Business Administration

Lecture No. 17: Facility Management and Automation

1. Evaluation/Decision of Capital Investment
2. Automation: Selection of Production Technology
3. Failure and Maintenance of Facility

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Facility Management (in broad term) ---

Regarding to facilities, jig tools, molds, etc. (tools and equipment) installed in a factory as the media for product design information,

how to conduct the following:

(1) employment decision

(2) design

(3) procurement

(4) maintenance, improvement

1. Evaluation and Decision of Capital Investment

Types of capital investment

Replacement investment

Expansion investment

Product development/refinement investment

Strategic investment

Decision making on capital investment --- capital budgeting

Evaluation of Capital Investment Scheme: Basic Consideration

Evaluate by an increment on top of a base case

Cash flow (profit before depreciation)

Nominal value

Cash flow before interest payment

Consideration on tax effect (after tax)

Consideration of time value (present value)

Cash flow = operating profit + depreciation cost − corporate tax, etc.

Patterns of Capital Investment Evaluation Method

Pay-back-period method

pay back "amount of capital investment + incremental working capital − residue value" with "cash flow from production/sales activities"

Return-on-investment method

projected operating profit (before tax) ÷ (amount of capital investment + incremental working capital)

Discount-cash-flow method

whether or not net present value, result of "capital investment (negative) + cash flow" discounted by cost ofcapital, is in positive

Internal-rate-of-return method

same principle with DCF. Find out discount rate leading to NPV = 0

while, discount rate = cost of capital

Weighted Average Cost of Capital (WACC)

In consideration of risks involved in investment projects,
set projected borrowing rate, equity capital rate (present value base).

At those rates,
run a weighted average on borrowing rate
(to be multiplied with "1 − rate of corporate tax")
corresponding to the project's risk,
and cost of equity capital (rate to stock price)

Calculation of cost of equity capital
--- CAPM (capital asset pricing method) is a standard.

After the war, WACC runs at 10 – 15% in America.

Characteristic of Assembly Factory in Fleet Car Maker (1989)

Year	-1	1	2	3	4	5	6	7	8	9	10	Total/ Remarks
Capital investment/Operating capital investment	100											
Sales amount		200	200	200	200	200	200	200	200	200	200	
Cost of sales /sales administrative expense		190	190	190	190	190	190	190	190	190	190	
Operating profit		10	10	10	10	10	10	10	10	10	10	
Interest payable		4	4	4	4	4	4	4	4	4	4	
Profit before tax		6	6	6	6	6	6	6	6	6	6	
Corporate tax, etc.		3	3	3	3	3	3	3	3	3	3	
Profit after tax		3	3	3	3	3	3	3	3	3	3	
Depreciation cost		10	10	10	10	10	10	10	10	10	10	
Operating cash flow		17	17	17	17	17	17	17	17	17	17	
Net present value (NPV: discount rate 1.1)	-100	15.5	14.0	12.8	11.6	10.6	9.6	8.7	7.9	7.2	6.6	4.5
Cumulative cash flow	-100	-83	-66	-49	-32	-15	2	19	36	53	70	pay back in 6 years approx.
ROI (operating income base)	0.1											
IRR and corresponding NVP	0.1103	15.3	13.8	12.4	11.2	10.1	9.1	8.2	7.4	6.6	6.0	0.0

Assumptions: rate of profit to sales at 5%; straight-line depreciation over 10 years; increment of working capital neglected for simplification purpose; residue value of equipment at zero. In unit of million Yen.

Capital Budgeting System and Competitiveness: Reflection of America in 1980s

Problem in setting base cases in manner of holding status quo
→ delay in investment

Separate screening by individual project
→expansion investment for existing factory being advantageous

Neglect on qualitative elements → turndown of strategic investment

Oversetting of discount rate

Concentration of screening capability to specialized staff
→ discrepancy from job site

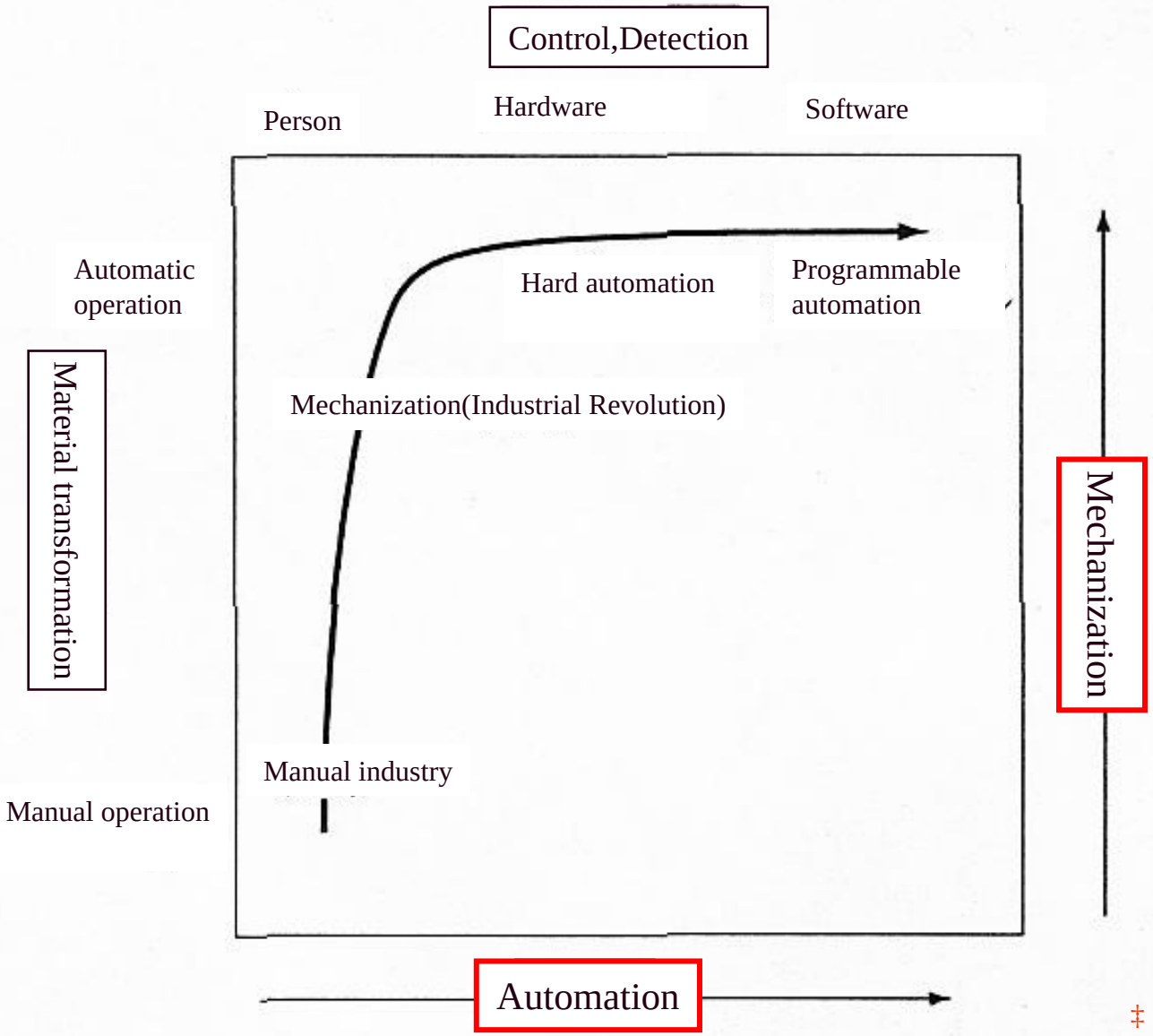
Excessive emphasis on big projects

2. Automation

Automation ＝ To switch the media
having accumulated product design information
from human and paper
to hardware and software of machinery
at a production job site (process).
(switch of media)

Mechanization: (switch of energy used for physical transformation) ought to be separated from the above.

General Route to Mechanization/Automation



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p77 figure.11.2)

Basic Structure of Automation

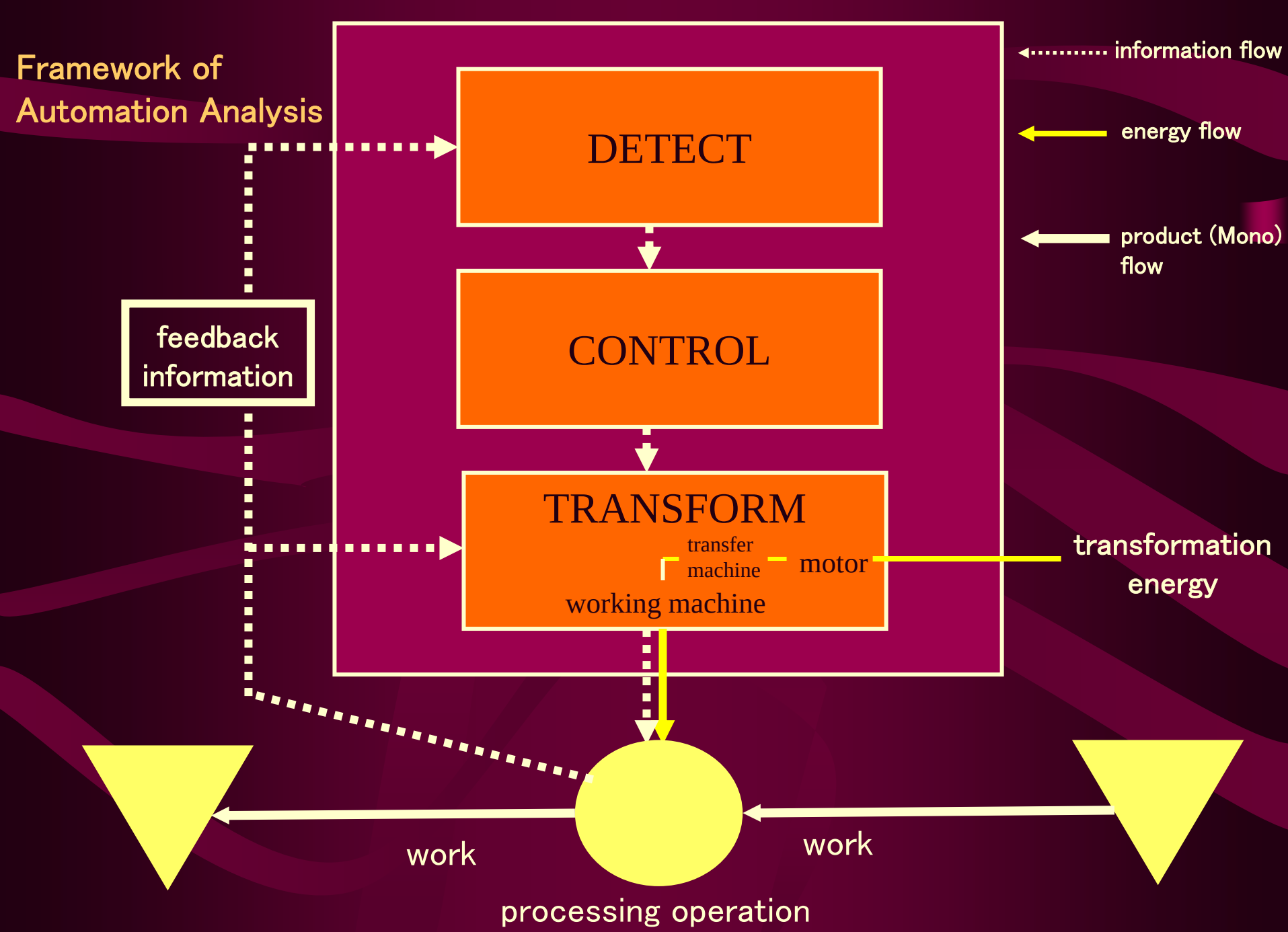
detect

control

transform

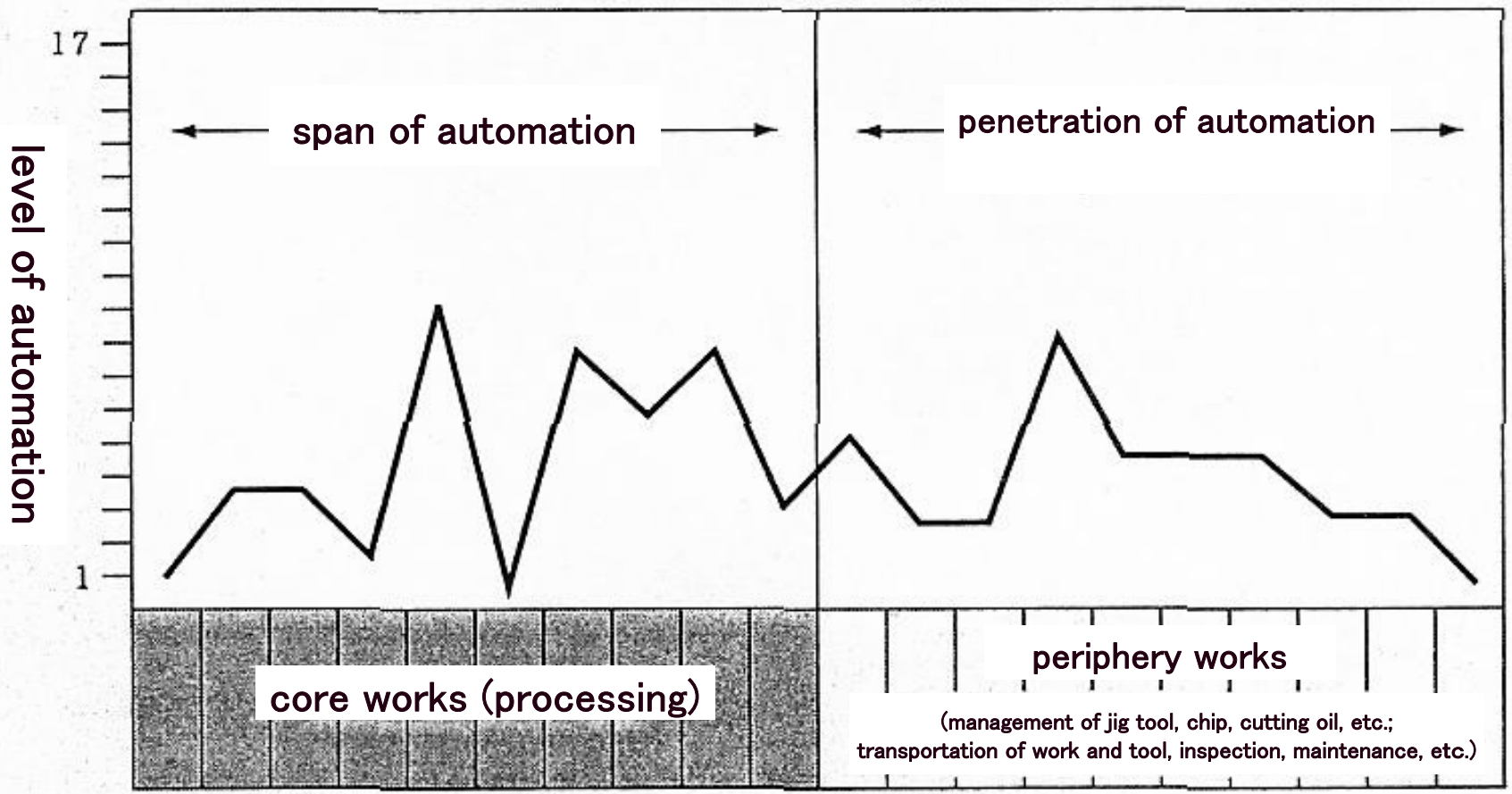
For each, analyze level, span (range), type (what to carry information on), of automation.

