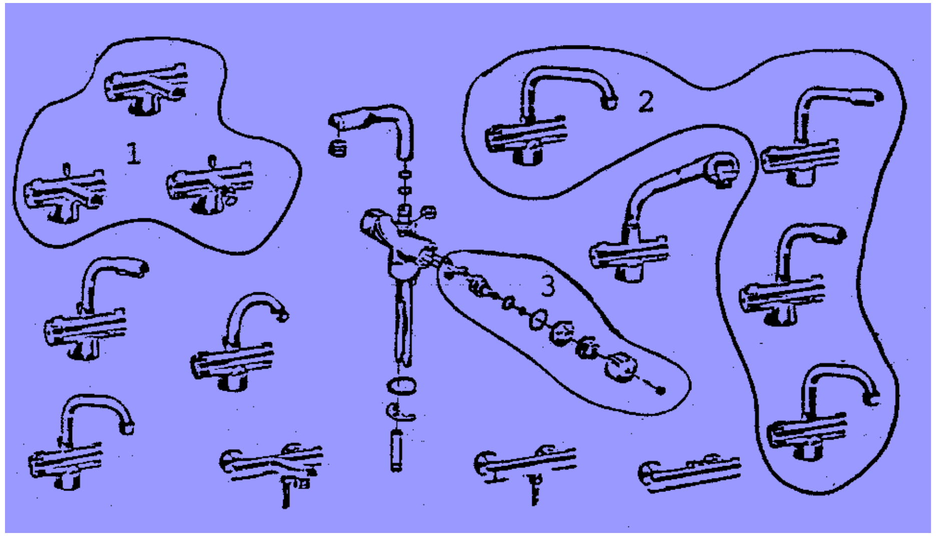
Design of Manufacturing Systems – Manufacturing Cells

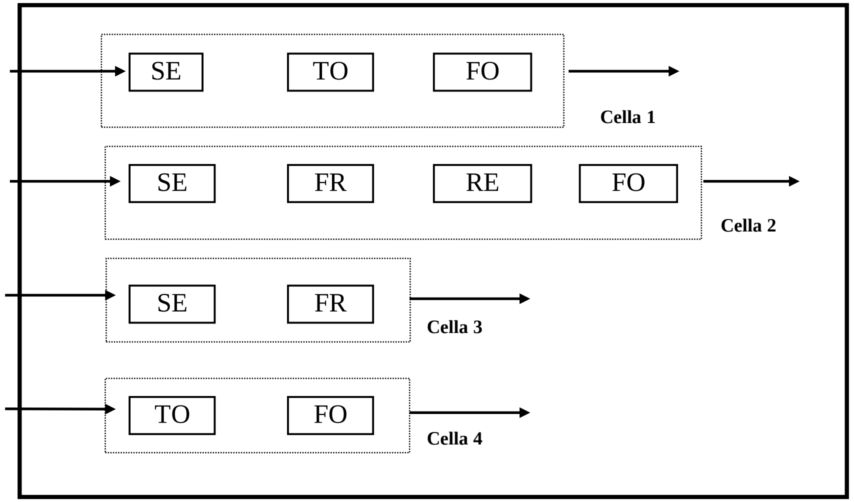
Outline

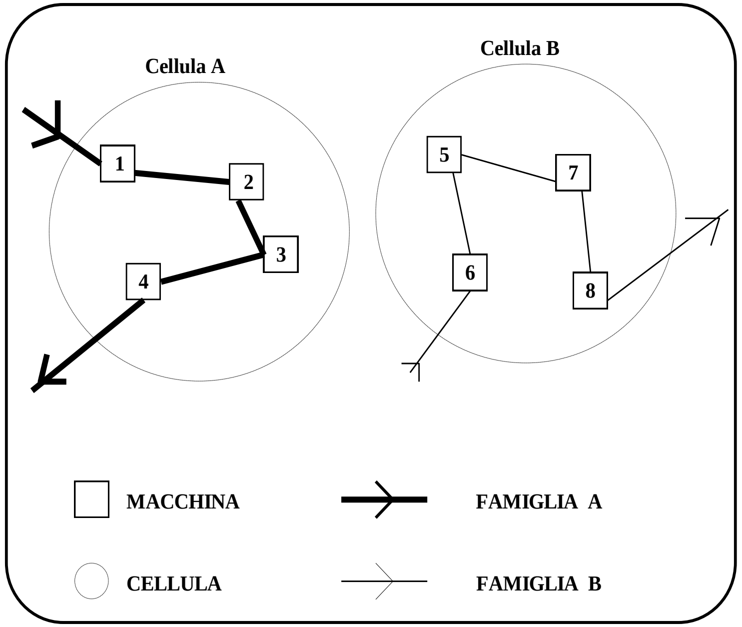
- General features
- Examples
- Strengths and weaknesses
- Group technology – steps
- System design
- Virtual cellular manufacturing

Manufacturing cells – general features



The machines are grouped on the basis of the **processing requirements** of the part families (different technological processes / machines in the same cell).

