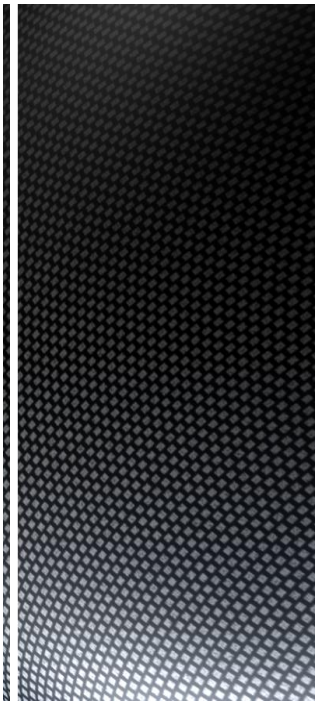


CAD/CAM (21-342)

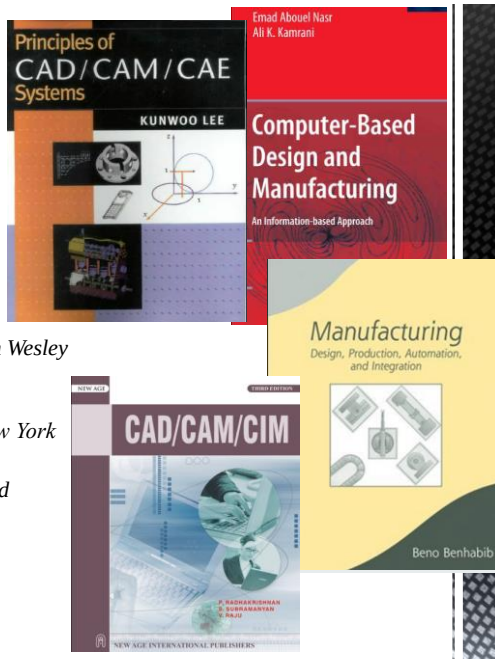
Advanced Manufacturing Laboratory
Department of Industrial Engineering
Sharif University of Technology

Session # 19

Course Description

- *Instructor*
  - *Omid Fatahi Valilai, Ph.D. Industrial Engineering Department, Sharif University of Technology*
  - *Email: FValilai@sharif.edu , Tel: 6616-5706*
  - *Website: Sharif.edu/~fvalilai*
- *Class time*
  - *Saturday- Monday* *10:30-12:00*
- *Course evaluation*
  - *Mid-term* *(25%)*
  - *Final exam* *(40%)*
  - *Quiz* *(5%)*
  - *Exercise* *(30%)*

Course Description *(Continued ...)*



- *Mid-term session:*
  - *Monday: 8th Ordibehesht 1393, 10:30 ~ 12:30*
- *Final Exam:*
  - *Saturday: 24th Khordad 1393, 15:00 ~ 17:30*
- *Reference:*
  - *Lee, Kunwoo; "Principles of CAD/CAM/CAE systems", 1999, Addsion Wesley*
  - *Abouel Nasr, Emad; Kamrani, Ali K.; "Computer-Based Design and Manufacturing: An Information-Based Approach", 2007, Springer, New York*
  - *Benhabib, Beno; "Manufacturing: Design, Production, CAD/CAM, and Integration", 2003, Marcel Dekker Inc, New York*
  - *Radhakrishnan, P.; Subramanian, S.; Raju, V.; "CAD/CAM/CIM", 3rd edition, 2005, New age international (P) limited publishers, New York*