Example: automation analysis by Bright



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p78 figure.11.3)

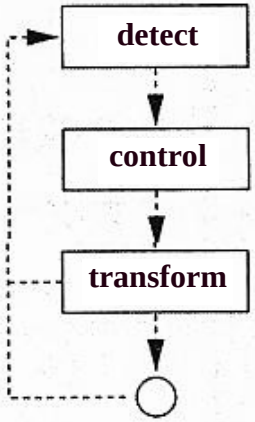
Profile of Bright's Mechanization (Virtual Example)



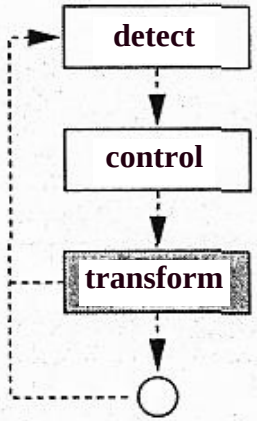
Author making (reference: Bright J.R. 'Automation and management, Plimpton Press')
Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp81)

Level of Automation (Bright): Reinterpretation by Framework of Automation Analysis

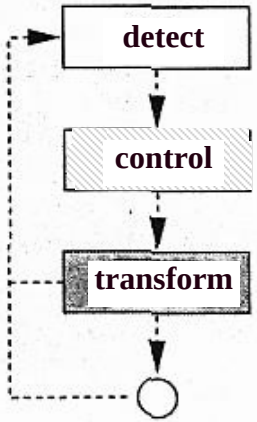
Level 1 – 2
manual tool



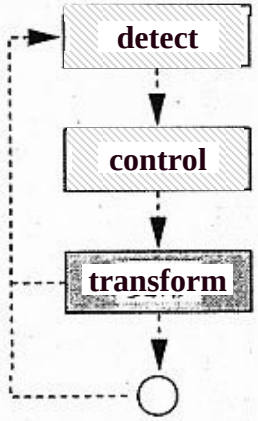
Level 3 – 4
multi-purpose machine



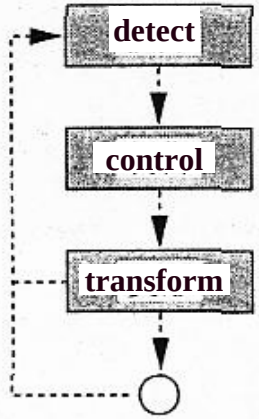
Level 5 – 8
fixed automation



Level 9 – 11
automatic measurement



Level 12 – 17
automatic control



= human

= human/machine mix

= machine

Author making (reference: Bright J.R. 'Automation and management, Plimpton Press')
Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p81)

Position control

--- Restrict a relative position of work and tool

restriction by hardware (machine structure per se)

restriction by software (via motor, etc.)

Sequence control

---- Control motion sequence of machine

e.g., full automatic washing machine, wind-up doll

Position Control and Sequence Control

(example of machine work)

Position control

human　　hardware　　software

Sequence control

software

hardware

human

FMS NC machine tool

programmable controller

transfer machine

special-purpose machine tool

multi-purpose machine tool

manual procedure

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p82 figure.11.5)

Fixed Automation

special-purpose machine

adaptable to speeding up

high repetitive precision

but, lacks flexibility

Programmable Automation

Numerical control (NC: program change being possible)

program →
control appliance →
body (motor → ball screw → table/spindle head)

Types of Machine Tool

①Multi-Purpose Machine Tool：

While rotation/others of tools are mechanized, a relative position (work shape) of work and tool is not completely restricted. Only craftsmanship of a skilled worker can apply a restriction on this machine tool through his operations of handles/others.

Thus, this type has a flexibility capable to produce anything if a good skilled worker is available. But it is slow in process speed, and not suitable to a mass production ofa single variety.

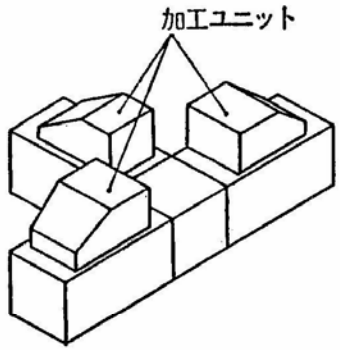
②Special-Purpose Automated Machine Tool (fixed automation)：

Fixed automation. Machine tool of a type in which a machine's degree of motional freedom (position, process sequence) is restricted by the machine's structure. Process sequence is restricted by the relay switch of an electric-machine system, and position control is restricted by the machine's structure per se (additionally, auto detection of defect, machine shut down, parts elimination).

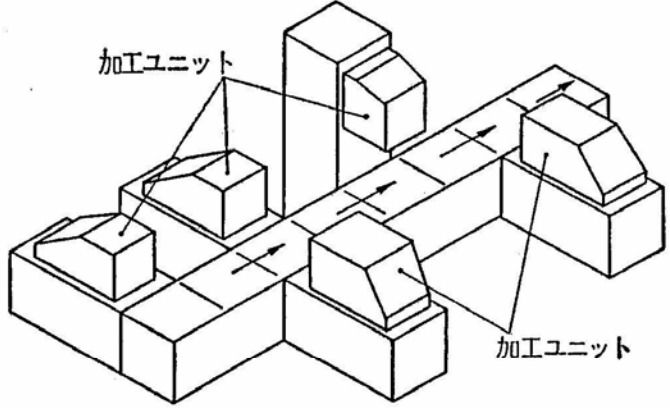
While special-purpose machine is generally higher in price than multi-purpose machine, it is lower than NC. And it is superior in a speed and a repetitive precision as the motion is restricted by its hardware structure. But it does not fit to complicated motions, and it lacks flexibility. Of course, even with a fixed automation, some level of flexibility adoptable to multi variety is possible through set-ups of jigs and multi-axis head charger, etc. (one-touch set up, rice-ball method, etc.). In addition to a single piece of special-purpose machine, there are a rotary-index machine, a transfer-line linked with an auto carrier machine in line, etc.

Types of Fixed Automation

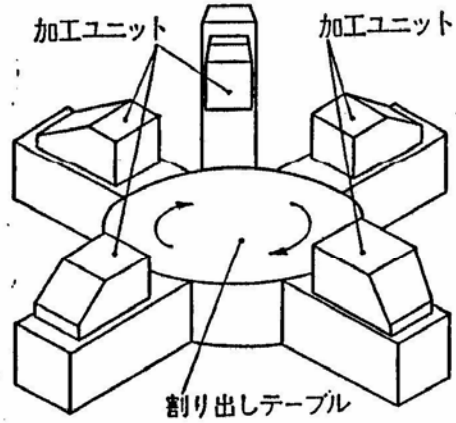
(special-purpose machine system)



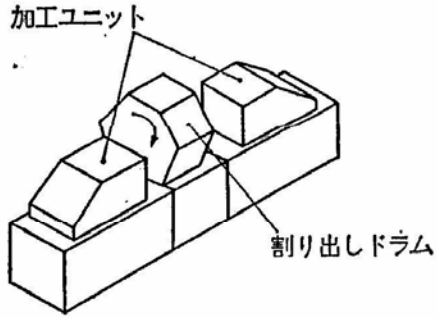
(I) シングルステーションマシン



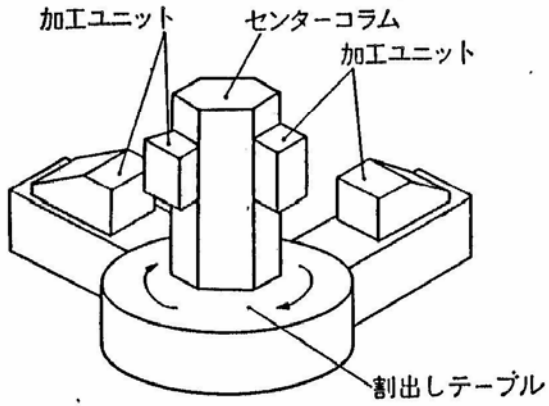
(i) トランスファマシン



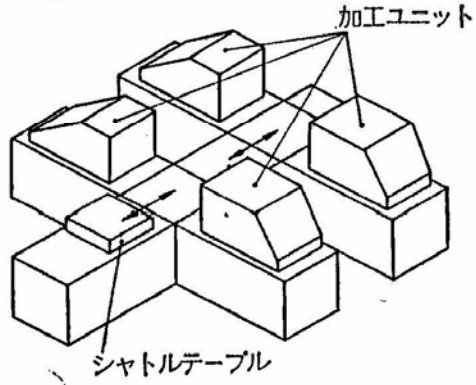
(ii) ダイヤルインデックスマシン



(iii) トラニオンタイプマシン



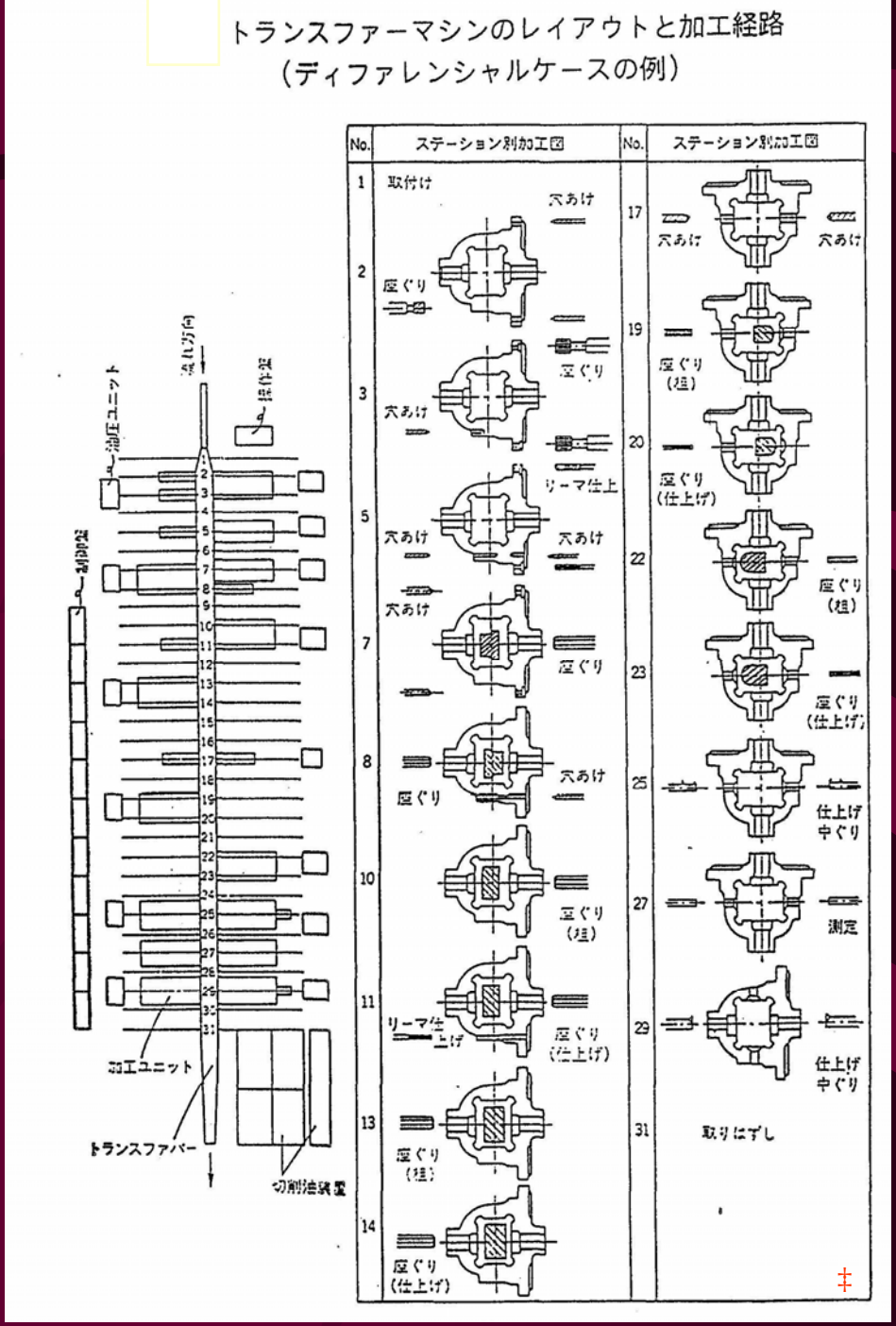
(iV) センターコラムマシン



(V) シャトルタイプマシン

Toshiro Seki 'Manufacturing Method of Car'
SANKAIDO PUBLISHING Co.,Ltd

Transfer Machine



Toshiro Seki 'Manufacturing Method of Car'
SANKAIDO PUBLISHING Co.,Ltd

③NC(Numerical Control):

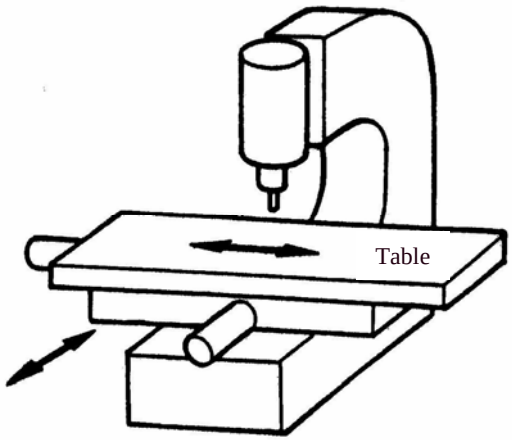
To mathematically define such information as process shape , process sequence, and to control (restricting motion) through numerically controlled program. It's also called a programmable automation. A single piece of NC is composed of the three factors which are process machine main body (to restrict table and the position of a spindle head with support motor and lead screw/others) controller unit (information processing such as program reading, process-signal power output, etc.) instruction program. Traditionally, process information is accumulated in 1-inch wide paper tape (8-digit punched tape), which is optically read and transformed into machinery motion. But this had problems of program mistakes, tape maintenance, and reliability in tape reader, etc. Now, an increased usage is seen for CNC(computerized NC under distributed control in machine language by small computer) DNC (direct NC central control by large computer) . Merits are reliabilityin information accumulation, ease of program editing, etc.

④FMS:

One which is designed for a high-mix low-volume production, and which links a flexible machine tool with a flexible career apparatus. As it has a restriction in process route/others, this system is said to adopt to a span where the lot is slightly larger but with a lesser variety than a stand-alone NC machine tool (lot size at 5-1000, variety from 5 to 1000 approx.). FMS consists of a flexible machine tool (NC, machining center, etc.), automatic tool exchange/transportation, flexible work career system, storage area for in-process works, computer control system, etc. In a further subdivision, there are FMC (Flexible Machining Cell being one unit of CNC and an automatic carry out/in apparatus only), FMS in narrow term (one linked with FMC, having a flexibility in selection of process route), FTL (Flexible Transfer Line where a process route is fixed), etc.