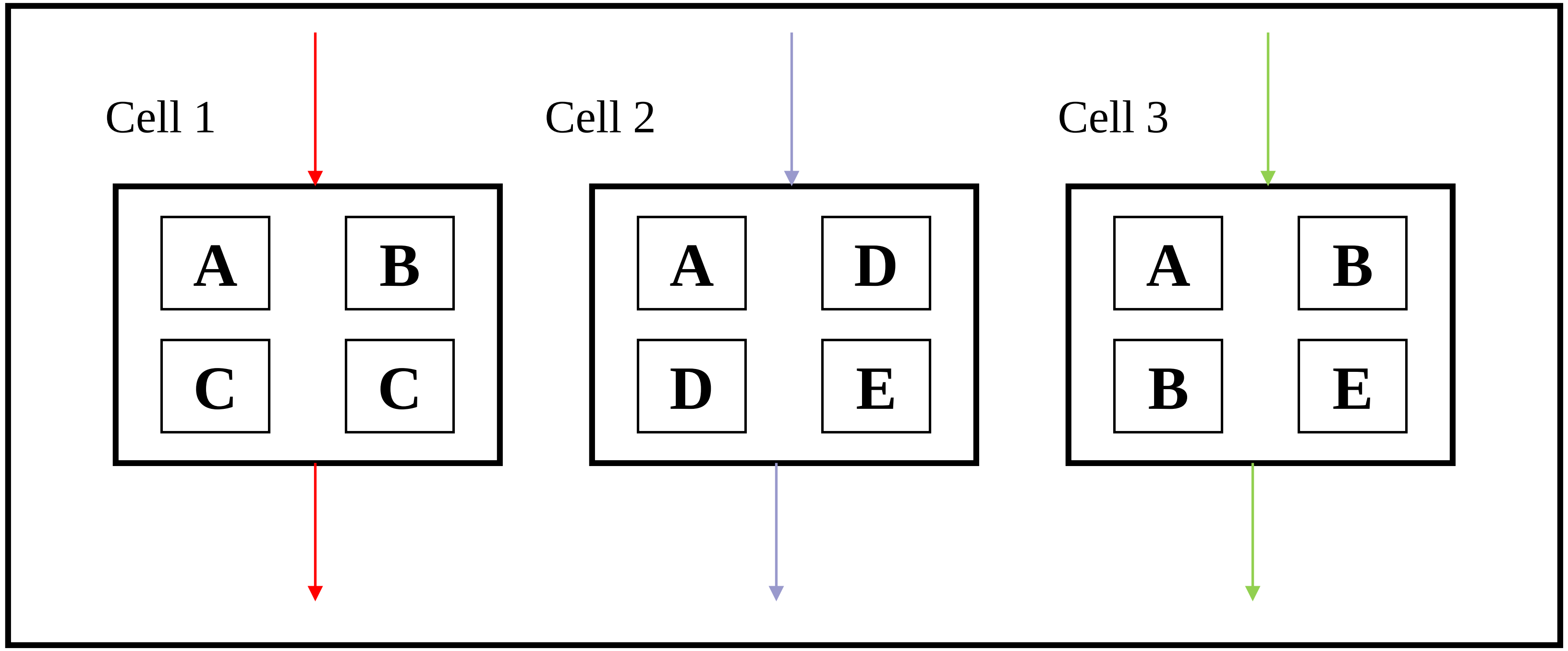




Manufacturing cells – general features

When cellular manufacturing is applied, parts are grouped into **part families** and machines into **cells**.

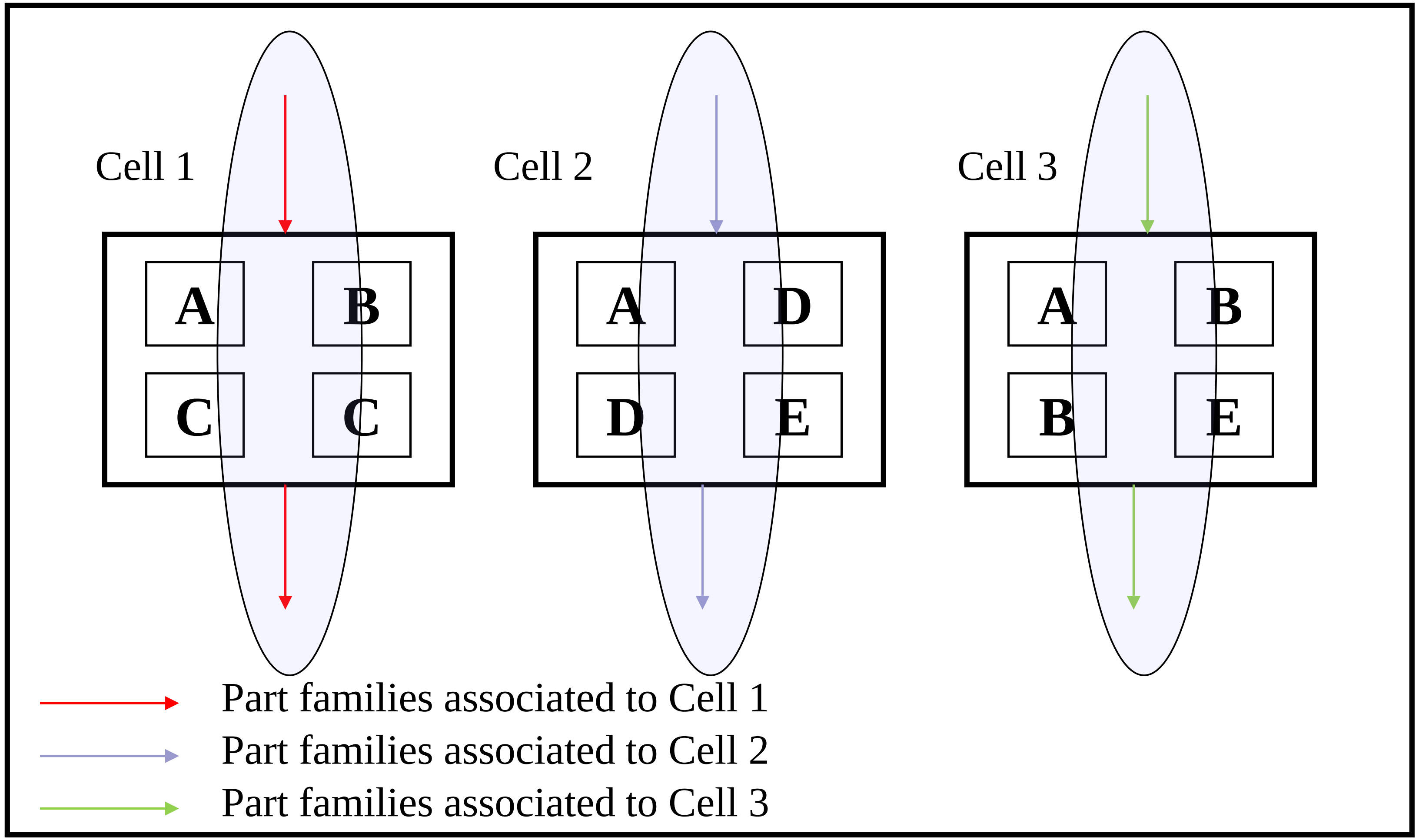
The machines are grouped on the basis of the **processing requirements** of the part families (different technological processes / machines in the same cell).



