5-8 June 2011

Symposium on Japan America Frontier of Engineering (JAFOE)

Robotics Session:

Human-like Assembly Robots in Factories

8th June 2011

YASKAWA ELECTRIC CORPORATION
Corporate R&D Center

Robotics Technology R&D Group
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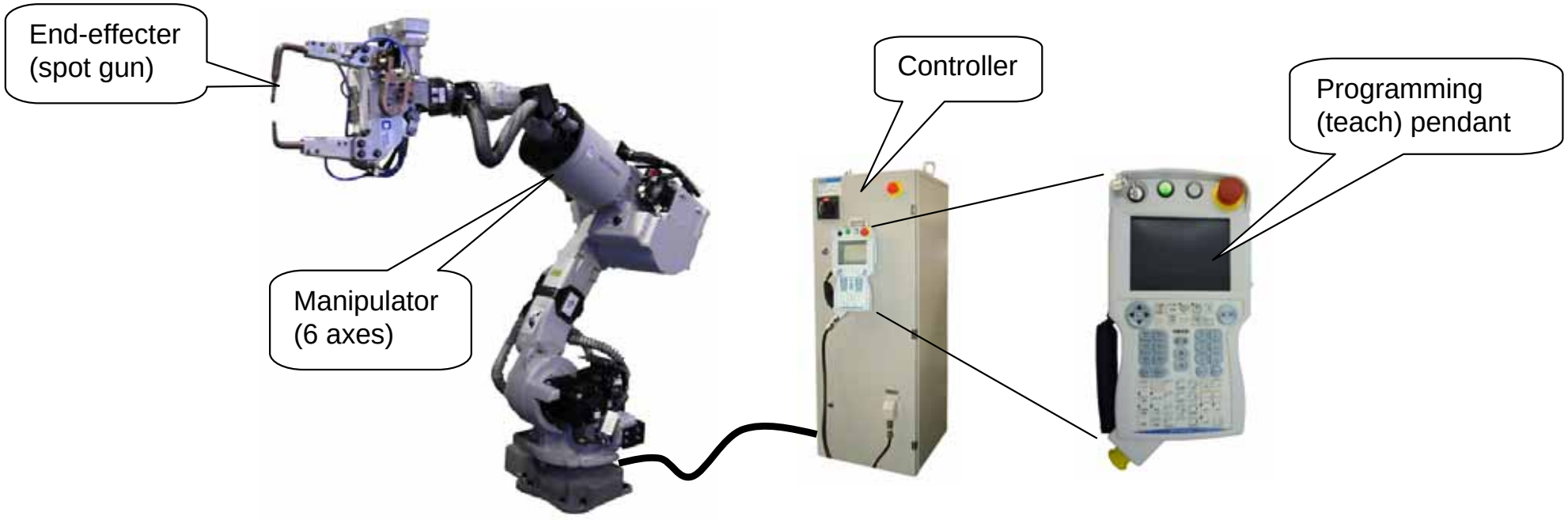
- Introduction: Overview of Industrial Robots
- Focus on “Force Control” and “Assembly Robots”
- Technical Problems on Human-like Assembly Robots
- How to deal the Problems (current solutions)
- Future Challenges and Directions

Introduction: Overview of Industrial Robots (1/3) 20110520

- What is Industrial Robot?
  - Manufacturing machine that substitutes for human worker(s)
  - Defined by ISO8373:1994 as an automatically controlled, re-programmable, multipurpose manipulator with three or more axes
  - Controlled by Teach & Playback method



Introduction: Overview of Industrial Robots (2/3) 20110520

- Brief History of Industrial Robots
  - Born in the USA in early 1960s (Unimate 1961, Versatran 1961)
  - Grown up in Japan in 1970s
    - ⇒ Unimate was imported by Kawasaki Heavy Industry
    - ⇒ Hydraulic to electric actuation
    - ⇒ Absolute encoder
  - Spread all over the world (more than one million robots are working)…why?
    - ⇒ High speed, high precision, high power and keep working