Basic Structure of NC Machine Tool

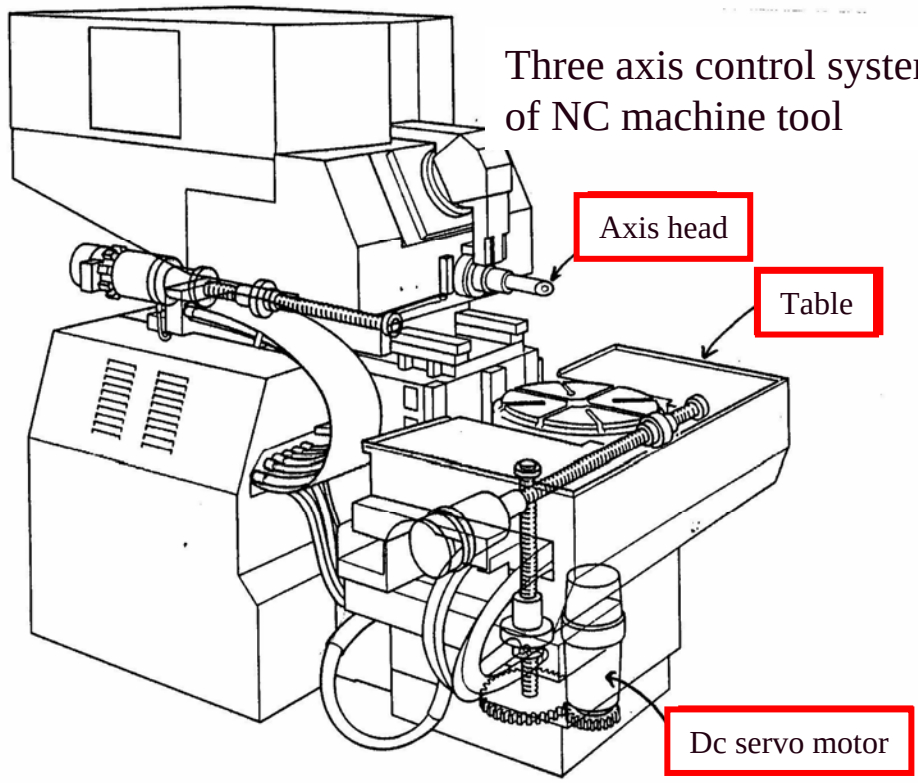
XY table of NC machine tool

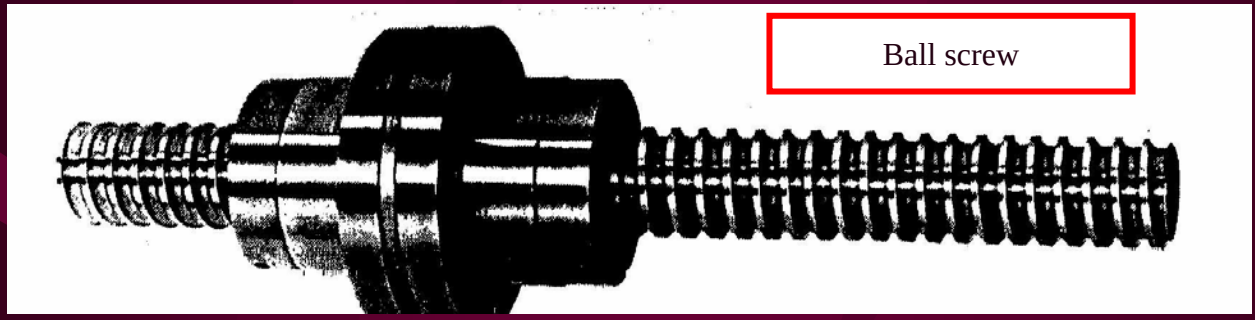


第 1 図

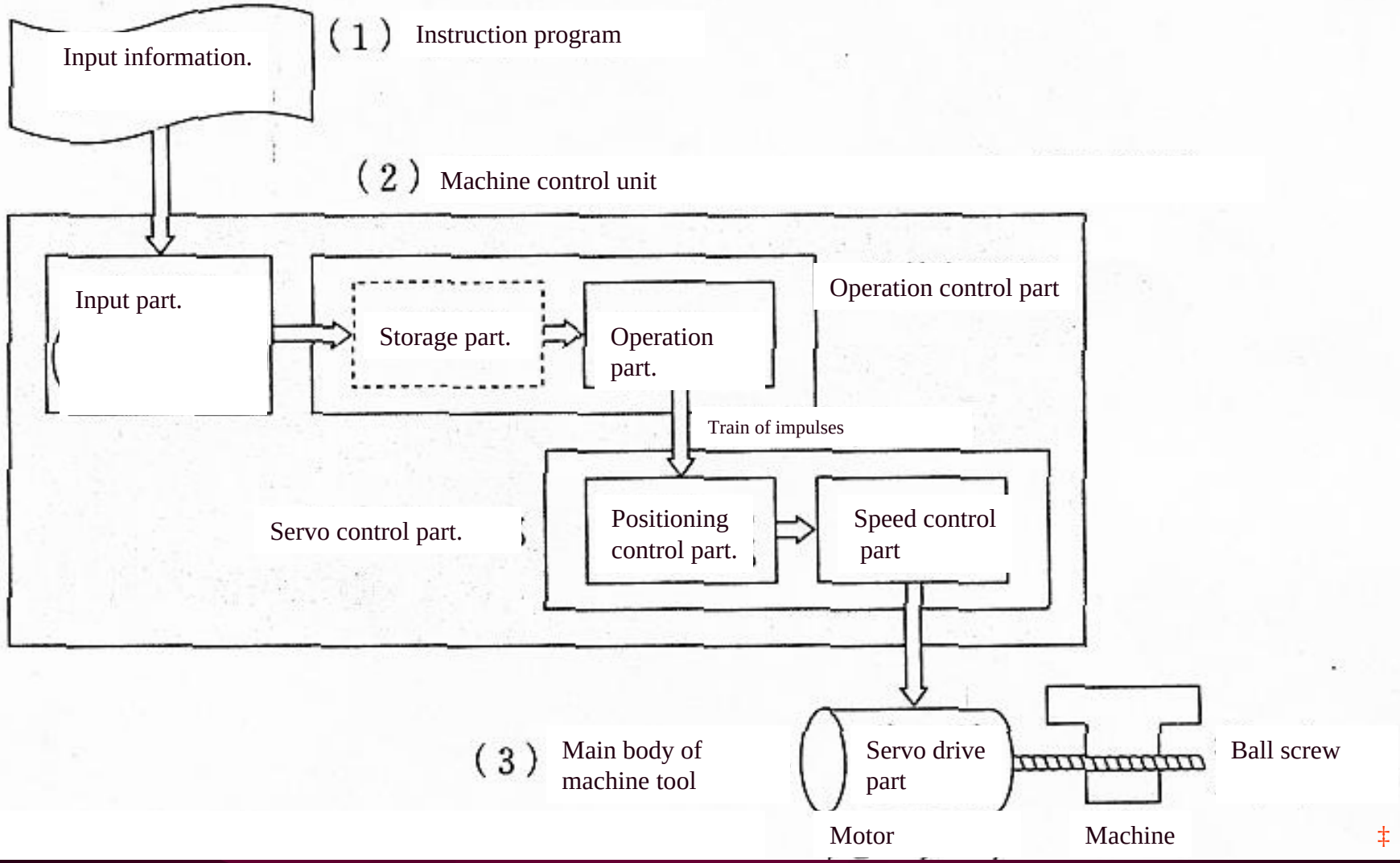
'The Latest Mechatoronics Technological Encyclopedia'
hmsha, Ltd.

Three axis control system of NC machine tool



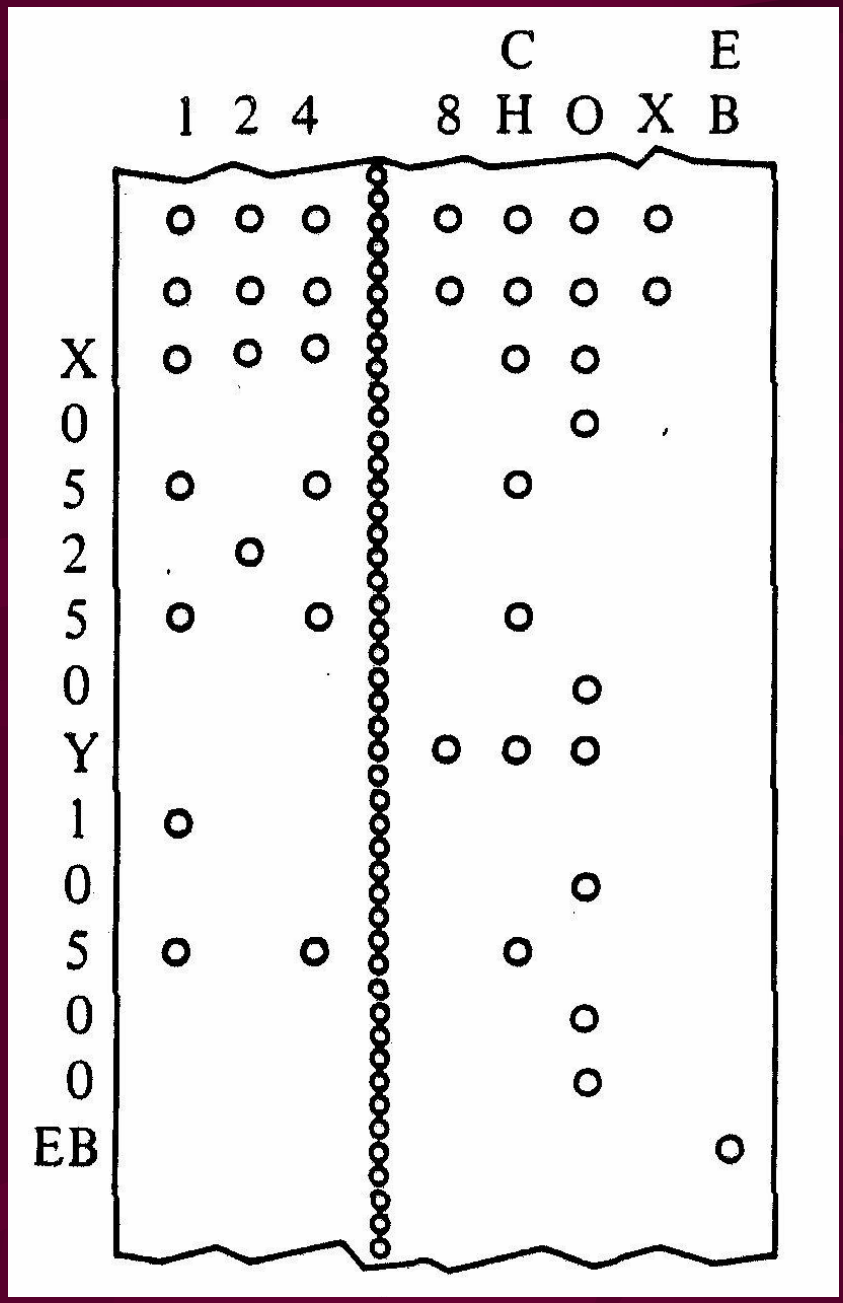


Structure of NC (Numerical Control) Machine Tool

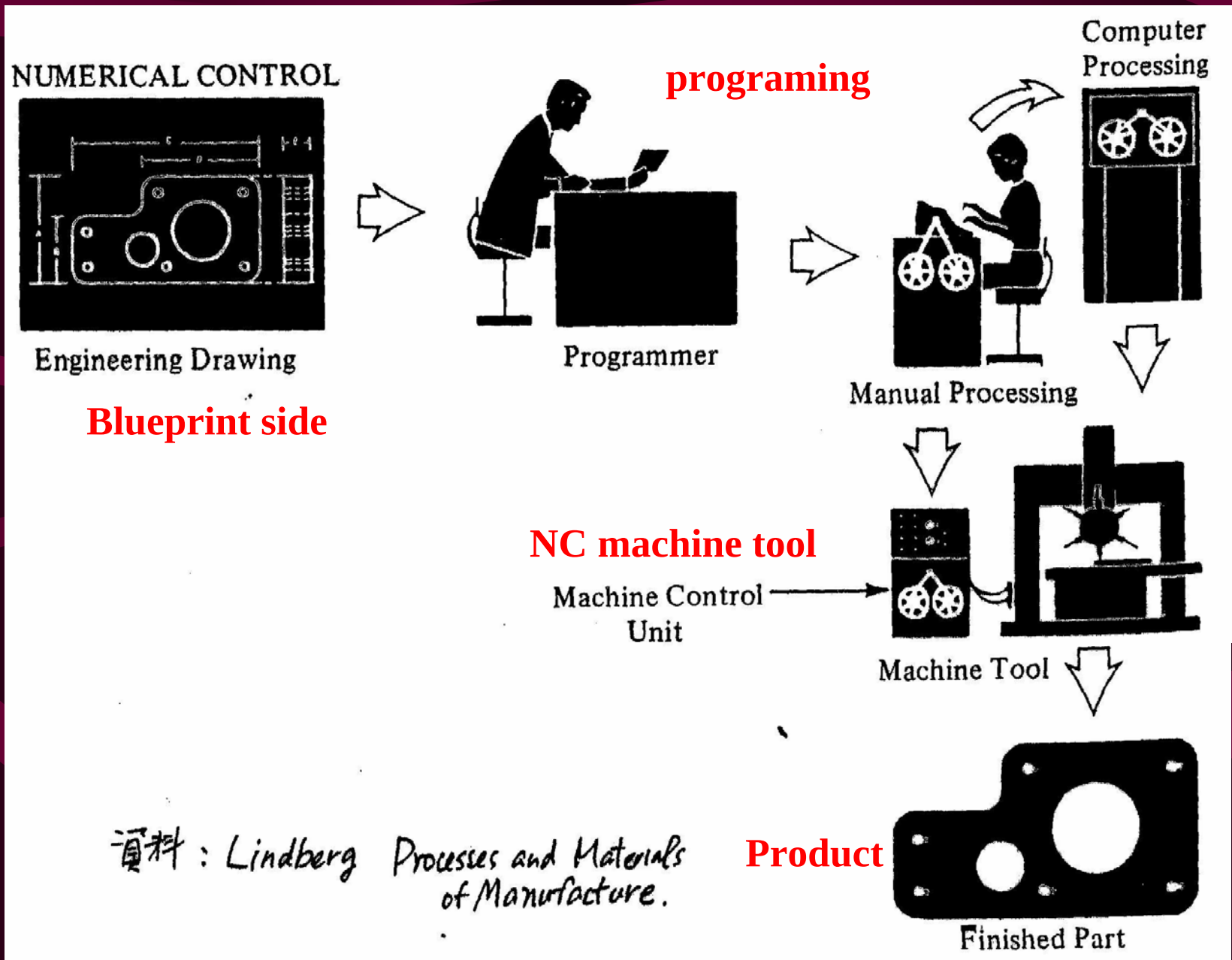


'The Latest Mechatoronics Technological Encyclopedia' Ohmsha, Ltd.

NC Tape



NC Programming



資料：Lindberg Processes and Materials of Manufacture.

Types of Numerical Control

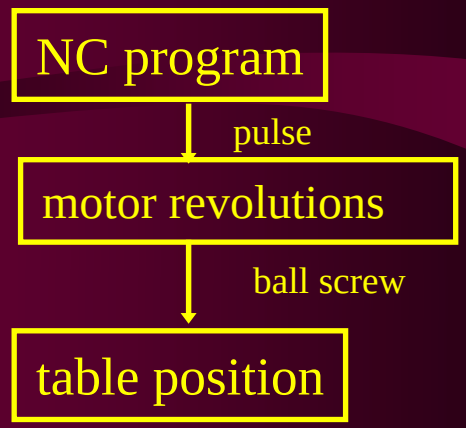
open-loop method ---- no feedback

closed-loop method ---- feedback on position information

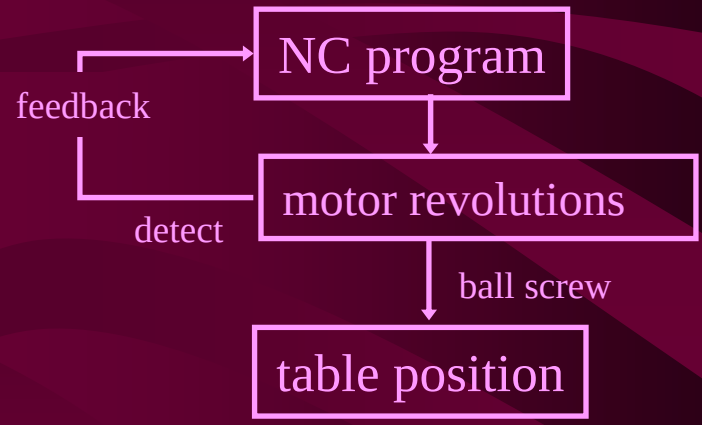
adaptive control method ---- switch objective by adapting to situation

Open-loop Control and Closed-loop Control

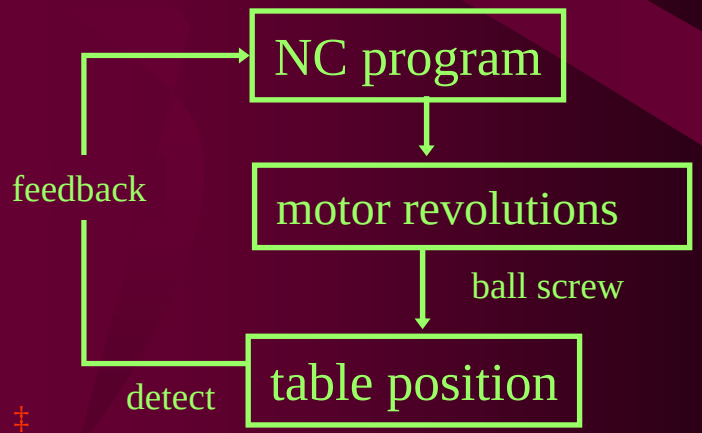
1 open-loop control



2 closed-loop control (indirect system)