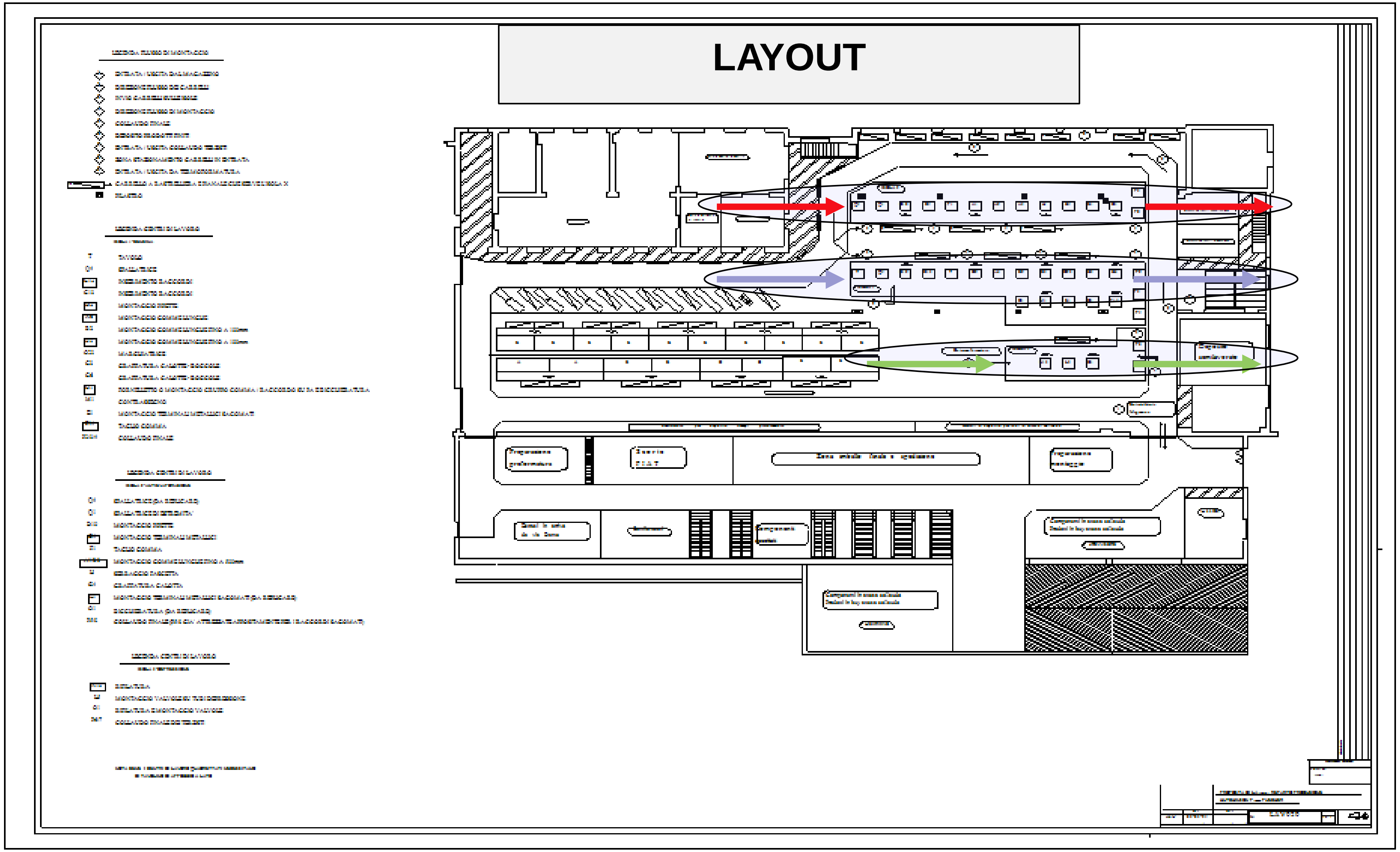
(*) Product and part are terms used as synonymous during this course

Manufacturing cells – general features

Each product has its own **routing** within the cell (this is the case when no inter-cell move is required > case of complete cell independence).



Example 1



Some examples

- https://www.youtube.com/watch?v=E54HAZWQpys
- https://www.youtube.com/watch?v=c50_lAIfzsk
- https://www.youtube.com/watch?v=Ynhp8Wi2qwM

Manufacturing cells – general features

When cellular manufacturing is applied, it may lead to:

- re-arrange existent equipment on the factory floor (i.e. machines, …);
- operate with new equipment, often incorporating various forms of flexible automation (i.e. from machines, material handling equipment, …, to FMC/FMS).

In other words, a typical question related to system design is required – "***which machines and their associated parts should be grouped together to form cells?***" – before re-arranging existent equipment on the factory floor, or incorporating flexible automation.

Manufacturing cells – Strengths

- Rationalization of material flows
- Setup time reduction
- Production management is easier

Overall (compared to the job-shop):

- WIP reduction
- Lead time reduction (also considering variability)
- More reliable estimates of delivery lead times

Manufacturing cells – Strengths

- Job enlargement + job enrichment for employees
- Team work within the cell
- Unification of product and process responsibilities
- More control on the quality characteristics of the products

Manufacturing cells – Weaknesses

- Difficulties with work load balancing between cells
- Problems related to production mix variability
- Difficulties with the application to the whole stages of the production chain
- In some cases, necessity of more machines than in a job shop
- Difficulties to manage technological operations outside the cells
- Problems related to breakdowns

Group technology – Steps

- Data collection regarding the production mix and technological routings
- Classification of products
- Standardization of products
- Standardization of technological routings
- Identification of product families
- Identification of machine groups forming the cells

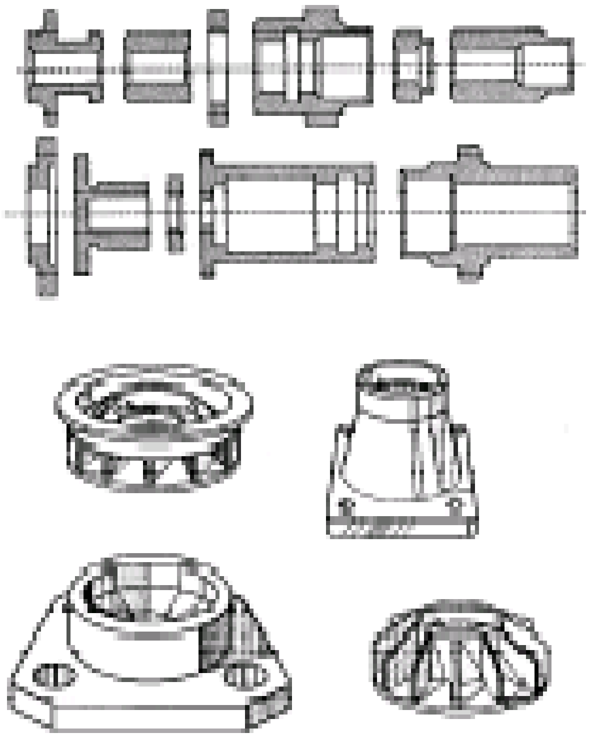
Rough design of a manufacturing cell

After the identification of product families and machine groups, the cells design can be based on the same approach used for the job-shop:

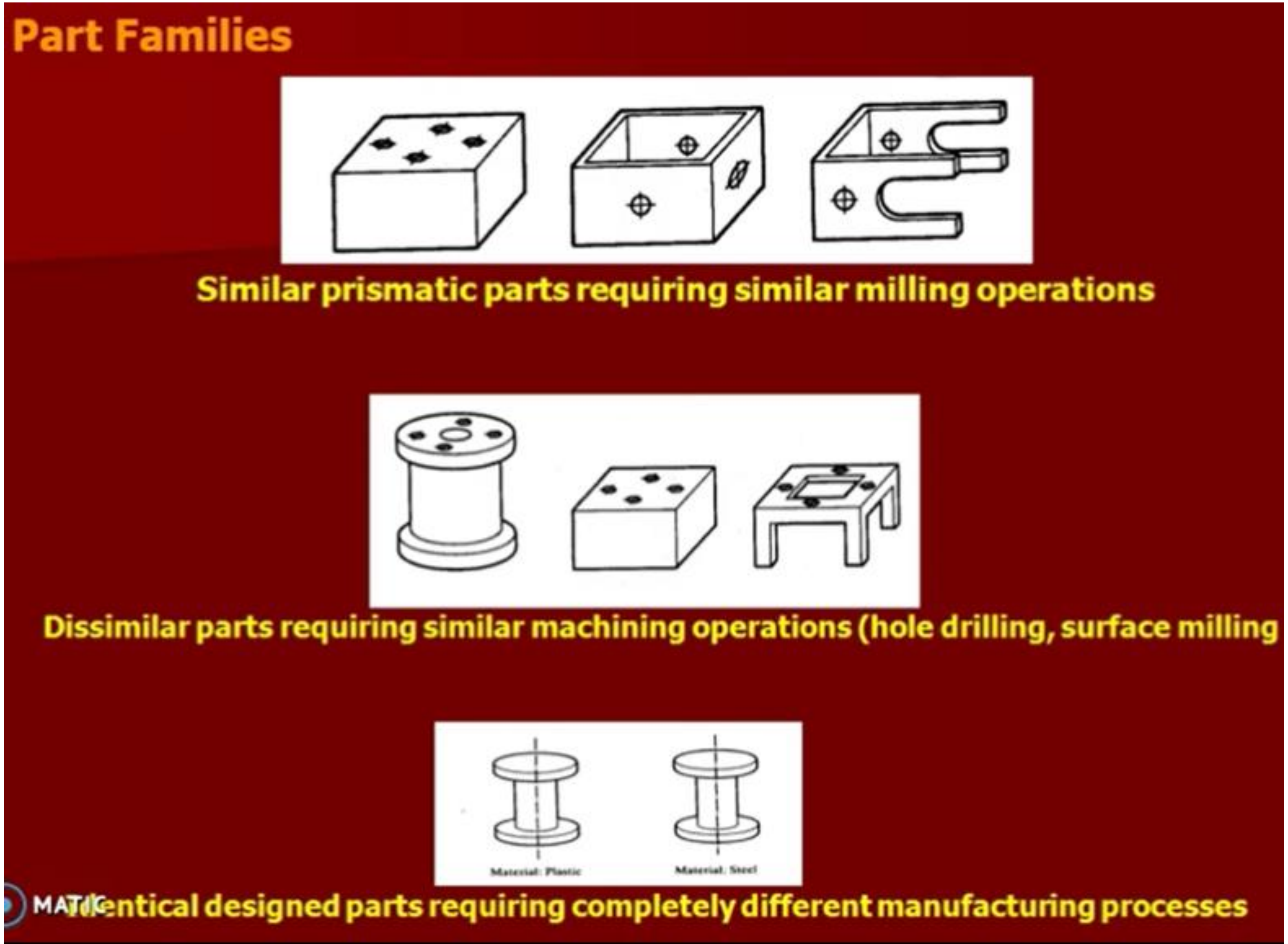
- calculate the number of machines of type i necessary in the cell;
- evaluate the number of shifts/day, computing the yearly costs adopting 1, 2 or 3 shifts/day.

Group technology – Methods

- Identification of product families based on the classification of products
  - Informal methods
    - Based on geometrical features
    - Based on technological features
  - Part coding analysis methods
    - Based on geometrical features
    - Based on technological features