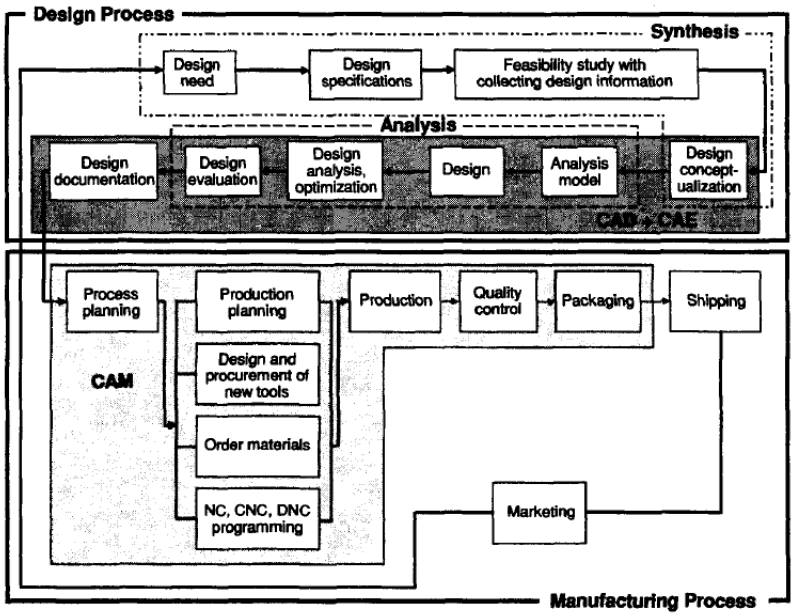
Course Description *(Continued..)*

- *Contents:*
  - *Introduction to CAD/CAM/CAE systems* *(5 sessions)*
  - *Components of CAD/CAM/CAE systems* *(2 sessions)*
  - *Geometric modeling systems* *(3 sessions)*
  - *Optimization in CAD* *(5 sessions)*
  - *Rapid prototyping and manufacturing* *(3 sessions)*
  - *Virtual engineering* *(2 sessions)*
  - *Product Life Cycle Cost Model* *(2 sessions)*
  - *Computer-Based Design and Features/Methodologies of Feature Representations* *(5 sessions)*
  - *Feature-Based Process Planning and Techniques* *(3 sessions)*
  - *Collaborative Engineering* *(2 sessions)*

Course Description *(Continued..)*

- *Contents:*
  - *Feature-Based Process Planning and Techniques* *(3 sessions)*
    - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Introduction to CAD/CAM/CAE systems



Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *After extracting the manufacturing features from the designed part, it is necessary to map all the extracted manufacturing features to the process planning point of view as an application of CAM.*
    - *It is necessary to determine the detailed machining information for each feature and the designed part by identifying:*
      - *The operation sequence of the designed part,*
      - *The operation type,*
      - *The machine,*
      - *The cutting tool,*
      - *The tool approach/machining direction, and*
      - *The removed machining volume for each feature.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining operations*

    The main objective of any machining operation is to create the required shape of the designed part by removing the excess material from the work piece in form of chips.
      - *Turning,*
      - *Milling,*
      - *Drilling,*
      - *Grinding,*
      - *Broaching and*
      - *Sawing.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*

No.	Feature	Operation Type	Machine	Cutting Tool
1	Step Through	Shoulder_Milling	Milling	Side Milling Cutter
2	Slot Through	Slotting_Milling	Milling	End mill Cutter
3	Step Blind	Shoulder_Milling	Milling	Side Milling Cutter
4	Slot Blind	Slotting_Milling	Milling	End Milling Cutter
5	Pocket Through	Pocket_Milling	Milling	End Milling Cutter
6	Pocket Blind	Pocket_Milling	Milling	End Milling Cutter
7	Hole Through	Drilling	Drilling	Twist Drill
8	Hole Blind	Drilling	Drilling	Twist Drill
9	Step Through RC	Shoulder_Milling	Milling	Corner Rounding Milling Cutter

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Sequence Procedure*
    - *Machining Direction Procedure*
    - *Machining Information Procedure*