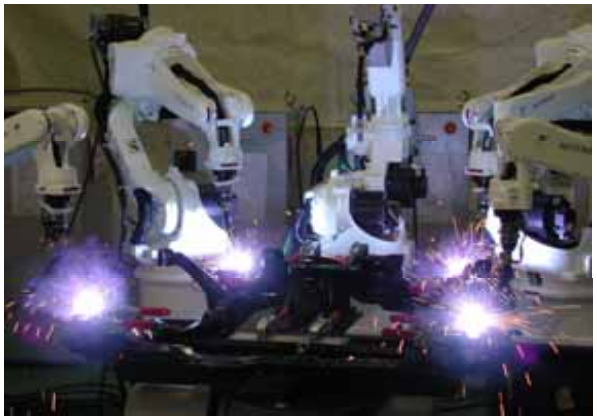
MOTOMAN-L10
1977

MOTOMAN-K10S
1988

Latest models of MOTOMAN

Introduction: Overview of Industrial Robots (3/3)

- Current Applications and Control
  - Welding, painting, handling…
  - Only position is controlled



Arc welding

Bumper painting

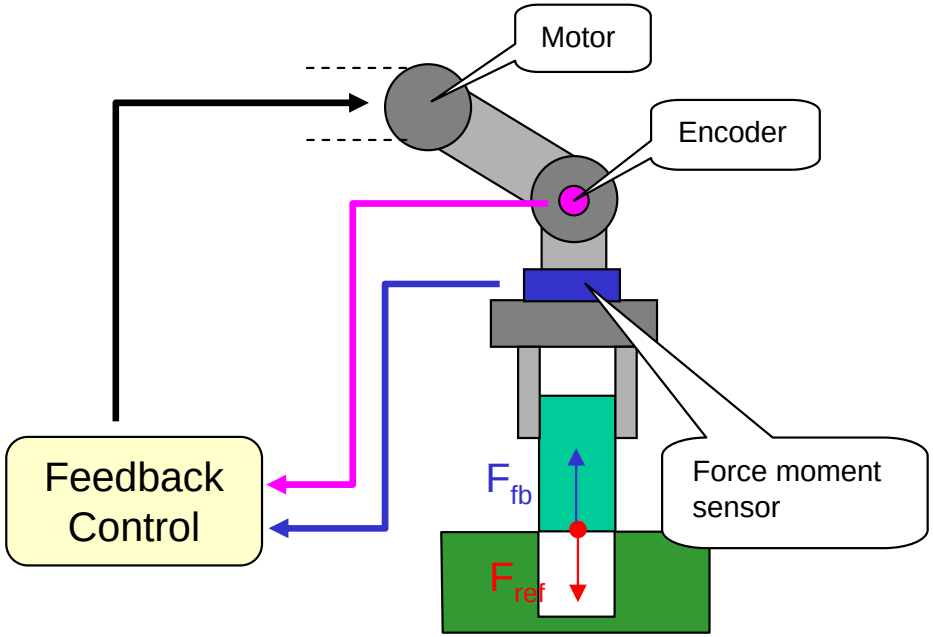
LCD glass handling

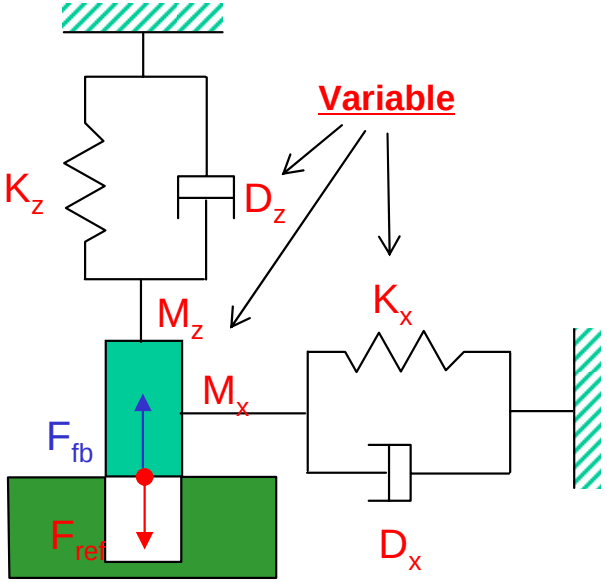
Even now, assembly process are done by human workers

⇒ Force control is needed to realize assembly task by robots

Focus on “Force Control” and “Assembly Robots” (1/3)

- Force control was intensively researched 1980～2000
  - Ex. Compliance Control, Impedance Control
- Not used for industrial robots…why?
  - Lack of CPU performance
  - High cost of force sensor