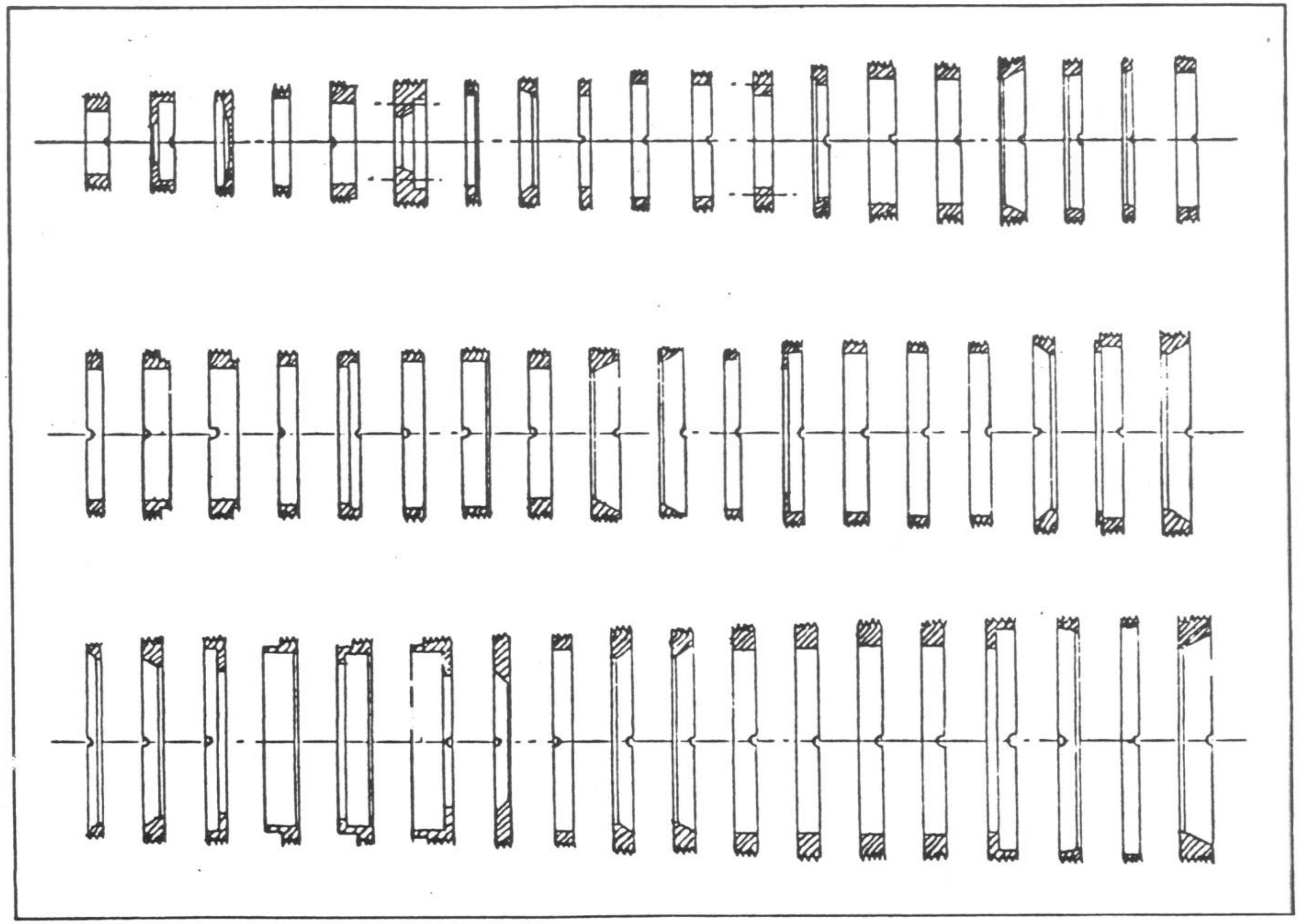


Group Technology



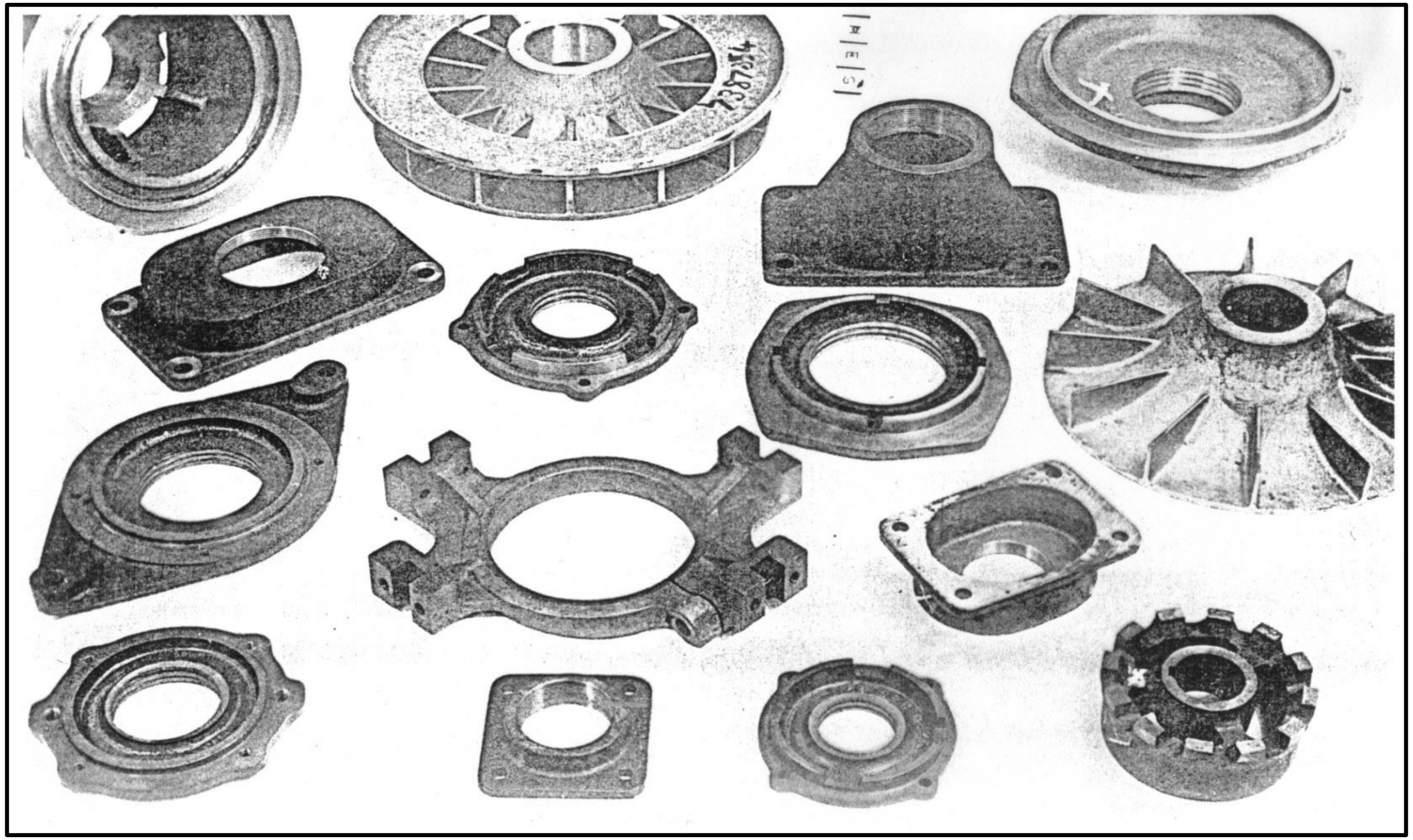
Based on the classification of products

- Based on geometrical features of products