Feature-Based Process Planning and Techniques

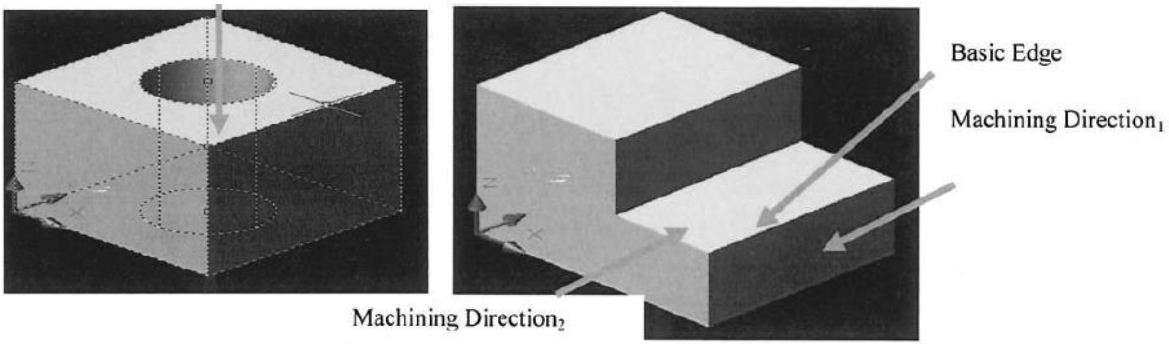
- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Sequence Procedure*
    - *For each feature recognized, its origin is designated as the point on the feature closest to the origin.*
    - *Sort all the features based upon the z coordinate (in descending order) of their respective origin.*
    - *The feature with the highest z value will be the first in machining sequence and the feature with the lowest z value will be the last in machining sequence.*
    - *Multiple features with same z value of their origin will be machined in the sequence in which they were originally recognized.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Direction Procedure*
      - *Each feature has a different machining direction based on its design and orientation.*
      - *When a feature is recognized, its machining direction is also identified based on the directions that are available for machining that feature and also the orientation of the feature.*
      - *The directions are identified using crucial edges as references in every feature.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Sequence Procedure*
    - *Steps of machining direction procedure are addressed:*



Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Information Procedure*
    - *This procedure addresses how the machining operations, machines, and tools associated for each recognized feature are identified*
      - *A map of features to machining information is defined.*
      - *The program uses this map to associate each feature to the machining operations involved in creating that feature.*
      - *The mapped machining operations will indicate the machine to be used in machining the feature.*
      - *The program also map machining operations to tools that will be used with each such machining operation.*
      - *The machining volume (V) for each extracted manufacturing feature is calculated.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*

No.	Feature	Operation Type	Machine	Cutting Tool
1	Step Through	Shoulder_Milling	Milling	Side Milling Cutter
2	Slot Through	Slotting_Milling	Milling	End mill Cutter
3	Step Blind	Shoulder_Milling	Milling	Side Milling Cutter
4	Slot Blind	Slotting_Milling	Milling	End Milling Cutter
5	Pocket Through	Pocket_Milling	Milling	End Milling Cutter
6	Pocket Blind	Pocket_Milling	Milling	End Milling Cutter
7	Hole Through	Drilling	Drilling	Twist Drill
8	Hole Blind	Drilling	Drilling	Twist Drill
9	Step Through RC	Shoulder_Milling	Milling	Corner Rounding Milling Cutter

Feature-Based Process Planning and Techniques

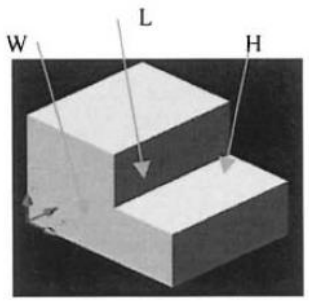
- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Information Procedure*
      - *The machining volume (V) for each extracted manufacturing feature is calculated.*

- *Step through (with round corner)*
- *Slot through (with round corner)*
- *Pocket through (with round corner)*
- *Hole through*
- *Dovetail Slot*
- *Cone*

Step Blind (with round corner)
Slot Blind (with round corner)
Pocket Blind (with round corner)
Hole Blind
V slot
Sink

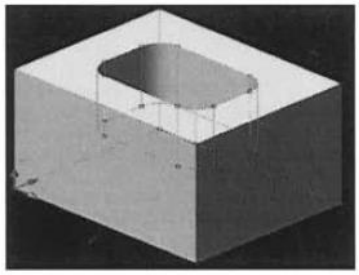
Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Information Procedure*

Step Through		$V = L \times W \times H$

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Mapping the Extracted Manufacturing Features to Process Planning*
    - *Machining Information Procedure*
      - *The machining volume (V) for each extracted manufacturing feature is calculated*