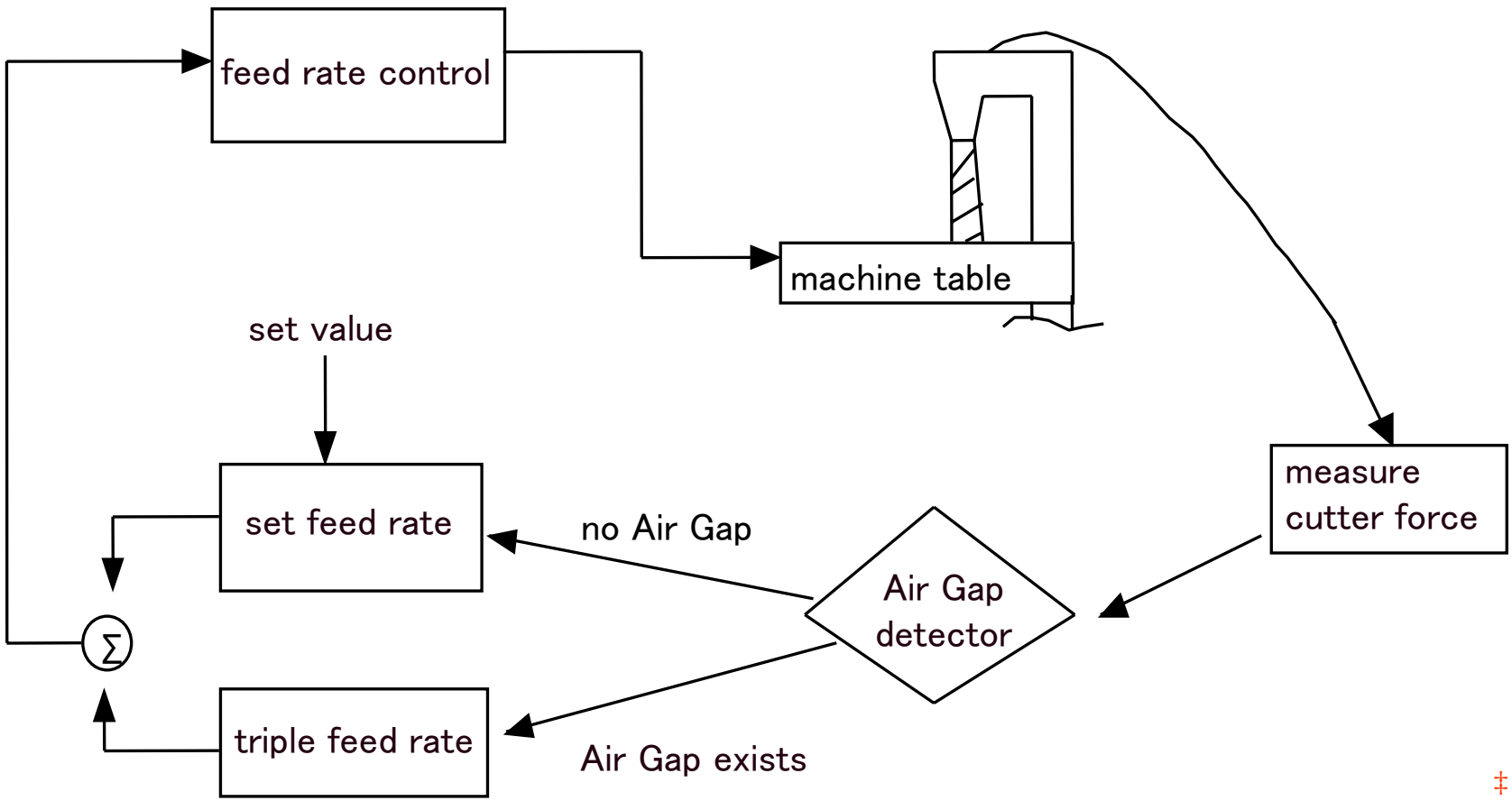


3 closed-loop control (direct system)



Takahiro Fujimoto 'Introduction to Production Management'
Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p84 figure.11.8)

Example of Adaptive Control



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p84 figure.11.9)

Types of Numerical Control

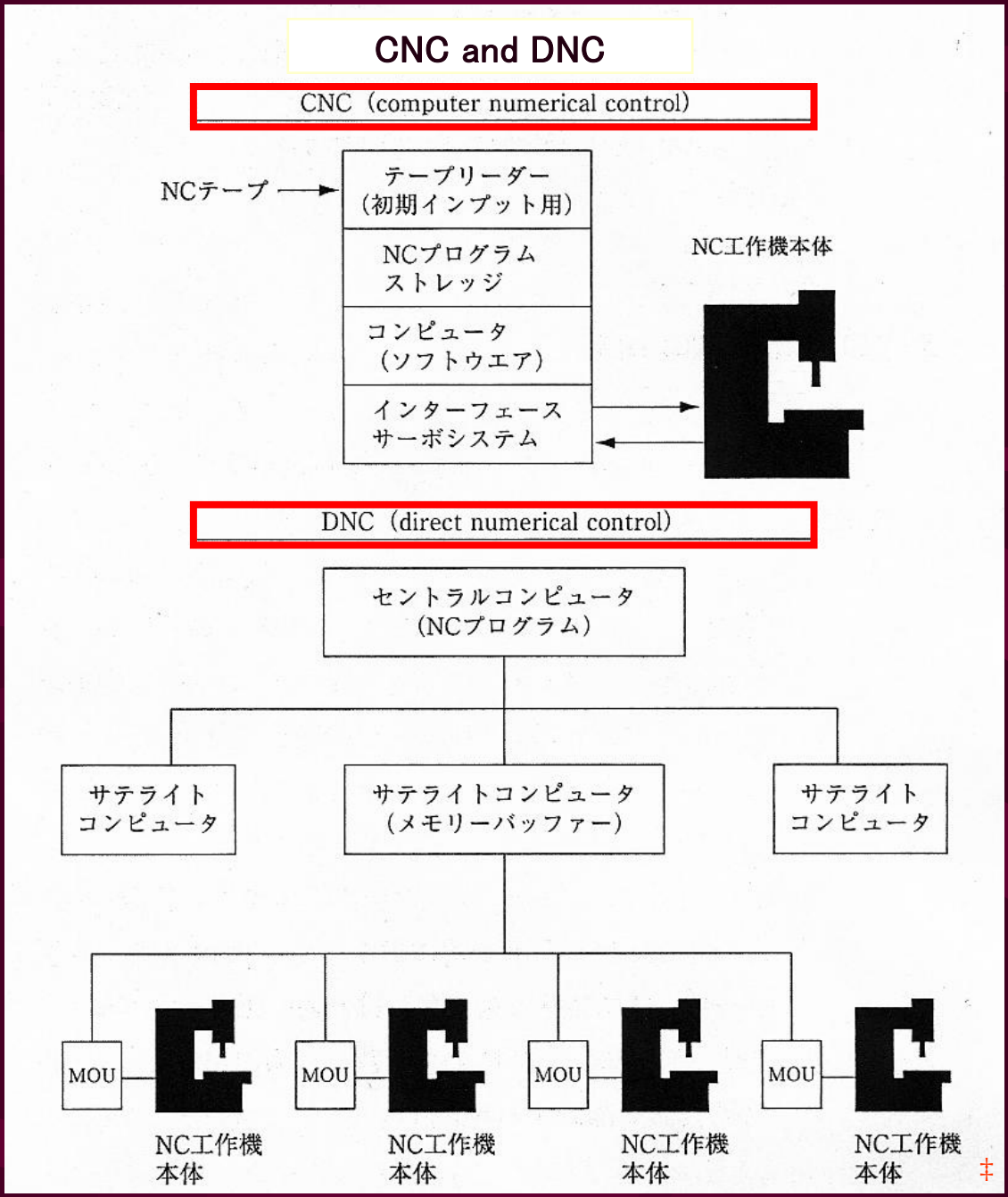
DNC (Direct Numerical Control)

--- central control by a large computer

CNC (Computer Numerical Control)

--- a small computer at a production site (machine tool exclusive)
machine tool with a feature on the conversion portion

CNC and DNC



Author making (reference: Groover. M. 'Groover. M., Automation, Production Systems, and Computer-Aided manufacturing,')
Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp85)

Types by Conversion Portion

MC (machining center)

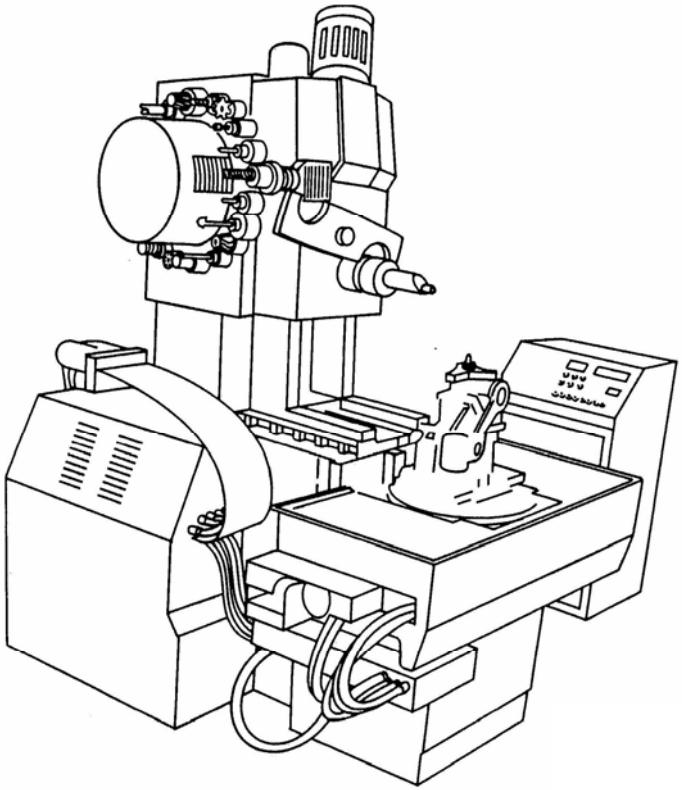
--- NC machine equipped with automatic tool change apparatus
（弁慶の七つ道具）

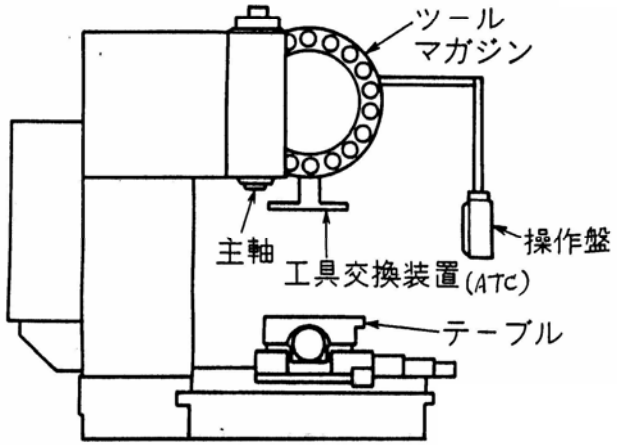
Machine tool of head-change model

--- The "hand" with the tool is switched. 。

having a function close to a single-purpose machine

Machining Center

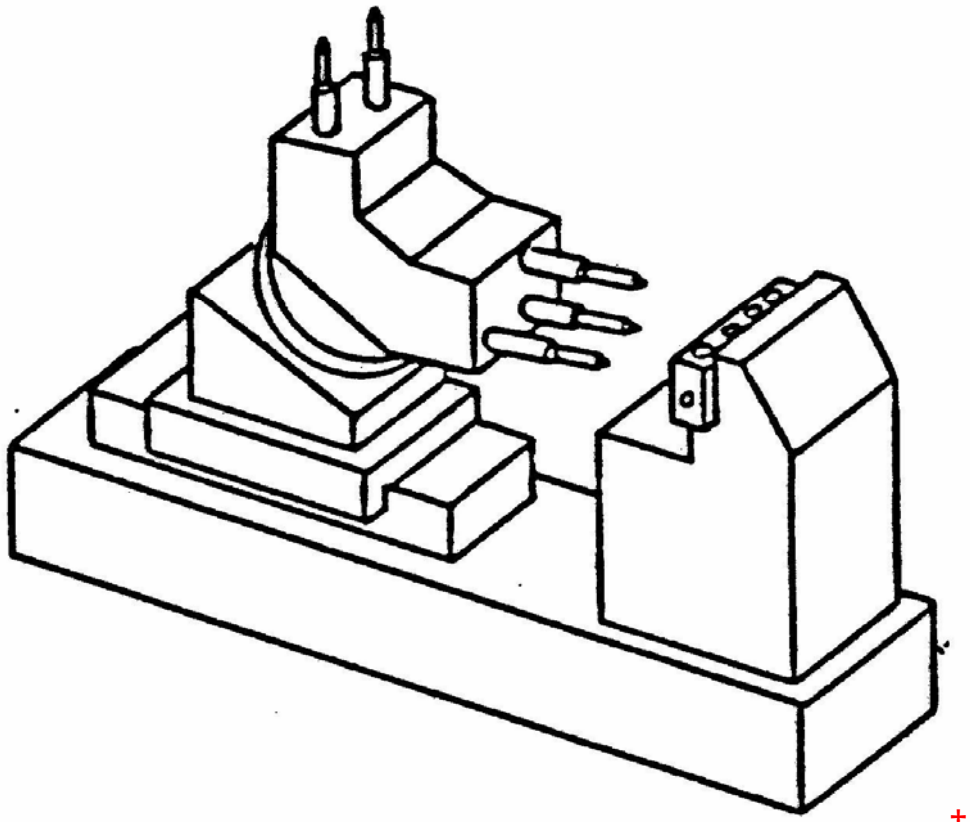




'The Latest Mechatoronics Technological Encyclopedia'
Ohmsha, Ltd.

Lindberg, R.A.
'Process and Materials of Manufacture::
3rd ed., Allyn and Bacon.'
Nihon Keizai Shimbun, Inc.

Multi Spindle Head Rotation Method



Yoshihiko Yamazaki, Masao Tsugami
'How has the machining technology changed ？-Mainly the cutting technology in the engine.' The Society of Automotive Engineers of Japan 1982
Reference: 'Automotive Engineering' No.10

Robot

Machine which is
automatically controlled
re-programmable
multi-purposed
equipped with much degree of freedom, and
manipulative function.

Types of control --- operation, sequence, playback, numerical control, intelligence

Types of structure --- articulate, orthogonal coordinates, SCARA (Japan's pride), cylindrical coordinates

In Japan ---

Penetrated into medium/small companies as well.

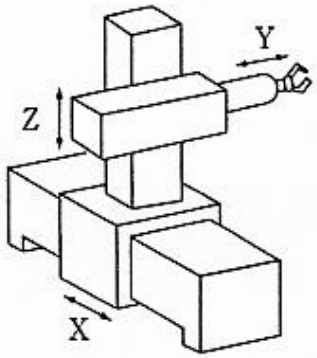
Total design including jigs. Limited-function model. In-house design.

Classification of Robots

Number	Term	Meaning	Correspondence in English (reference)
1110	operating robot	robot which can accomplish part or all of work to have the robot done by human's direct manipulation of the robot	operating robot
1120	sequence control robot	robot which successively proceeds each step of motion as per pre-arranged information (sequence, condition, and position, etc.)	sequence control robot
1130	playback robot	robot which can process work based on such information as sequence, condition, position, etc.that are instructed on the robot by human's manipulation of the robot	playback robot
1140	numerically controlled (NC) robot	robot which can operate itself by numerical and linguistic instructions on such information as sequence/condition/position, etc. without human manipulation of the robot	numerically controlled (NC) robot
1150	intelligent robot	robot which can judge its motion by artificial intelligence. Remark: Artificial intelligence means cognitive ability and learning ability. It's an artificial actualization of abstract thinking ability and ability for adaptation to environment, etc.	intelligent robot

Type of Robot

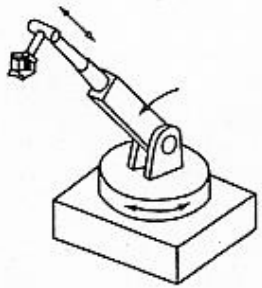
(1) cartesian coordinate robot



・安価・簡単な作業・精度・剛性

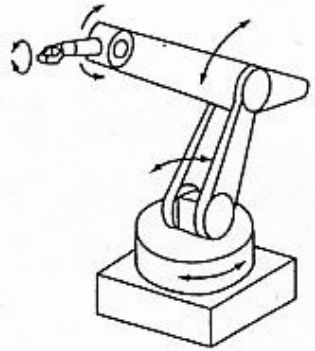
(2) spherical robot

(例：ユニメート)



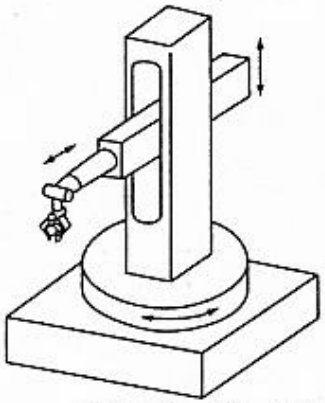
・作業範囲広い
・動作速い

(3) articulated robot



・作業範囲広い・融通性広い
・動作速い・精度悪い

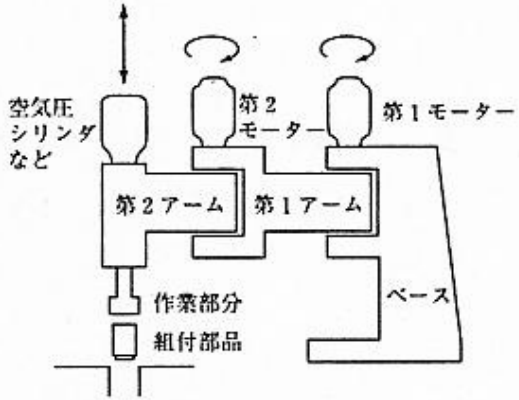
(4) cylindrical coordinate robot



(例：バーサトラン)

・垂直方向挿入作業
・作業範囲広い

(5) SCARA type robot



・一方向挿入作業・水平方向の腕の柔軟性

‡

'The Latest Mechatoronics Technological Encyclopedia' Ohmsha, Ltd.