Based on the classification of products

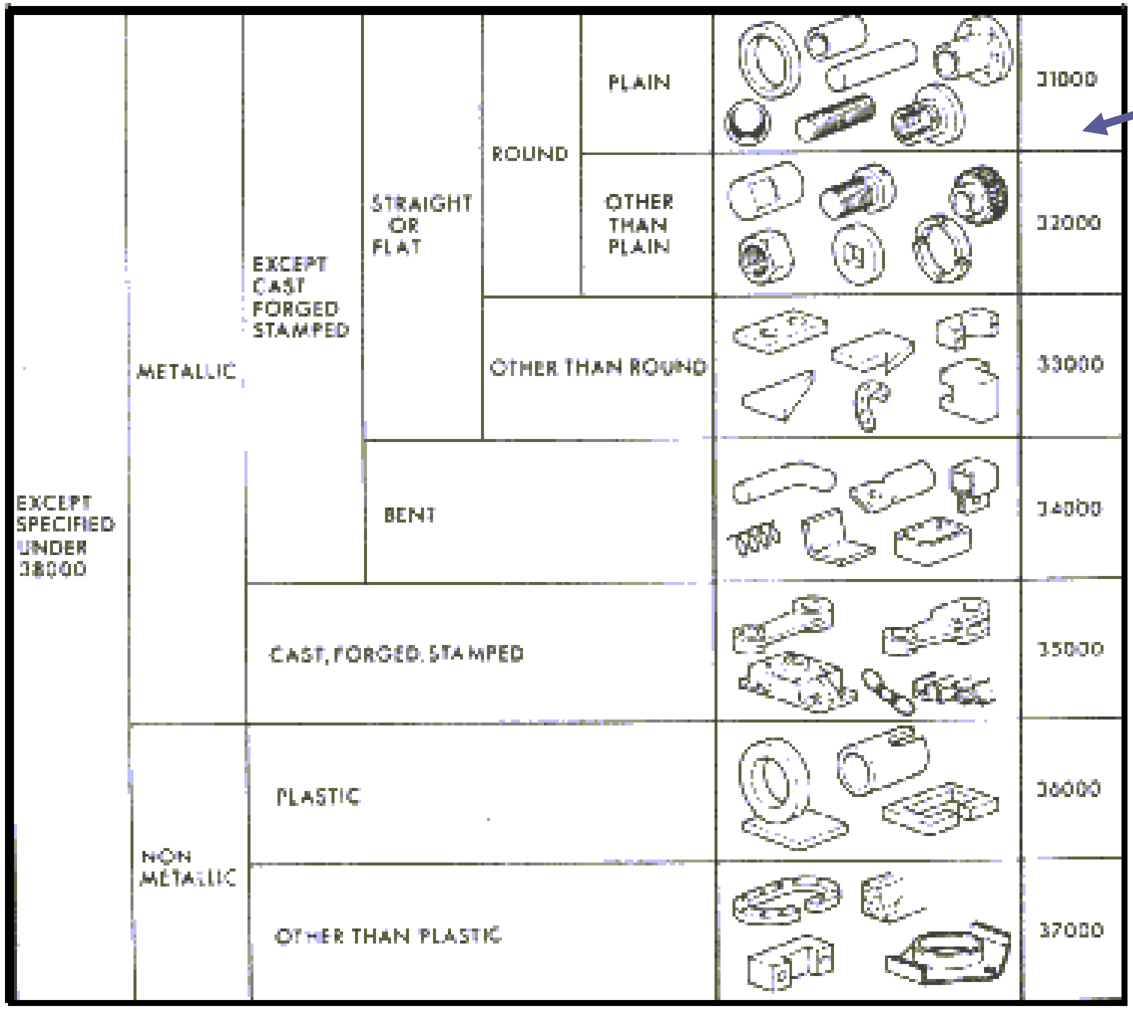
- Based on technological features of products



Based on the classification of products

- Part coding analysis (example 1)