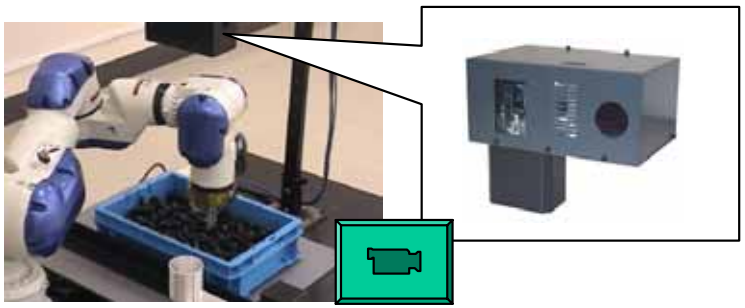


Virtual mechanical impedance

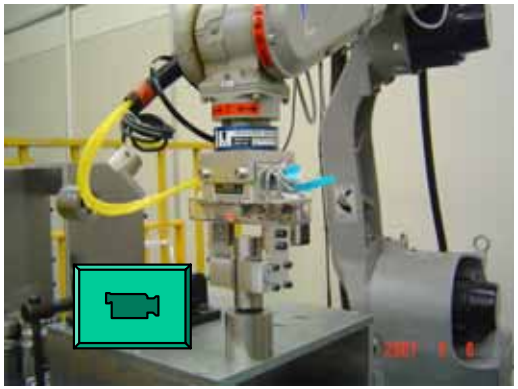
Focus on “Force Control” and “Assembly Robots” (2/3)

- Situation changed 2000s〜
  - CPU performance Improved
  - Force sensor cost down
  - Vision sensor advanced

⇒ Attempts to develop assembly robots



Parts picking by 3D vision sensor



Insertion by Force control

Focus on "Force Control" and "Assembly Robots" (3/3)

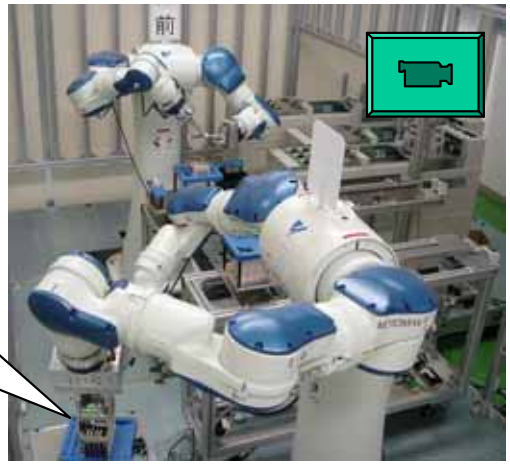
- Human-like Industrial Robots
  - Redundant degrees of freedom
  - Dual arm
  - Almost same size as human