Automation of Carrier/Storage

Conveyer

stacker crane, automatic warehouse

monorail

autoloader (monorail with handle)

rackrail truck (run on rail)

automatic guided vehicle (AGV)

robot

Automatic Guided Vehicle (AGV)

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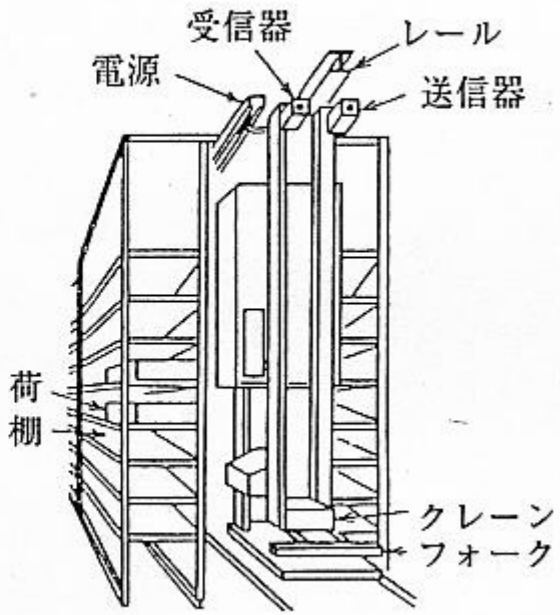
Keicho Aburai 'Achievement of Production Sales Integration‘
Nihon Keizai Shimbun, Inc.

Automation Warehouse



'The Latest Mechatoronics Technological Encyclopedia'
Ohmsha, Ltd.

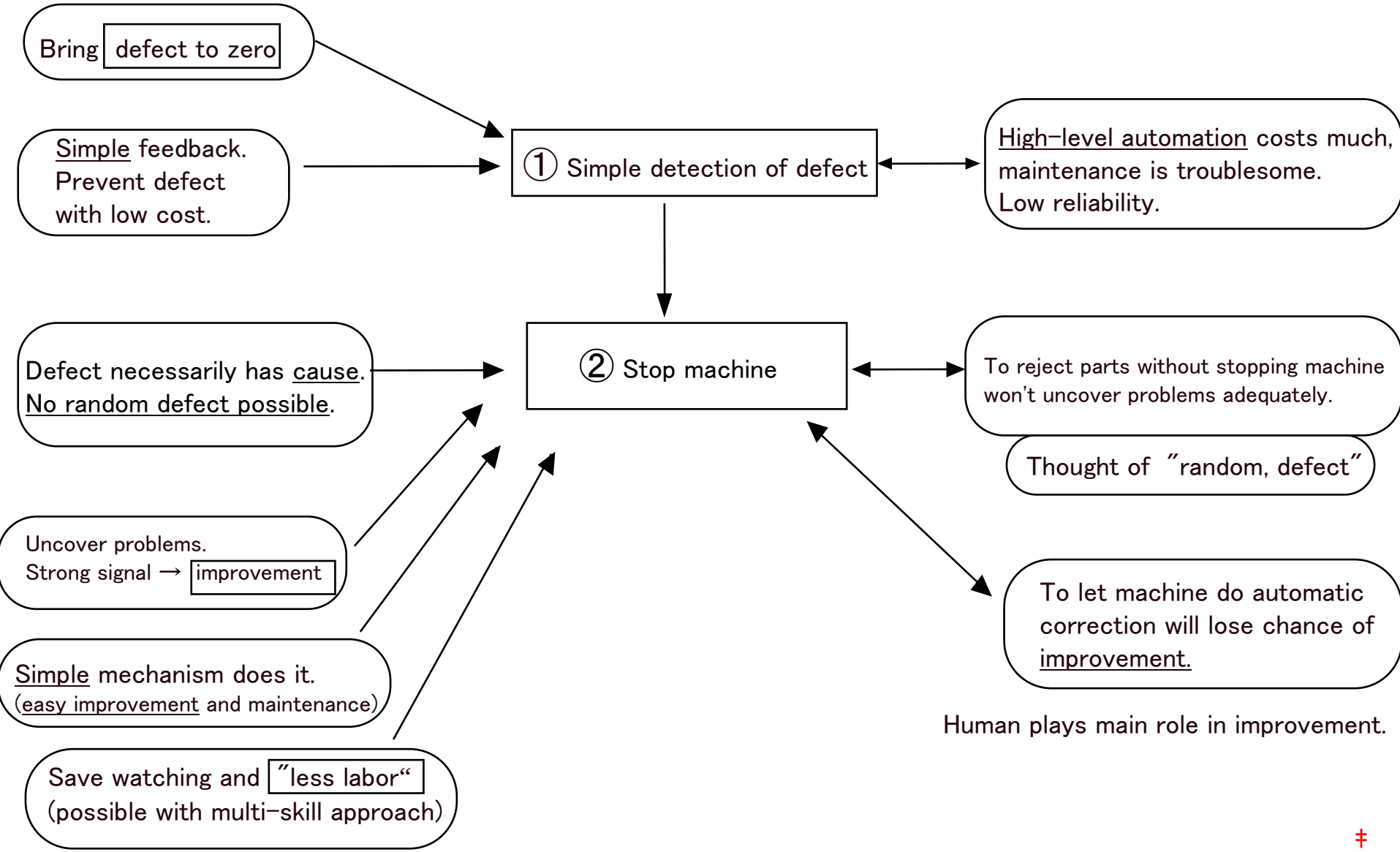
Automation of Detection: (″Automation with Humanity″)

Simple automated detection (to find defect)

→ Stop the machine immediately
(dare not correct automatically)

Aim ––– to dismantle problems
→ Enforce improvements (human intervention) at job site

Background Thought on "Automation with Humanity"



‡

Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p91 figure.11.16)

Automation of System in Total

FMC (Flexible Manufacturing Cell: automation of process cell)

FMS (Flexible Manufacturing System: process in total)

FA (Factory Automation: factory in total including design)

CIM (Computer Integrated Manufacturing: integration of production and sales)

CALS (among companies; to exchange data in seconds including design information)

Where is a net contribution to competitiveness? --- A cool judgment is required.

Example of FMC

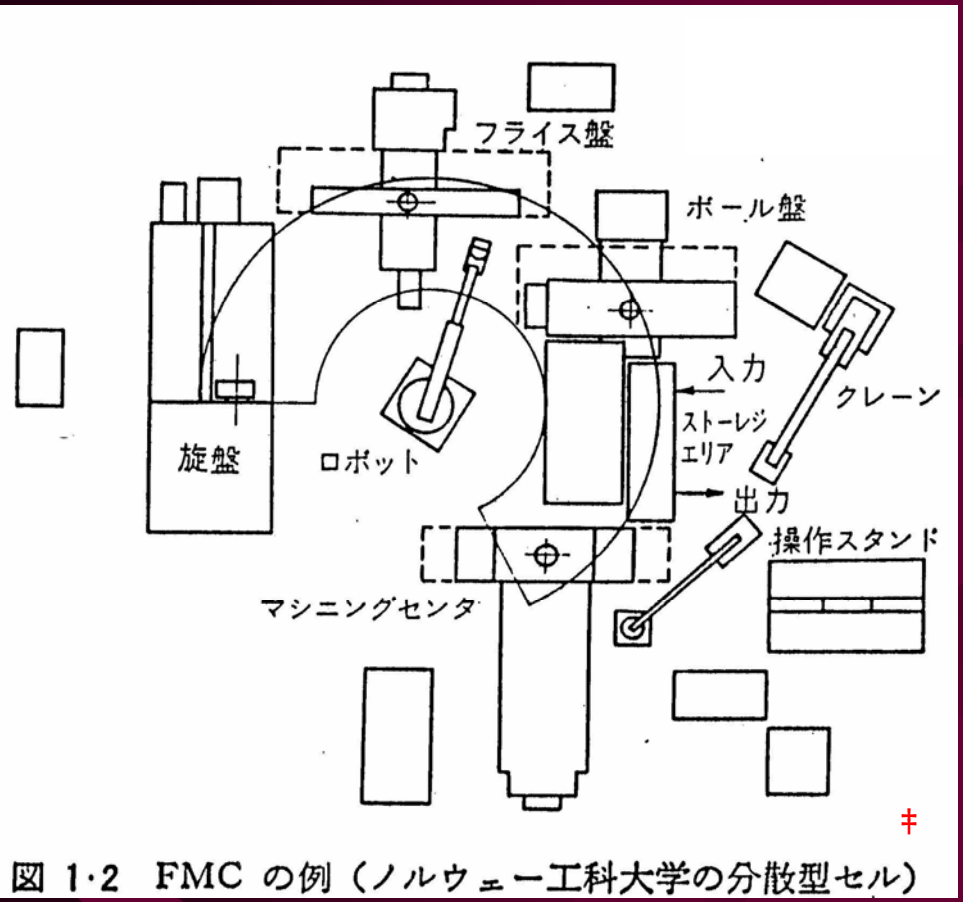
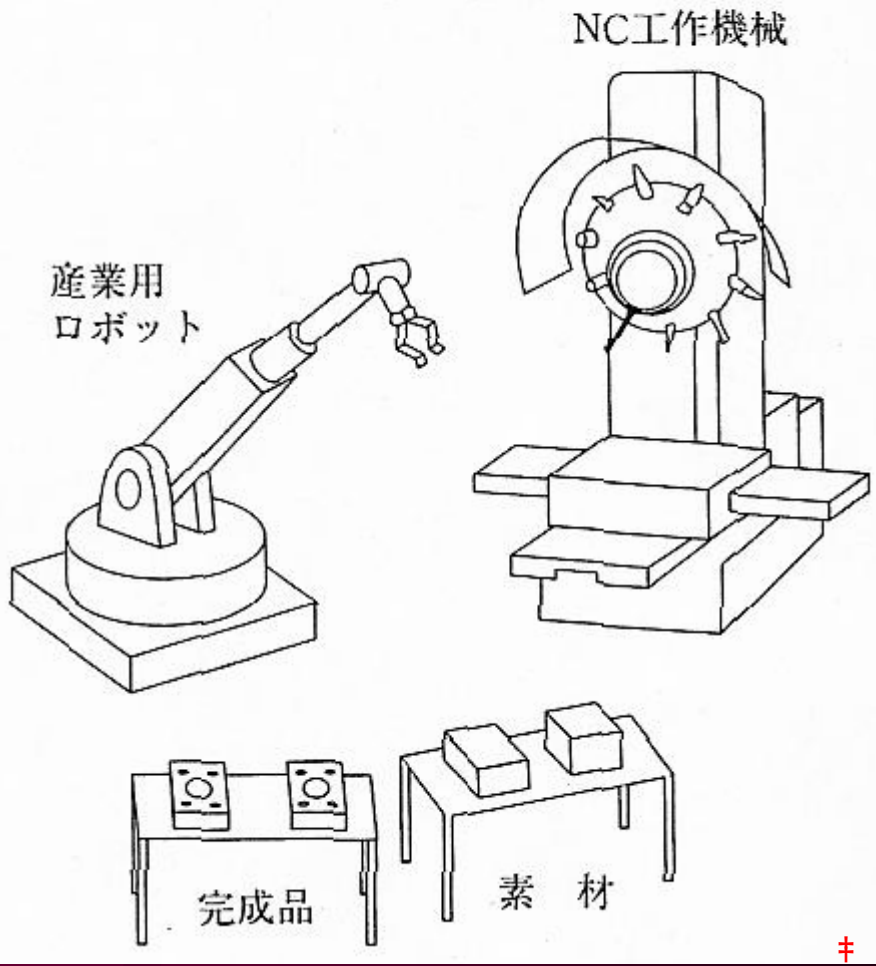


図 1·2 FMC の例（ノルウェー工科大学の分散型セル）

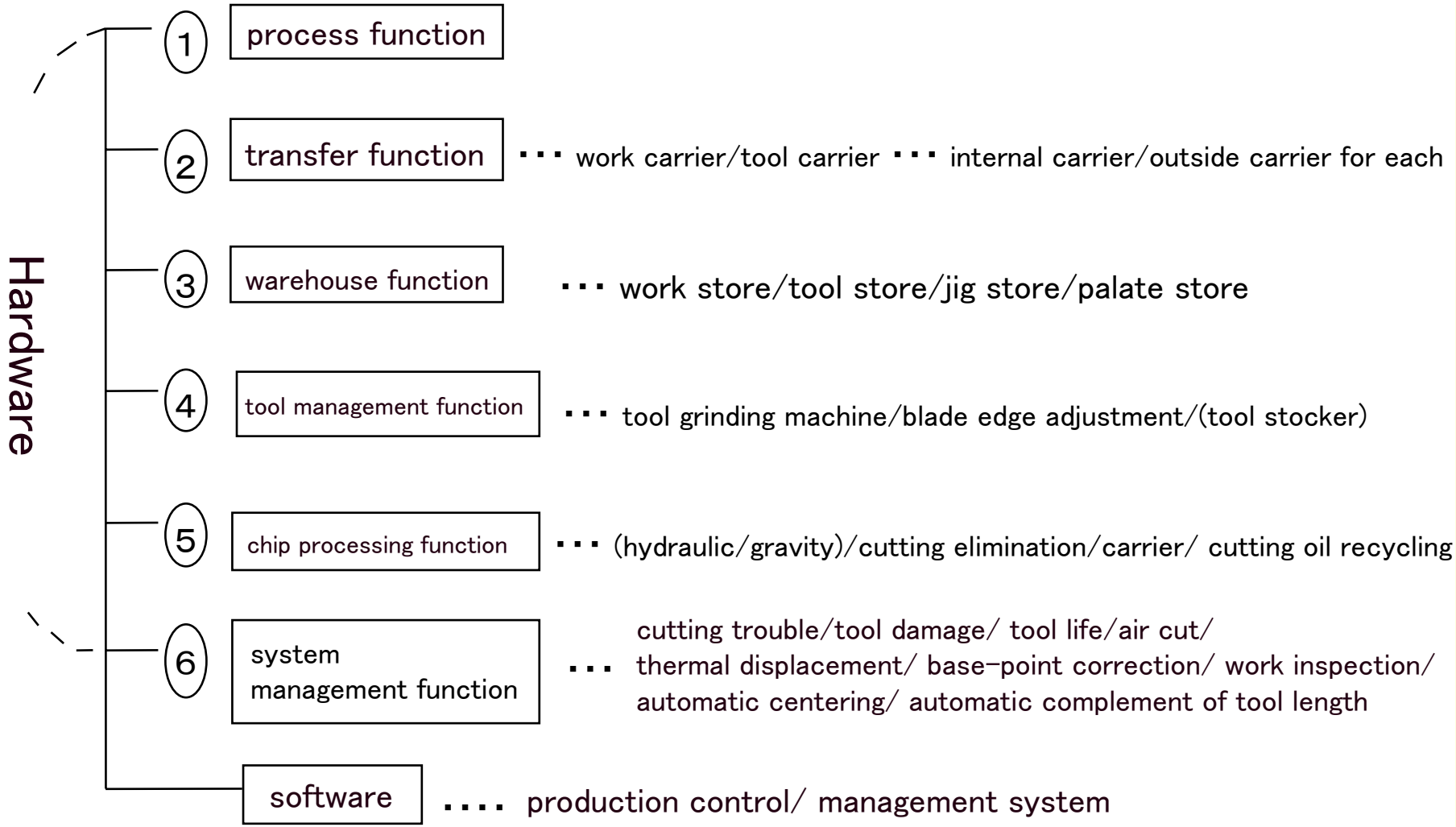
Yoshimi Ito, Kazuaki Iwata 'Flexible Manufacturing System'
THE NIKKAN KOGYO SHIMBUN,LTD. 1984 (p.4)

Example of Flexible Manufacturing Cell (FMC)