Part



Coding system

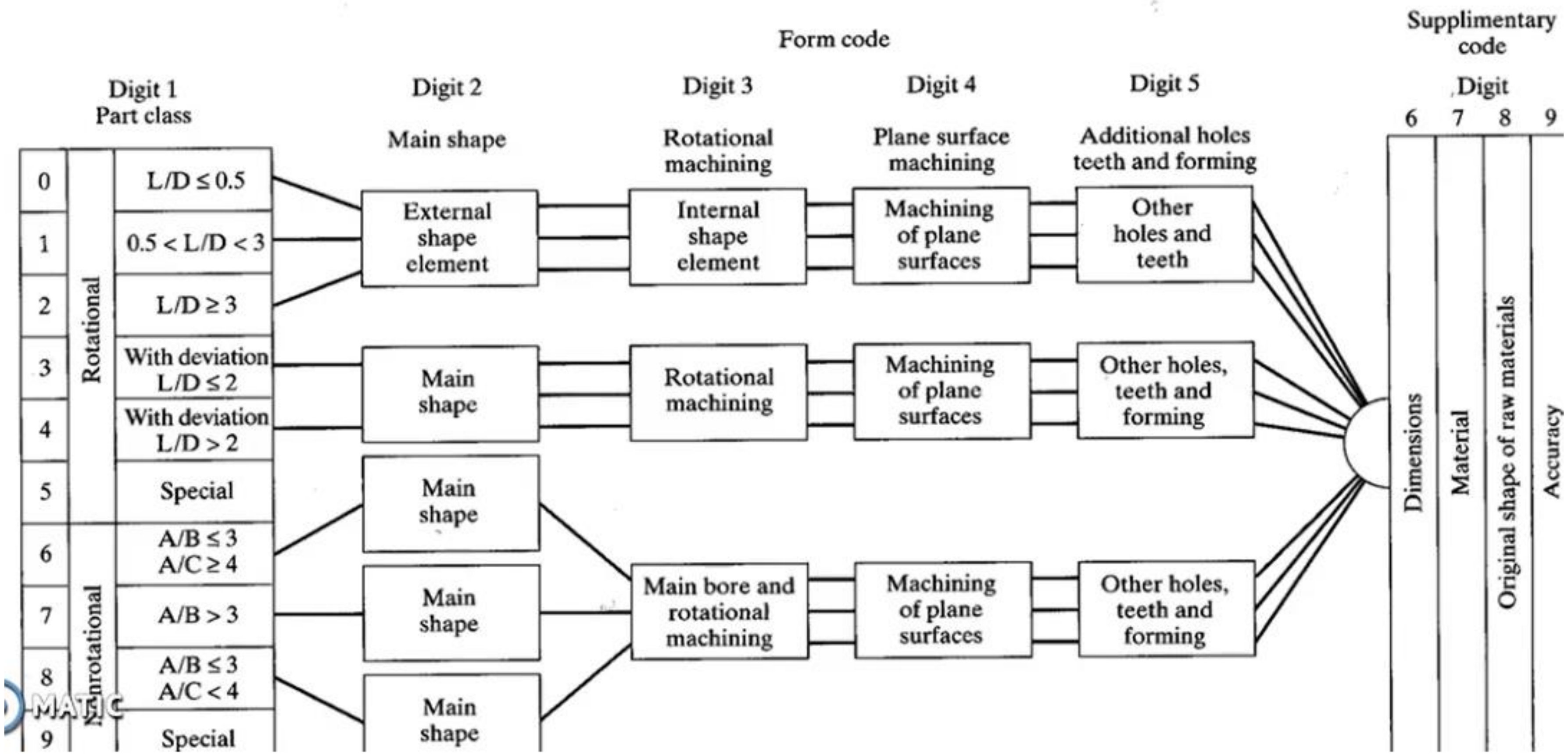
Part code

Based on the classification of products

Opitz coding system

Form code: for design attributes (1-5 digits)

Supplementary code: for manufacturing attributes (6-9 digits)

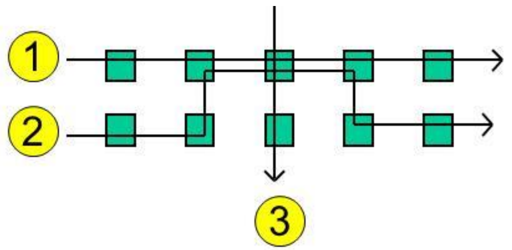


Based on the classification of products

	Digit 1		Digit 2		Digit 3		Digit 4	Digit 5	
	Part class		External shape, external shape elements		Internal shape, internal shape elements		Plane surface machining	Auxiliary holes and gear teeth	
0	Rotational parts	L/D ≤ 0.5		Smooth, no shape elements		No hole, no breakthrough	No surface machining	No gear teeth	No auxiliary hole
1		0.5 < L/D < 3	Stepped to one end or smooth	No shape elements	Smooth or stepped to one end	No shape elements	Surface plane and/or curved in one direction, external		Axial, not on pitch circle diameter
2		L/D ≥ 3		Thread		Thread	External plane surface related by graduation around the circle		Axial on pitch circle diameter
3				Functional groove		Functional groove	External groove and/or slot		Radial, not on pitch circle diameter
4			Stepped to both ends	No shape elements	Stepped to both ends	No shape elements	External spline (polygon)		Axial and/or radial and/or other direction
5				Thread		Thread	External plane surface and/or slot, external spline		Axial and/or radial on PCD and/or other directions
6	Nonrotational parts			Functional groove		Functional groove	Internal plane surface and/or slot	With gear teeth	Spur gear teeth
7				Functional cone		Functional cone	Internal spline (polygon)		Bevel gear teeth
8				Operating thread		Operating thread	Internal and external polygon, groove and/or slot		Other gear teeth
9				All others		All others	All others		All others

Group technology – Methods

- Identification of product families / machine groups forming the cells simultaneously based on PFA (Production Flow Analysis)
  - Cluster analysis
    - ROC (Rank Order Clustering)
    - Similarity coefficients
  - Graph partitioning
  - Mathematical programming
  - …



Based on PFA – Rank Order Clustering

- Step 1: read each row as a binary number
- Step 2: order rows according to descending binary numbers
- Step 3: read each column as a binary number
- Step 4: order columns according to descending binary numbers
- Step 5: if on steps 2 and 4 no reordering happened go to step 6, otherwise go to step 1
- Step 6: stop

Rank Order Clustering – Example (1/3)

Machine/part matrix

$a_{ij} = 1$ if part j visits machine i
$a_{ij} = 0$ otherwise

MACHINE TYPE	PRODUCTS 1	2	3	4	5	6	7	8	Decimal number
A	1	1	0	0	1	0	0	0	200
B	0	0	0	1	0	0	0	1	17
C	0	1	1	0	0	1	1	0	102
D	0	0	0	1	0	0	0	1	17
E	0	0	1	1	0	1	1	0	54
F	1	1	0	0	1	0	0	0	200

(binary number) $1 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 = 200$

Rank Order Clustering – Example (2/3)

MACHINE TYPE	PRODUCTS 1	2	3	4	5	6	7	8	Decimal number
A	1	1	0	0	1	0	0	0	200
F	1	1	0	0	1	0	0	0	200
C	0	1	1	0	0	1	1	0	102
E	0	0	1	1	0	1	1	0	54
B	0	0	0	1	0	0	0	1	17
D	0	0	0	1	0	0	0	1	17
Decimal n.	48	56	12	7	48	12	12	3	

(binary number) $1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 = 56$

Rank Order Clustering – Example (3/3)

MACHINE TYPE	PRODUCTS 2	1	5	3	6	7	4	8	Decimal number
A	1	1	1	0	0	0	0	0	224
F	1	1	1	0	0	0	0	0	224
C	1	0	0	1	1	1	0	0	156
E	0	0	0	1	1	1	1	0	30
B	0	0	0	0	0	0	1	1	3
D	0	0	0	0	0	0	1	1	3
Decimal n.	56	48	48	12	12	12	7	3	

Exceptional parts

- inter-cell moves
- duplication of machines
- alternative routings
- buy operations from third parties

Cell formation

- 3 potential cells

Based on PFA – Similarity coefficients
Single Linkage Clustering Algorithm (SLCA)

1. compute the similarity coefficients **between i and j:**

$$s_{ij} = \frac{a_{ij}}{(a_{ij} + b_i + c_j)}$$

a_{ij}=number of parts worked by both the machines.

b_i = number of parts worked by only machine i

c_j = number of parts worked by machine j

2. Compute the similarity matrix.

3. Given a threshold, group parts with higher similarity coefficient

Based on PFA – Similarity coefficients
Single Linkage Clustering Algorithm (SLCA)

