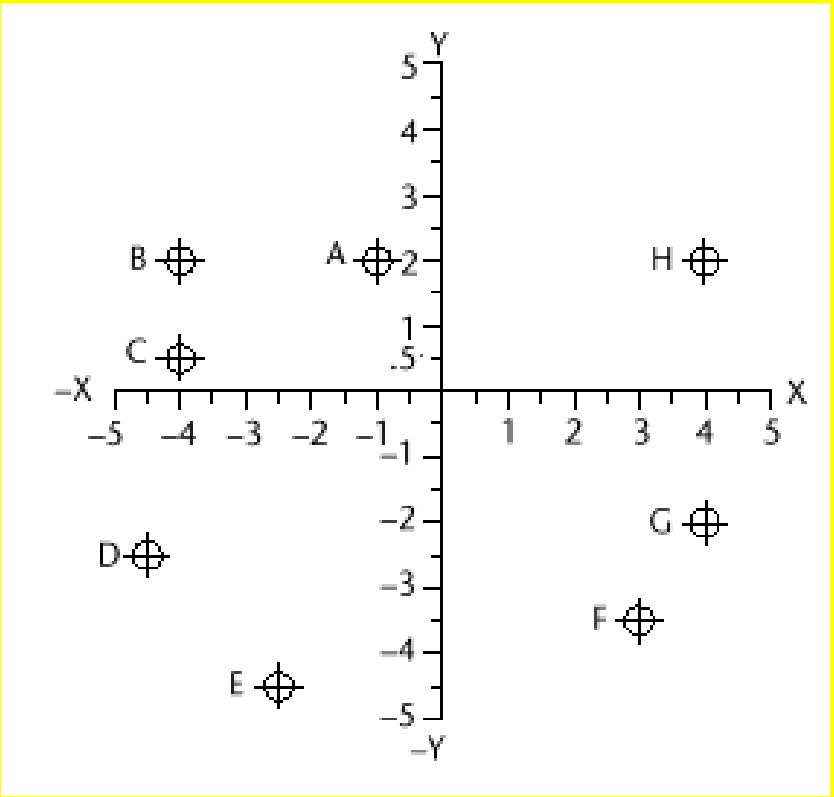
A: X_____, Y_____
B: X_____, Y_____
C: X_____, Y_____
D: X_____, Y_____
E: X_____, Y_____
F: X_____, Y_____
G: X_____, Y_____
H: X_____, Y_____



Fundamentals of NC machine tools – Incremental vs. absolute coordinates:

- EXERCISE 2: Fill in the X and Y blanks with the appropriate **incremental coordinates** for points A through H.

A: X_____, Y_____
B: X_____, Y_____
C: X_____, Y_____
D: X_____, Y_____
E: X_____, Y_____
F: X_____, Y_____
G: X_____, Y_____
H: X_____, Y_____



Advantages of CNC machine tools:

1. Increased productivity.
2. High accuracy and repeatability.
3. Reduced production costs.
4. Reduced indirect operating costs.
5. Facilitation of complex machining operations.
6. Greater manufacturing flexibility.
7. Improved production planning and control.
8. Lower operator skill requirement.
9. Facilitation of flexible automation.

Limitations of CNC machine tools:

1. High initial investment.
2. High maintenance requirement.
3. Requirement of skilled part programmers.
4. Not cost effective for low production levels.

Applications :

Machine tool applications:

1. Milling machines.
2. Drilling machines.
3. Boring machines.
4. Turning machines.
5. Grinding machines.
6. Sawing machines.

Non- machine tool applications:

1. Welding machines - flame cutting machines.
2. Press-working machines - assembly machines.
3. Inspection machines - automatic drafting machines.