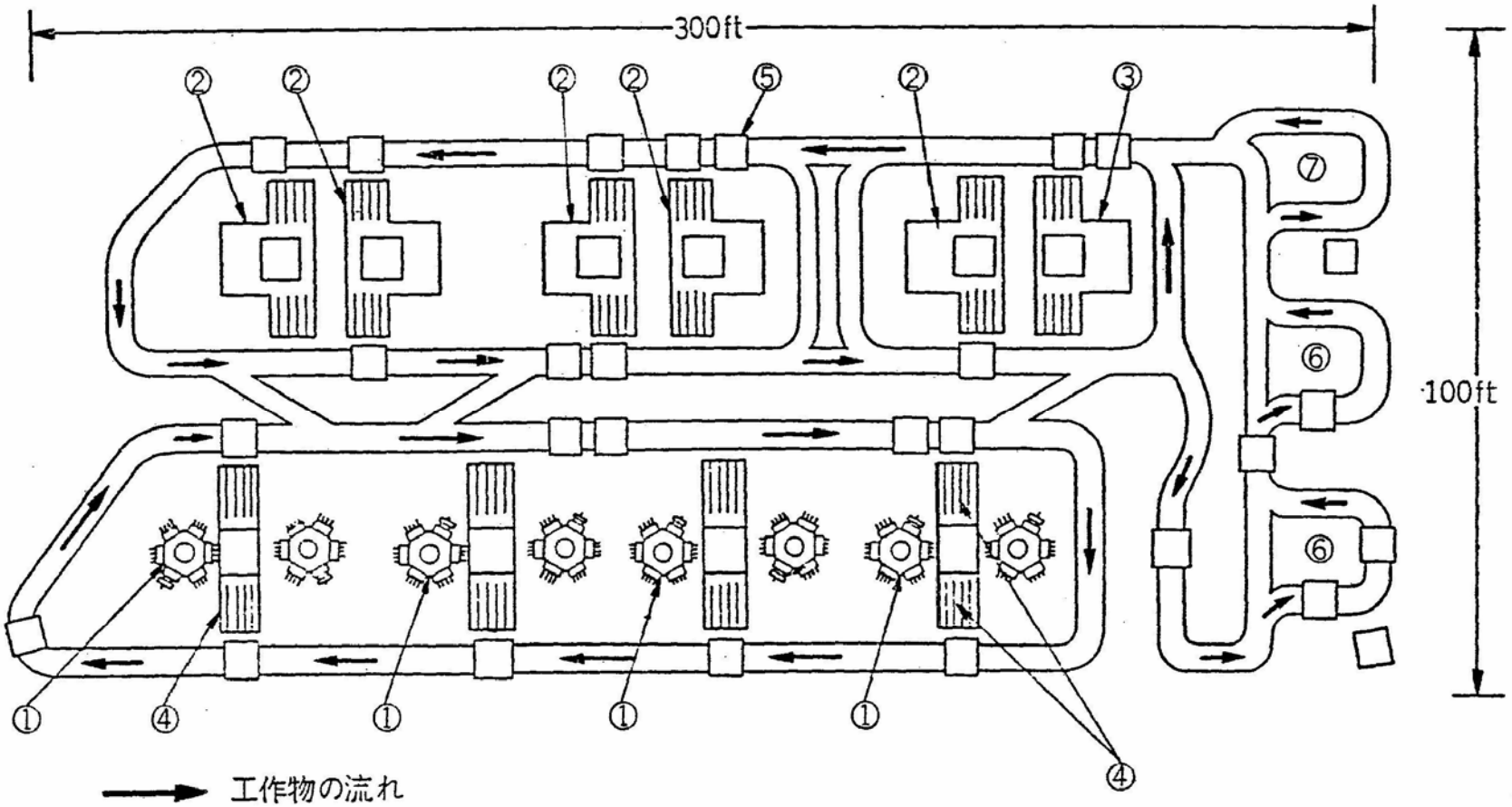
'The Latest Mechatoronics Technological Encyclopedia' Ohmsha, Ltd.

6 Major Functions of FMS' Hardware



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp92 figure.11.17)

Example of FMS

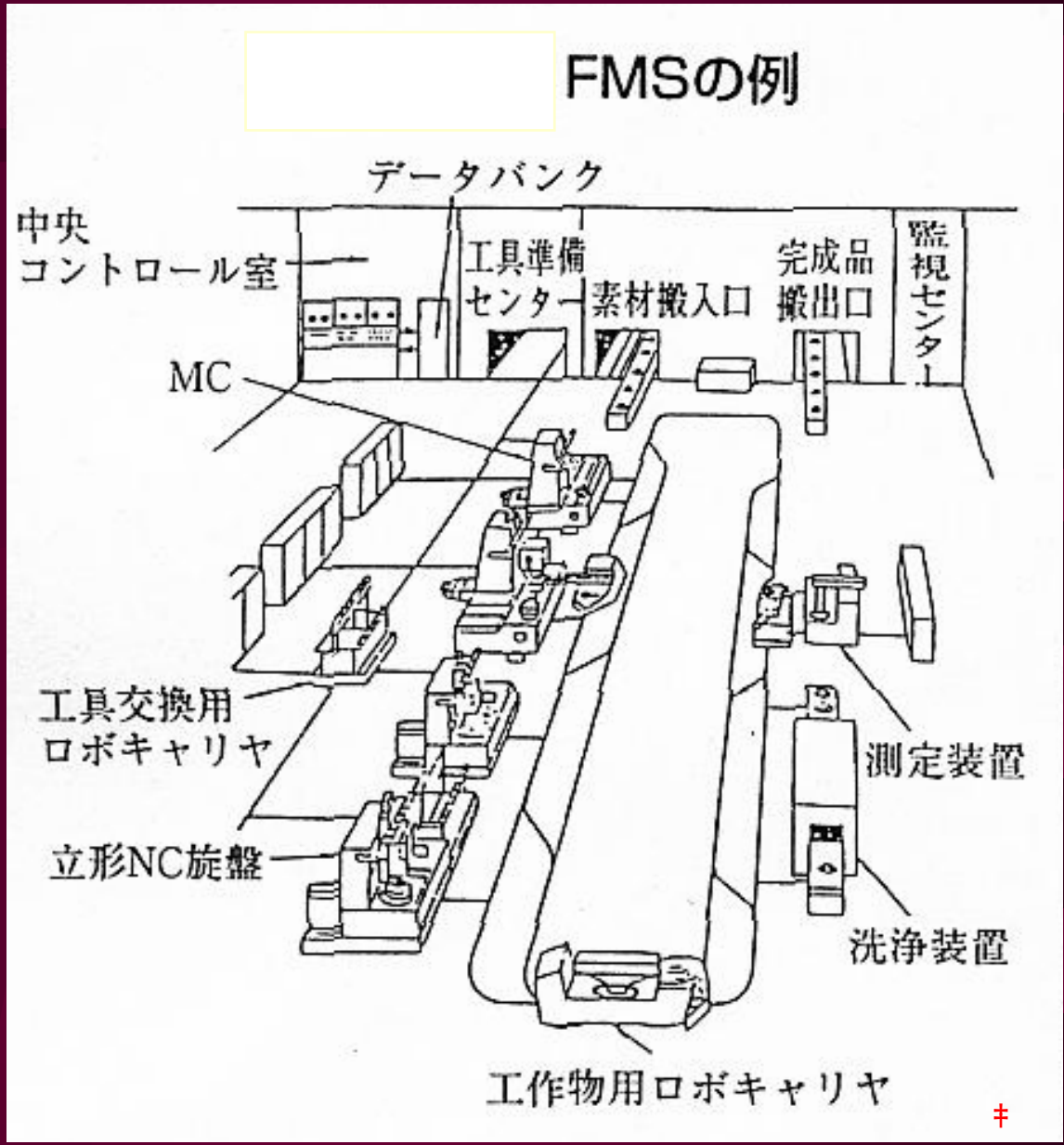


①多軸ヘッドインデクシングマシン
②マシニングセンタ
③3軸NCフライス盤
④シャトル
⑤カート（パレットに固定された工作物を搬送）
⑥ローディング・アンローディングエリア
⑦検査エリア

Milwaukee FMS-1 のシステム構成

Yoshimi Ito, Kazuaki Iwata 'Flexible Manufacturing System' THE NIKKAN KOGYO SHIMBUN,LTD. 1984

CIM and FA



Yoshimi Ito, Kazuaki Iwata 'Flexible Manufacturing System' THE NIKKAN KOGYO SHIMBUN,LTD. 1984

Comparison of FMS' Actual Conditions in Japan and U.S.A

Jaikumar
Postindustrial Manufacturing

・Jaikumar は、1984年における日米のFMSの比較調査の結果を次のように示した。

	FMS in Japan (dynamic)	FMS in America (static)
Intention	・ Flexibility intention (many varieties and small lot)(100 kinds and 200 pieces). The automation of the job shop is intended.	Extension of fixed automation (small kind and large lot)(100 kinds and 200 pieces). Making the transfer line flexible is intended.
Operation results	・ The downtime is small (20% or less). It masters it. ・ Automating driving. Three Naosougyou. ・ Flexibility to a new product is high. ・	The downtime is large (50%). FMS cannot be mastered. Automating cannot be driven. Flexibility to a new product is low.
Resource policy	・ The ratio of the university graduate engineers is high (40%). Training is long (three times the United States). The CNC ratio is high (flexibility of the machine).	The ratio of the university graduate engineers is low (8%). Training is short. The worker's making to desktill. The CNC ratio is low (Flexibility is low).
Develo -pment	・ The development lead time is short (1.5 years). Development team small dice (It is flexible). The development team continues and production continuance → improvement continues.	The development lead time is long (2.5〜3 years). The development team is large. In the development team, neither dissolution nor rupture → improvement are absorbed.
Economic effect	Cost reducing by half. It collects it in three years.	?
Summary	It succeeds because of management based on the dynamic approach. (flexibility, experiment, study, improvement, and training)	FMS is engrafted to a tailor approach and it fails. (extension, desktill, and indiscipline of fixed automation)

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Keicho Aburai 'Achievement of Production Sales Integration' Nihon Keizai Shimbun, Inc.

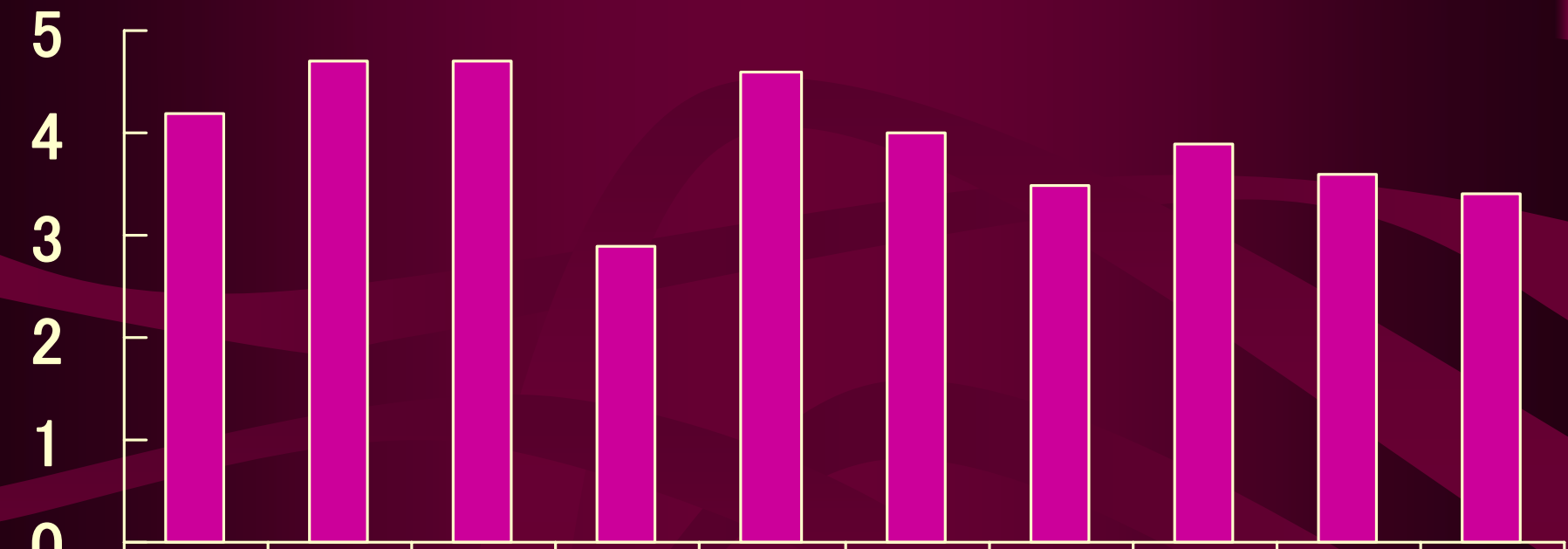
Automation Strategy

Competitiveness Effect and Problems of Automation

- Labor productivity
- Cost reduction
- Manufacturing quality
- Delivery
- Flexibility
- Improvement of working environment
- De-skill / labor alienation
- Employment

Objective/Expectation Effectiveness of Automation (average of 11 companies) (1990)

This questionnaire is about an automation of the final assembly process in your company. As criteria to proceed on the automation of your company's assembly process toward yr. 2000, do you place emphasis on the following objectives or expectation effectiveness? In 5 ranks ranging from "Important (5)" to "Unimportant (1)", select and circle one closest to your opinion.



	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Ave.	4.2	4.7	4.7	2.9	4.6	4	3.5	3.9	3.6	3.4

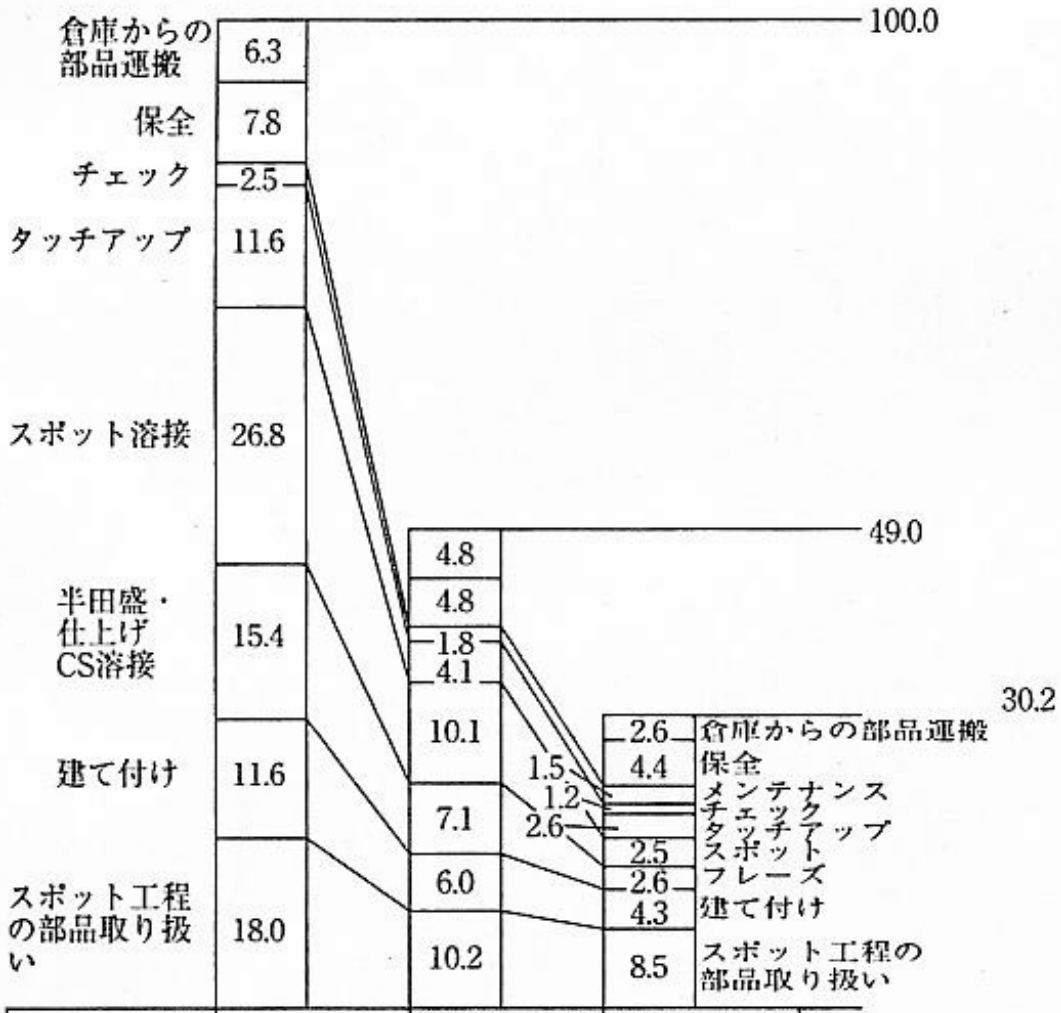
①cost down
②"less labor"
③increase in manufacturing quality
④reduction in delivery time
⑤improvement of working environment/ reduction in workload
⑥response to aging workforce
⑦shortage in new worker recruitment
⑧response to time problem
⑨enhance company image
⑩activation of company/organization