Machines/parts matrix

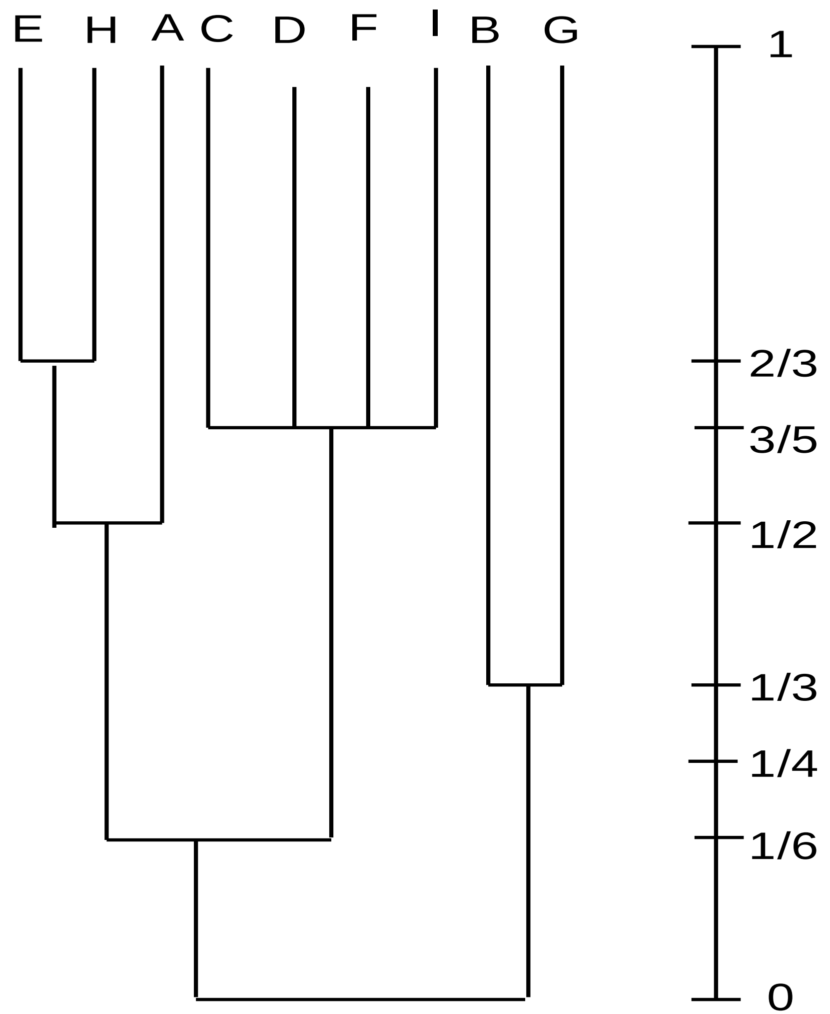
	Macchine											
Parti	1	2	3	4	5	6	7	8	9	10	11	12
A			1	1				1				
B						1			1			1
C		1	1							1	1	
D		1	1				1			1		
E	1			1				1				
F		1	1				1				1	
G					1	1						
H	1			1								
I		1					1			1	1	

Metodi basati su coefficienti di somiglianza
Single Linkage Clustering Algorithm (SLCA)

Similarity matrix (McAuley):

	A	B	C	D	E	F	G	H	I
A	-	0	1/6	1/6	1/2	1/6	0	1/4	0
B		-	0	0	0	0	1/3	0	0
C			-	**3/5**	0	**3/5**	0	0	3/5
D				-	0	**3/5**	0	0	3/5
E					-	0	0	**2/3**	0
F						-	0	0	**3/5**
G							-	0	0
H								-	0
I									-

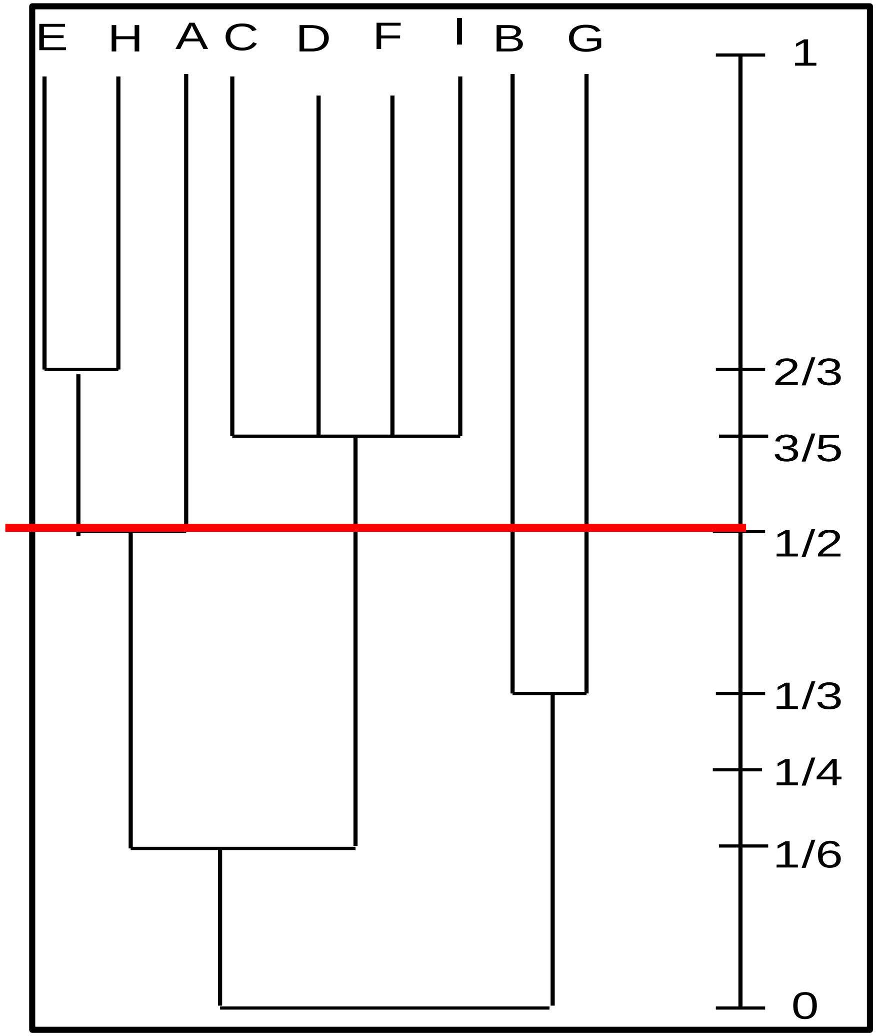
Based on PFA – Similarity coefficients
Single Linkage Clustering Algorithm (SLCA)



Dendrogram

Similarity coefficient equal to 2/3 means grouping E and H. For similarity coefficients smaller, it is possible to group more parts.

Based on PFA – Similarity coefficients
Single Linkage Clustering Algorithm (SLCA)



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