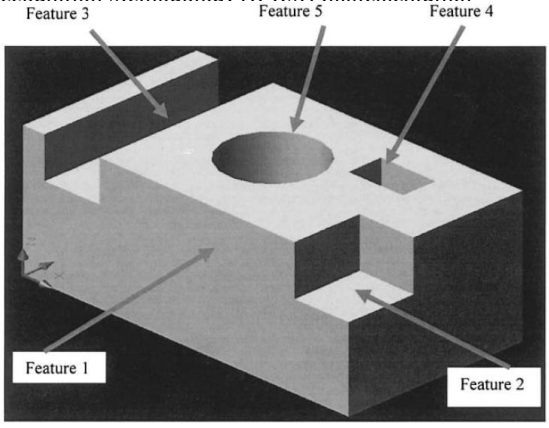
Pocket Blind (Round Corner)		$V=LxWxH-4HxR^2+(\pi)R^2xH$

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*
    - *At first we should generate the geometrical attributes of the designed part by CAD system and save them into a geometrical attributes file.*
    - *Then the feature recognition program will be executed to read and interpret this geometrical attributes and transform them into design information.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*



Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*
    - *Feature's extraction and classifications methodology:*
      - *Extract the geometry and topology entities for the designed object model from IGES file:*
        - *(a) Identify vertices, edges, faces, loops of the object.*
      - *Extract topology entities in each basic surface and identify its type:*
        - *(a) Identify the total number of loops in each surface.*
        - *(b) Identify the basic surface due to total number of loops.*
        - *(c) Classify the loops into different types (concave, convex, and hybrid).*
      - *Test the feature's existence in the basic surface based on loops*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-1. Extraction of vertices

NO.	Vertex ID	Coordinates (X,Y,Z)	NO.	Vertex ID	Coordinates (X,Y,Z)
1	[1]	(19,8,16)	18	[18]	(25,0,16)
2	[2]	(19,8,0)	19	[19]	(30,6,16)
3	[3]	(11,8,16)	20	[20]	(30,0,0)
4	[4]	(11,8,0)	21	[21]	(30,16,0)
5	[5]	(25,13,8)	22	[22]	(30,16,16)
6	[6]	(25,10,8)	23	[23]	(7,16,11)
7	[7]	(20,13,8)	24	[24]	(7,0,11)
8	[8]	(20,10,8)	25	[25]	(2,16,11)
9	[9]	(20,10,16)	26	[26]	(2,0,11)

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-2. Extraction of edges (example 1)

Edge ID	Edge type	Coordinates			Length /Radius	Concavity
		Starting point	Terminate point	Center		
[1]	Line	[1]	[2]		16	Tangent
[2]	Cir. Arc	[3]	[1]	(15,8,16)	4	
[3]	Line	[4]	[3]		16	Tangent
[4]	Cir. Arc	[2]	[4]	(15,8,0)	4	
[5]	Line	[5]	[6]		3	Concave
[6]	Line	[7]	[5]		5	Concave
[7]	Line	[8]	[7]		3	Concave
[8]	Line	[6]	[8]		5	Concave

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-3. Extraction of loops (example 1)

Loop ID	Loop type	Loop category	Face ID	Edge ID
[1]	External	Hybrid	[1]	[1][2][3][4]
[2]	External	Concave	[2]	[5][6][7][8]
[3]	External	Hybrid	[3]	[9][10][11][8]
[4]	External	Hybrid	[4]	[12][13][9][7]
[5]	External	Hybrid	[5]	[14][15][12][6]
[6]	External	Hybrid	[6]	[11][16][14][5]

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-4. Extraction of faces (example 1)

Face ID	Surface Type	Normal Vector	Concavity	Number of Loops	Loop ID
[1]	Surface of revolution		Concave	1	[1]
[2]	Plane Surface (parameterized)	(0,0,1)	Concave	1	[2]
[3]	Plane Surface (parameterized)	(0,1,0)	Concave	1	[3]
[4]	Plane Surface (parameterized)	(0,0-1)	Concave	1	[4]
[5]	Plane Surface (parameterized)	(0,-1,0)	Concave	1	[5]
[6]	Plane Surface (parameterized)	(-1,0,0)	Concave	1	[6]
[7]	Surface of revolution		Concave	1	[7]