important ← → unimportant

5 4 3 2 1

Labor Productivity

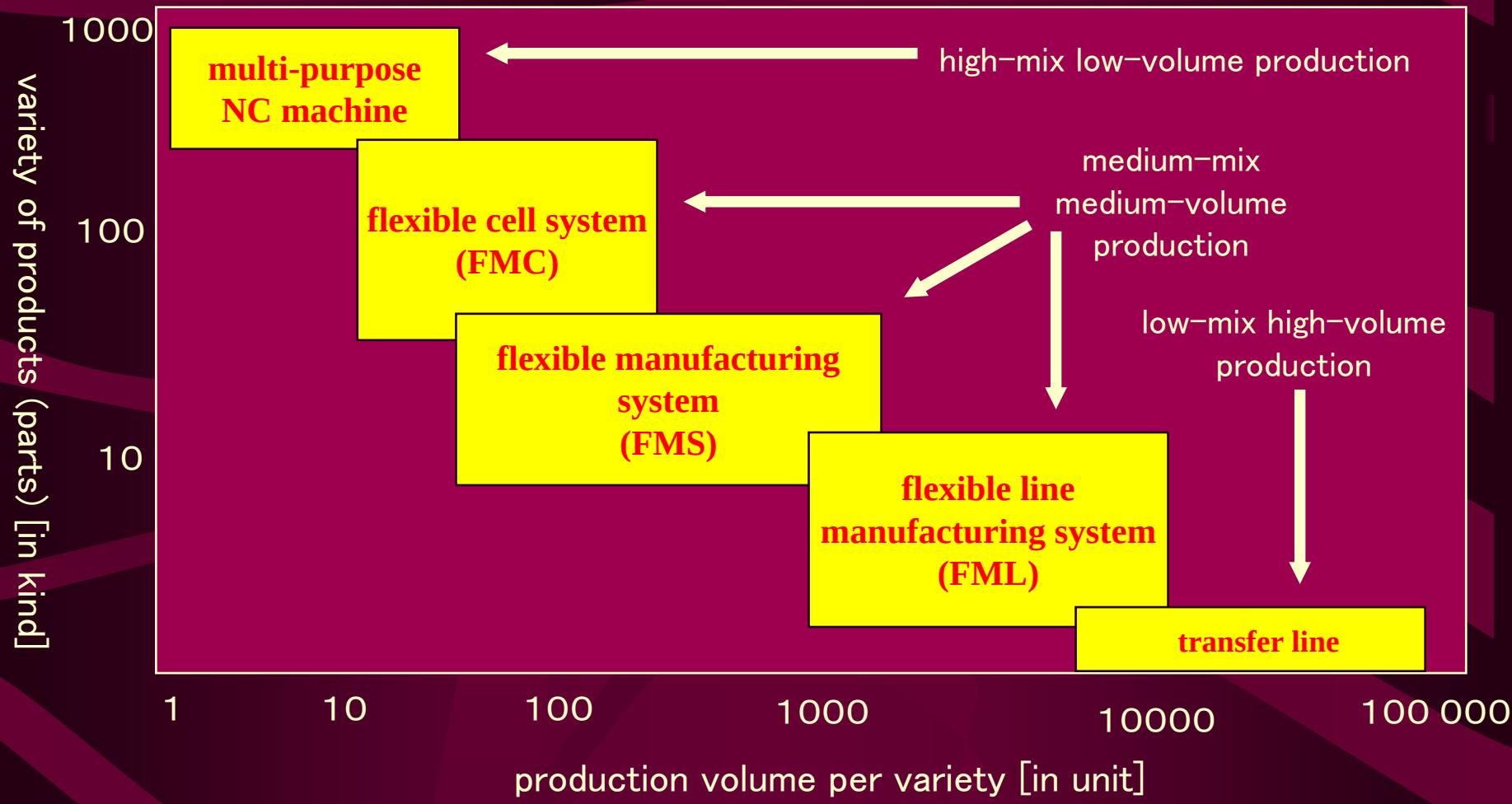
Decrease in Auto-Body Manufacturing Man-Hours per Car by Automation



年　度	1975年	77年	82年
生産規模	4000台/月のライン	7000台/月のライン	18000台/月のライン
スポット溶接の自動化率	10%	60%	94%

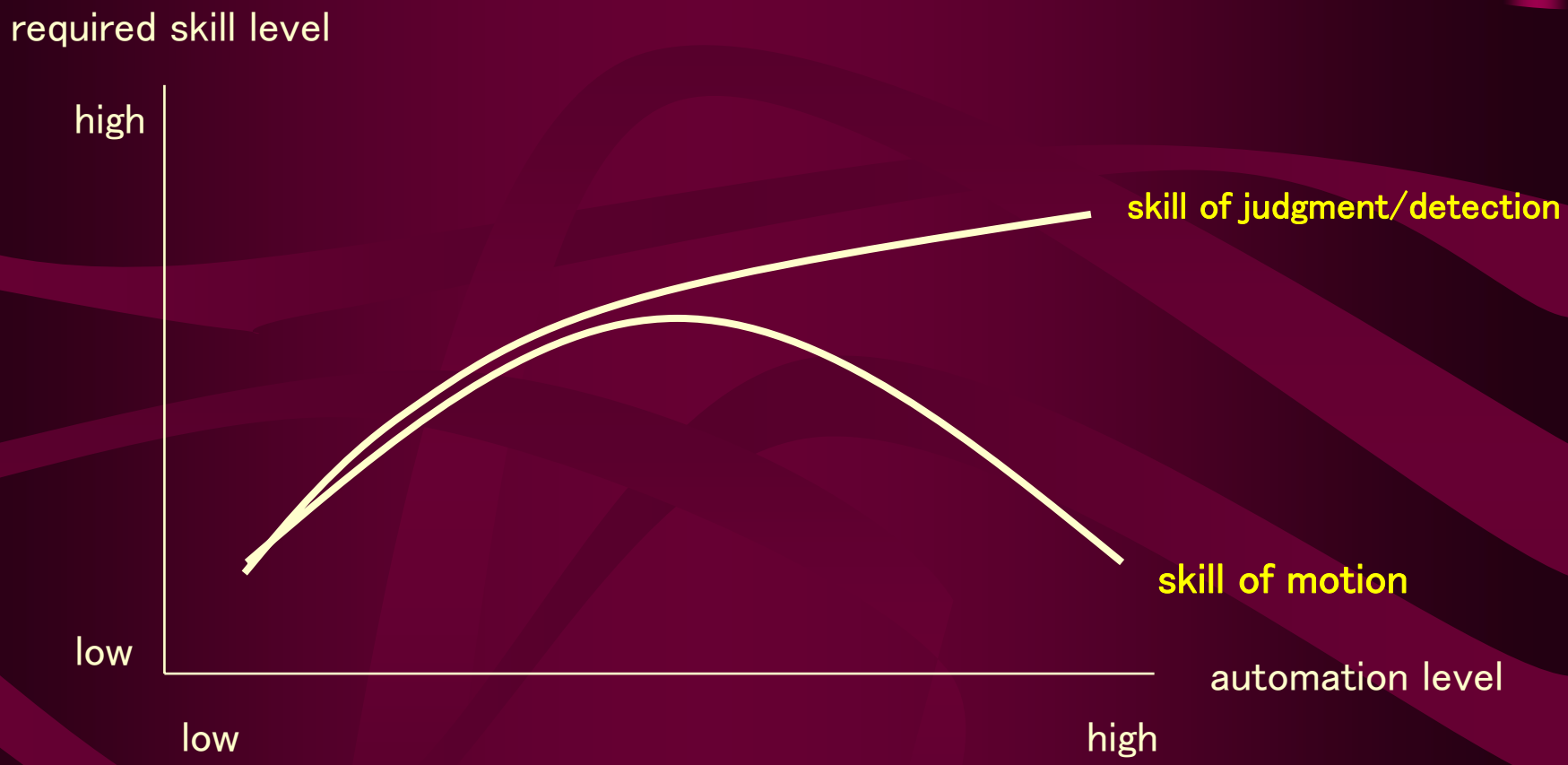
Mitsuo Takahashi
'Current state of automation of body welder place and problem in the future.' The Society of Automotive Engineers of Japan 1982
Referentce: 'Automotive Engineering' No.10

Flexibility Application Domain of Machine Process System



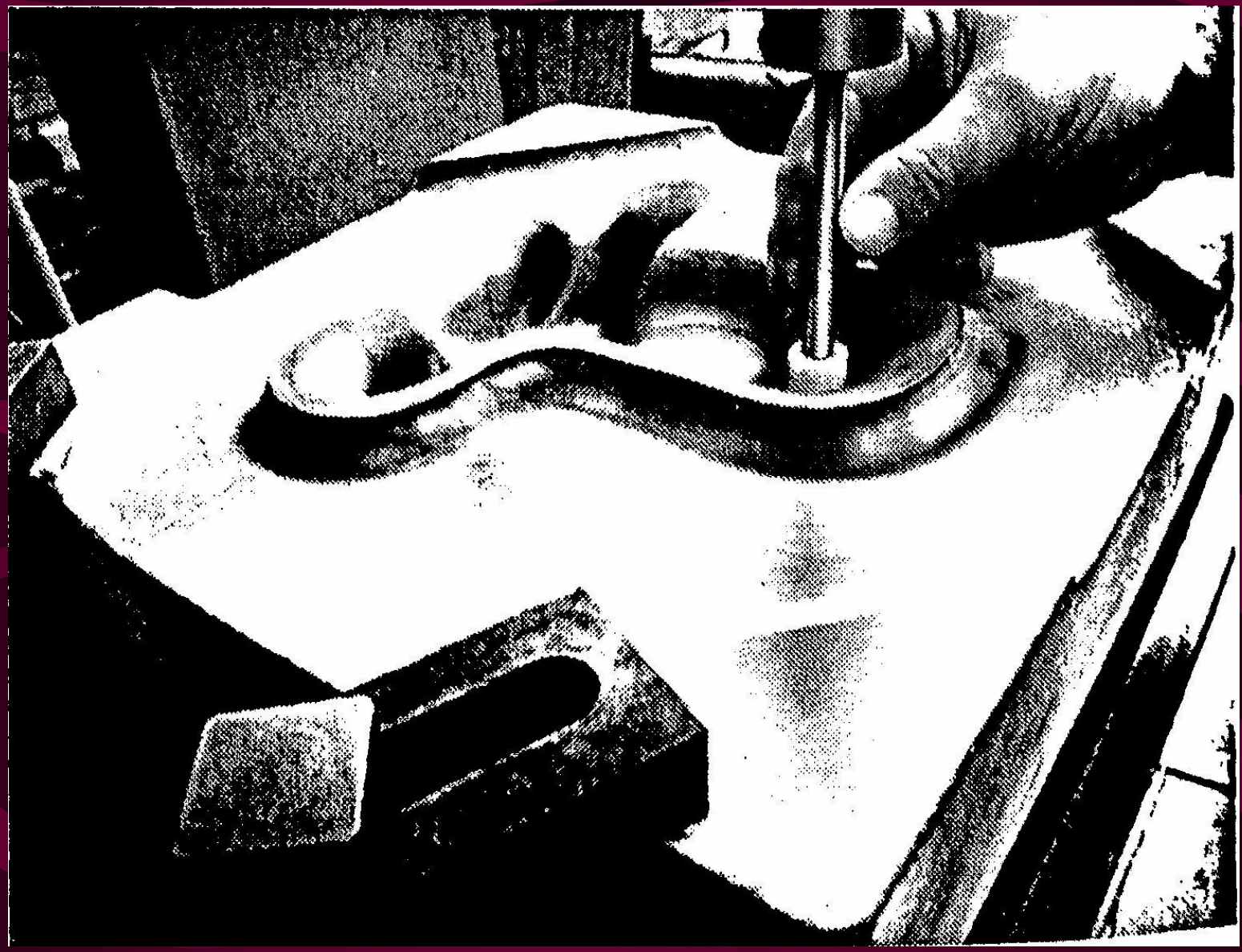
'The Latest Mechatoronics Technological Encyclopedia' Ohmsha, Ltd. ‡

Impact on Skill Level by Automation (conceptual diagram)



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱ p100 figure.11.23)

Teaching of Playback Work Machine



Reference: Lindberg

Low Cost Automation Strategy and High-Tech Automation Strategy

Depending on type of business ---

Japanese companies in general are good at low cost automation strategy.

(although some inclinations toward high-tech strategy were observed in the bubble economy years.)

Characteristics of Assembly Factory in Fleet Car Maker (1989)

	日本にある日本車工場	北米にある日本車工場	北米にある米国車工場	欧州全体
Results:				
Productivity (time/stand)	16.8	21.2	25.1	36.2
Quality (defect the number of/100)	60.0	65.0	82.3	97.0
Factory layout:				
Space (superficial feet/number/year)	5.7	9.1	7.8	7.8
Area of adjustment part:				
(% to area of assembly part)	4.1	4.9	12.9	14.4
Stock (There are eight kinds of sample parts on the day)	0.2	1.6	2.9	2.0
worker:				
Team organization rate(%)	69.3	71.3	17.3	0.6
Alternation system (0=none,4=frequent).	3.0	2.7	0.9	1.9
Instruction frequency (piece/person).	61.6	1.4	0.4	0.4
Number of duties.	11.9	8.7	67.1	14.8
New figure training time number of absence	380.3 5.0	370.0 4.8	46.4 11.7	173.3 12.1

Source：IMVP World Assembly Plant Survey, 1989, and J.D. Power Initial Quality Survey, 1989

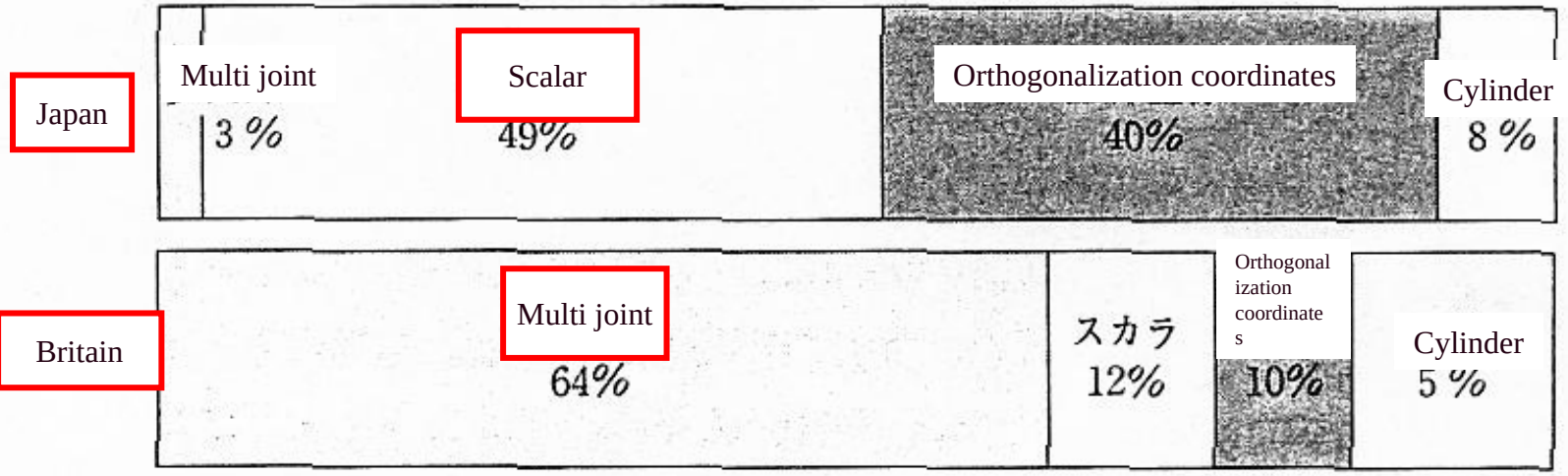
Two Types of Automation Strategy

	1 Low cost automation strategy	2 High-tech automation strategy
Purpose	competitiveness-oriented (Automation is just a means.)	prone to technocentrism
Sequence	total-system-oriented (process improvement first)	right out on automation without system improvement
Facility planning	limited-function, cheap machine facilities emphasis on facility function expansion in future	expensive machine facilities of over-function static facilities lacking function-expansion possibility
Self-/outside-manufacturing	inclination toward self-manufacturing of facilities	inclination toward outside-manufacturing of facilities aiming at effect of quantity production of facilities
Improvement/maintenance	emphasis on intermittent facility improvement at job site innovation principle	facility improvement by specialist up above inclination toward large scale automation system (one-shot deal)

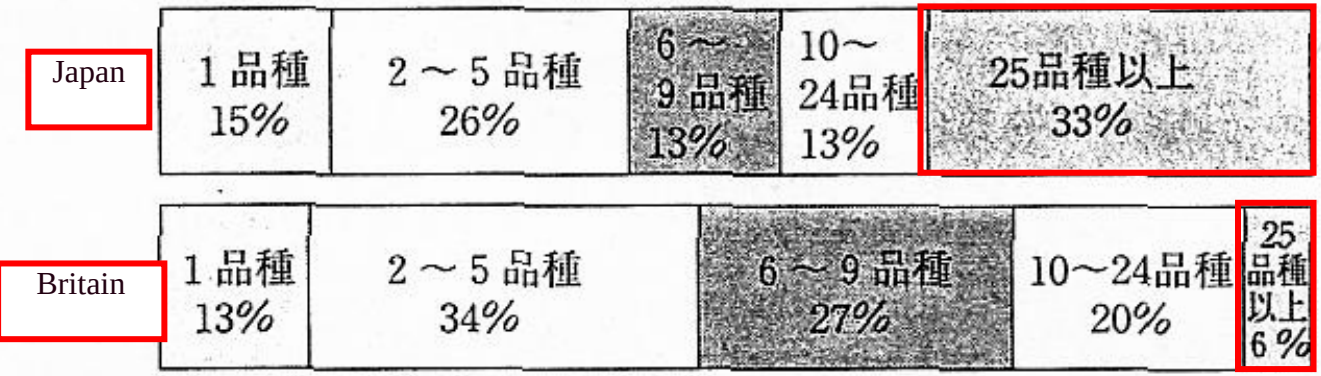
Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp102 table.11.5)

Japan-U.K. Comparison of Robots (1980s)

(a) Composition of assembly robots by type



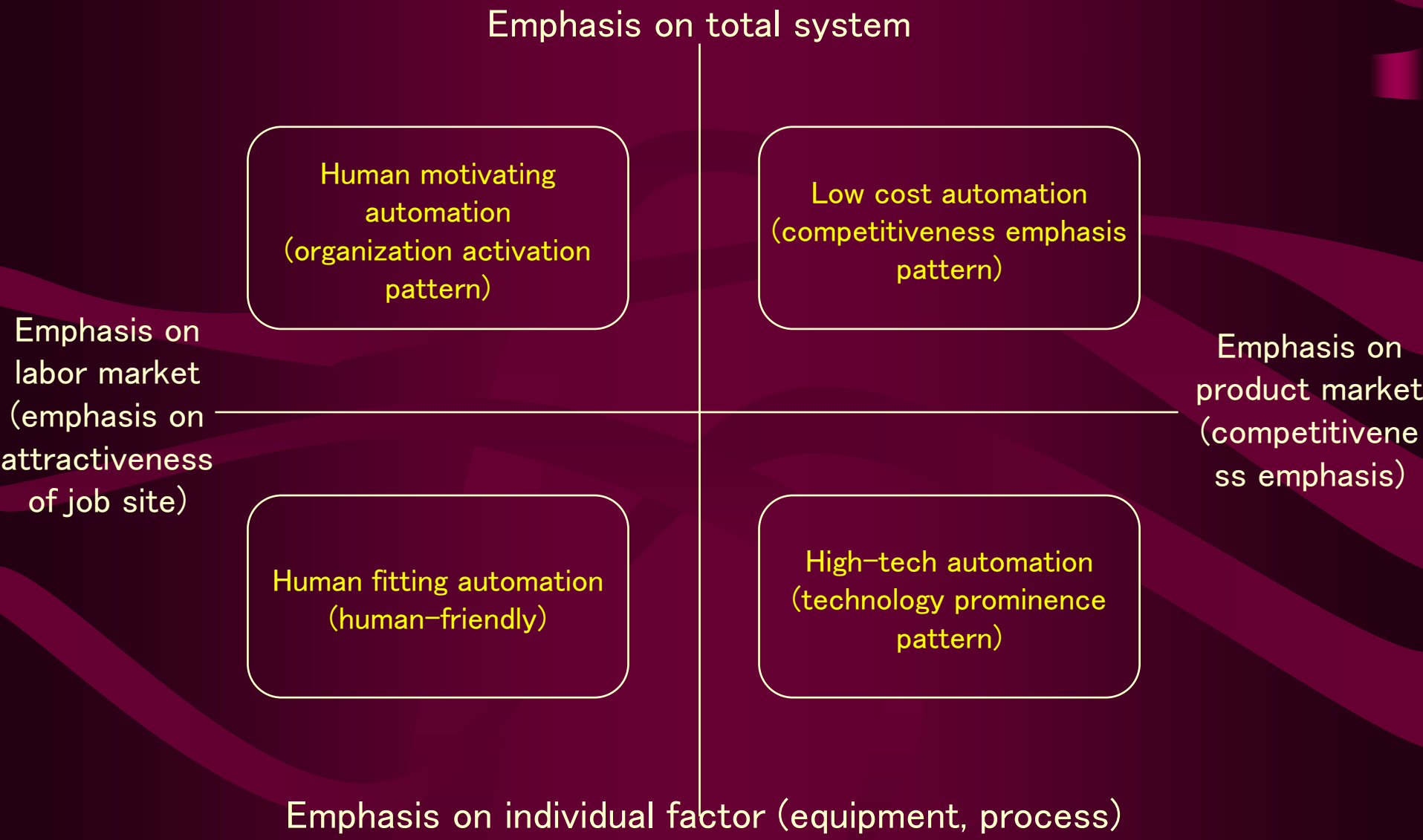
(b) Product variety accommodated by robot system in total



Author making (reference: 'Tidd.J., Key Characteristics of Assembly Automations Systems. In Shimokawa, K., Juergens,U. and Fujimoto,T.(eds.) Transforming Automobile Assembly, Springer')
Reference: Takahiro Fujimoto 'Introduction to Production Mmanagement' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp103)

New Expansion of Assembly Automation

Types of Assembly Automation Strategy



Takahiro Fujimoto 'Introduction to Production Management' Nihon Keizai Shimbun, Inc. 2001 (Ⅱp107 figure.11.26)

3. Failure and Maintenance of Facility

Maintenance ＝

To prevent (**preventive maintenance**)
failure and capability decline in advance, and
to recover when they incur (**post maintenance**)

Failure ＝

For facility to lose its function aimed in design

Reliability/Downtime/Availability

Reliability = rate at which facility exerts its function as per design

Uptime = time span when facility is capable to motion

Downtime = time span when facility is incapable to motion

Availability = average UT / (average UT + average DT)

--- to increase this → increase in facility productivity

"Jerky halt" : no need for repair, but facility at halt
big cause to downtime

Maintenance Activity and Maintenance Organization

Specialty maintenance (maintenance division) :
response to trouble → skill, atypical pattern, irregularity

Self-maintenance (direct operation division)

Productive maintenance :
to comprehensively reduce cost throughout the life of facility

- Post maintenance (restoration)
- Preventive maintenance (periodic/continuous inspection)
- Improvement maintenance (facility improvement → recurrence prevention)
- Maintenance prevention (to design facility requiring no maintenance, to begin with)

Development of Maintenance Management

BM ↓
post maintenance repair after breakdown

PM ↓
planned maintenance planned repair
progressed in England

PM ↓
preventive maintenance daily/periodic inspection, periodic maintenance
1925 appeared in American literature
1951 introduced first time in Japan

PM ↓
productive maintenance
maintenance to increase productivity --- emphasis on economical efficiency
1954 advocated by GE in USA

CM ↓
reform maintenance internal reform of facility per se
stressed since approx. 1957

MP ↓
maintenance prevention PM design for new facility
1960 inserted in FACTORY

Reliability engineering ↓
reliability (longevity), maintainability (reduction in repair time)
stressed since approx. 1962

LCC ↓
to minimize cost over life of facility
1966 development started in US Department of Defense

Technology ↓
advocated by British Commerce Department in 1970

TPM
PM of full participation
advocated by Japan Plant Engineering Association in 1971

Rintaro Muramatsu
'Manufacturing Control of Automobile'
SANKAIDO PUBLISHING Co.,Ltd 1980 ‡

TMP and Self-Maintenance

TMP（Total Productive Maintenance）

--- self-maintenance and productive maintenance participated by all members

Defend my facility by myself.

Education/training as part of fostering multi-skilled worker

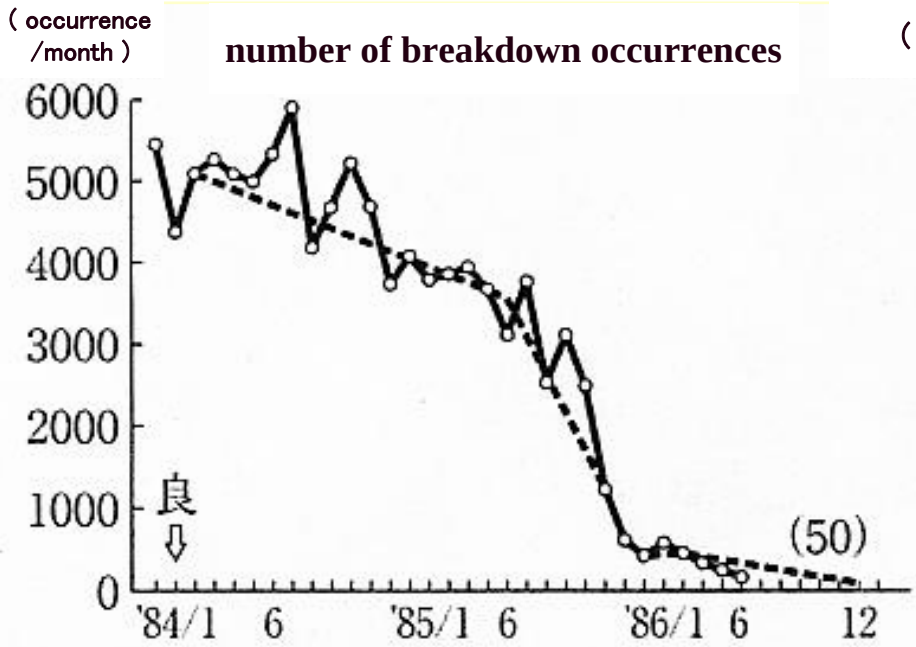
Leverage small group activities

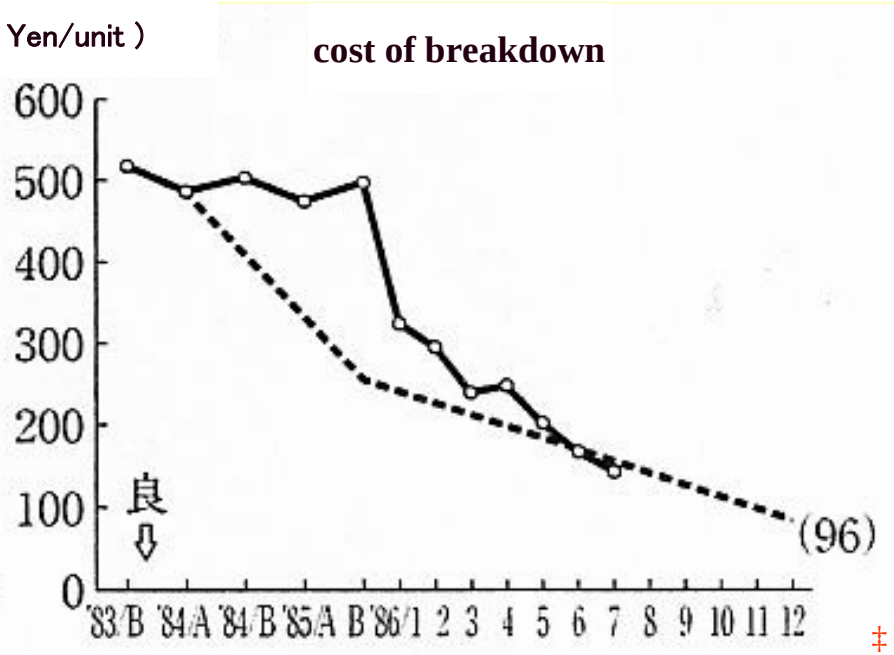
Advocated by "Japan Plant Maintenance Association"

Total efficiency of facility

= hourly operating rate x capability operating rate x pass rate

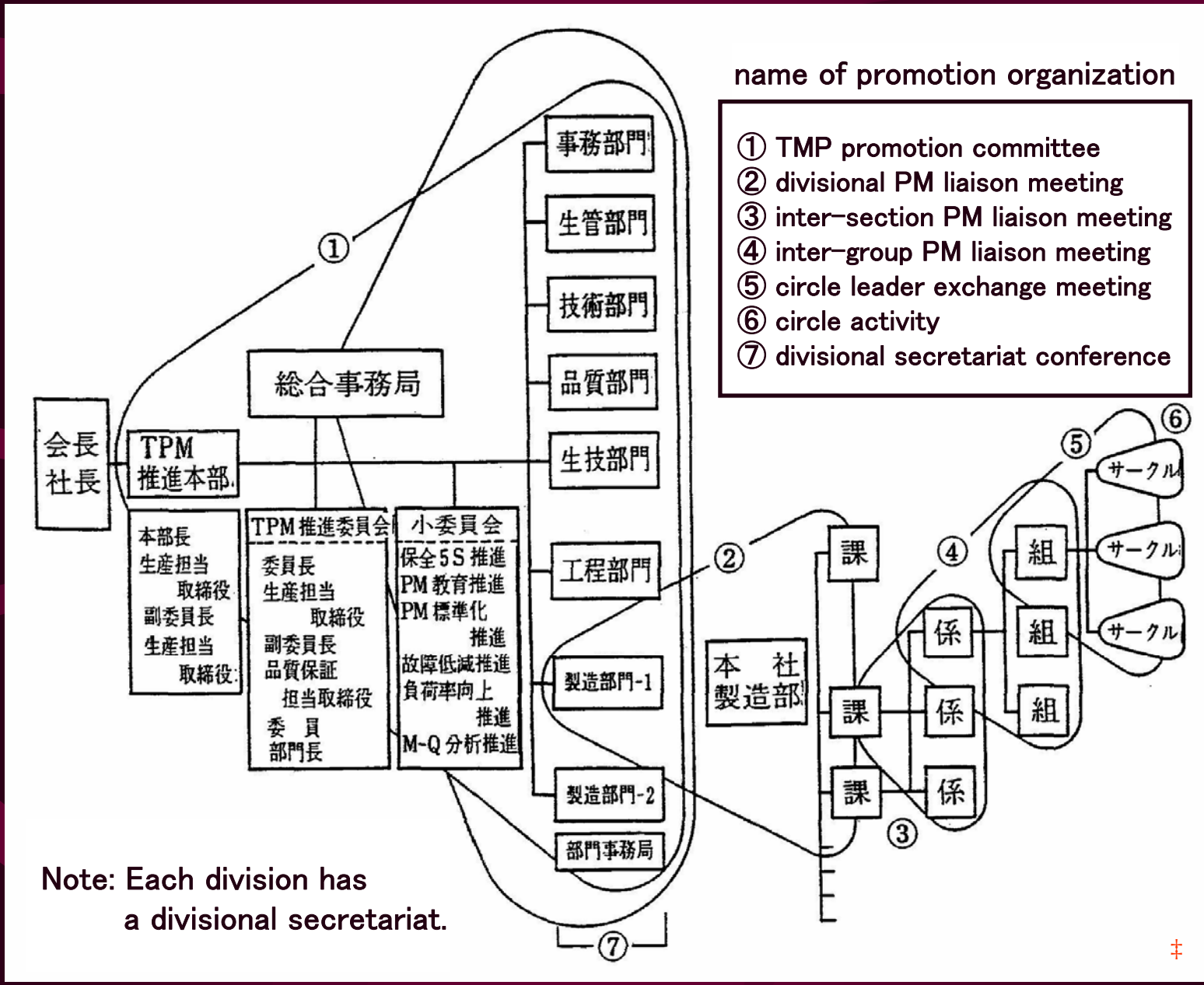
Achievement of TPM (total productive maintenance) : Example of Daihatsu Motor Co., Ltd.





Tokutaro Suzuki 'New Development of TPM' Japan Management Association

TPM Promotion Organization



Summary: Automation and Facility Management in Japan

Total-system-oriented (not automation for automation's sake)

Low-cost-oriented

Both self-maintenance and specialty maintenance to enhance organizational capability

Having good command of existing facility

"Ripen the factory" "Instill wisdom into the facility"

→ to accomplish low downtime, high facility productivity.