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*
    - *Feature's extraction and classifications methodology:*
      - *Identify feature type:*
        - *(a) Identify exterior form features (FFexterior) by searching for the hybrid loop.*
        - *(b) Identify interior convex form features (FFinterior) by searching for the convex loop.*
        - *(c) Identify interior concave form features (FFinterior) by searching for the concave loop.*
      - *Identify the detailed features and extract the related feature geometry parameters:*
        - *(a) Identify feature's details (number of surfaces, surface type).*
        - *(b) Identify the parameters of each feature: length (L), width (W), height (H), radius (R).*
        - *(c) Identify the relative location of each feature due to the origin coordinates of the object.*

Feature-Based Process Planning and Techniques

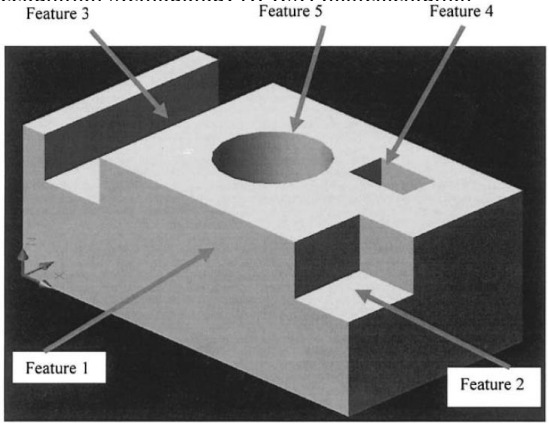
- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-5. Extraction of features (example 1)

Feat. ID	Feature type	Faces ID	Edges ID	Location	Feature name	Dimension L	W	H	R
[1]	prismatic	[11][18][20] [15][18][19]	[29][30][37][40][44] [45][47][49][50][51]	[32] = (0,0,0)	Raw Material	30	16	16	
[2]	$FF_{exterior}$	[8][10][9]	[20][21][23]	[16] = (25,0,10)	Step_Blind	6	6	5	
[3]	$FF_{exterior}$	[13][12][14]	[34][[32]	[26] = (2,0,11)	Slot_Through	16	5	5	
[4]	$FF_{interior}$	[3][4][5][6][2]	[5][6][7][8] [9][12][14][11]	[8] = (20,10,8)	Pocket_Blind	8	5	3	
[5]	$FF_{interior}$	[1][7]	[1][2][3][4] [17][18]	(15,8,0)	Hole_Through	16			4

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*



Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*
    - *Feature's extraction and classifications methodology:*
      - *Identify the detailed machining information for each feature and the designed part:*
        - *(a) Identify the operation sequence of the designed part.*
        - *(b) Identify the operation type, the machine, and the cutting tool for each feature.*
        - *(c) Identify the tool approach/machining direction for each feature.*
        - *(d) Identify the removed machining volume for each feature.*

Feature-Based Process Planning and Techniques

- *Implementation consideration*
  - *Intelligent Feature Recognition Methodology (IFRM) Implementation*

Table 10-6. Machining information (example 1)

Operation sequence	Feature ID	Feature type	Operation type
1	[3]	Slot_Through	Slotting_Milling
2	[2]	Step_blind	Shoulder_Milling
3	[4]	Pocket_Blind	Pocket_Milling
4	[5]	Hole_Through	Drilling

Table 10-6. Machining information (example 1) (cont.)

Operation sequence	Feature ID	Machine	Cutting tool	Tool Approach	Removed volume
1	[3]	Milling	End milling cutter	[0,1,0] or [0,-1,0]	400.00
2	[2]	Milling	Side milling cutter	[-1,0,0] or [0,1,0]	180.00
3	[4]	Milling	End milling cutter	[0,0,-1]	120.00
4	[5]	Drilling	Twist drill	[0,0,-1]	804.25