MOTOMAN-SIA

MOTOMAN-SDA

- Human-like Assembly Robots are in the spotlight

Inverter V1000

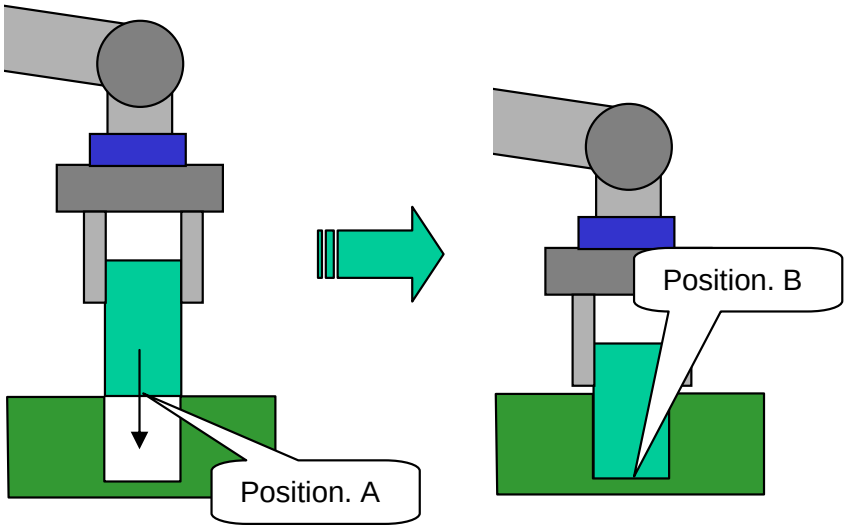


Technical Problems on Human-like Assembly Robot

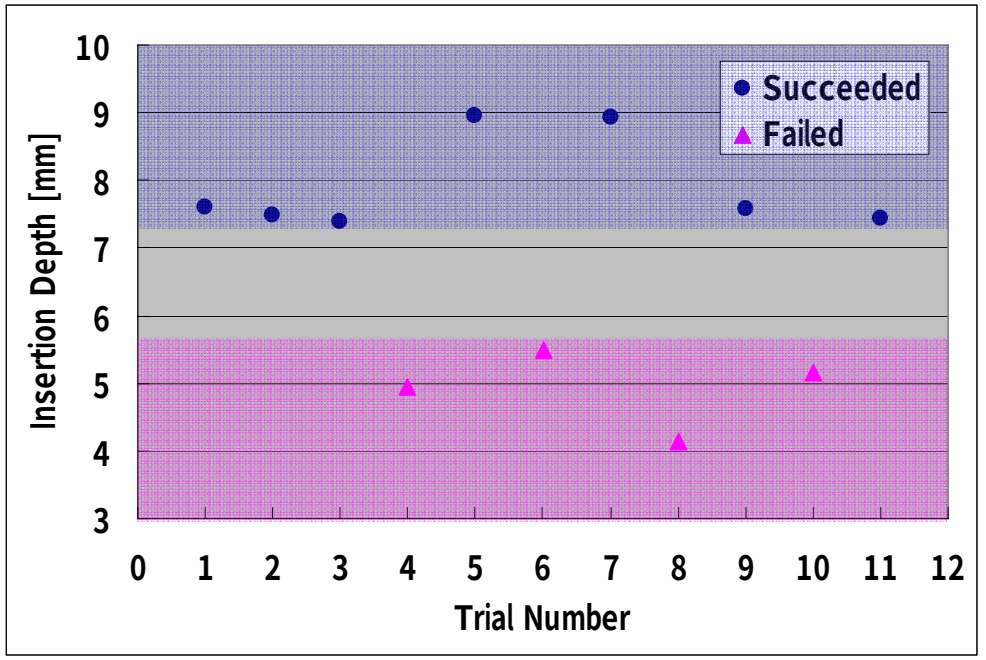
1. Recognition problem: how to precisely recognize success or failure of assembly task
   - Need to prevent defective products from shipping
2. Tuning problem: how to easily tune parameters of force control in short time
   - Everyone needs to easily tune parameters
   - Or robots tune (learn) parameters by themselves?

How to deal Recognition Problem (1/2)

- Difficult to precisely decide success or failure
  - Mostly, it is possible to distinguish success from failure by measuring (calculating) insertion depth.

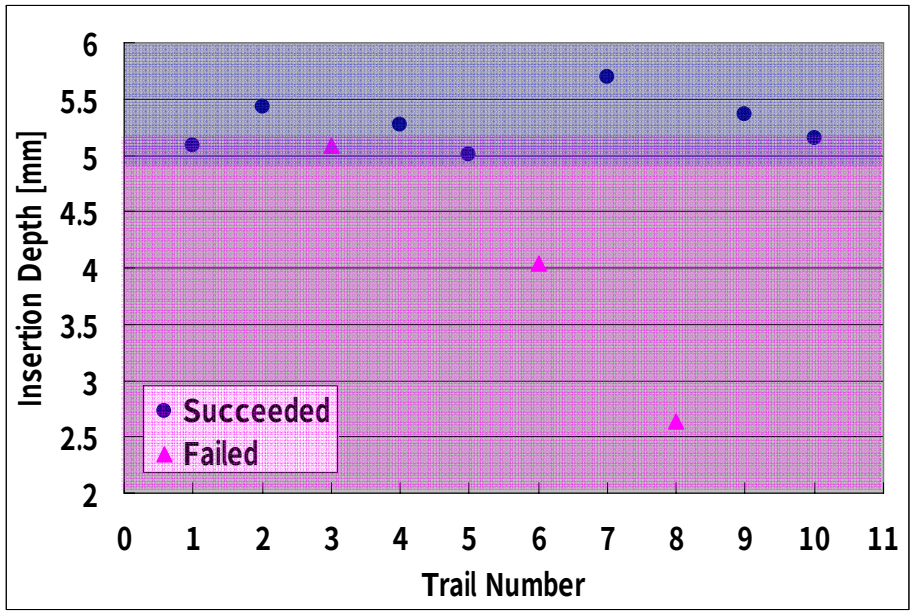


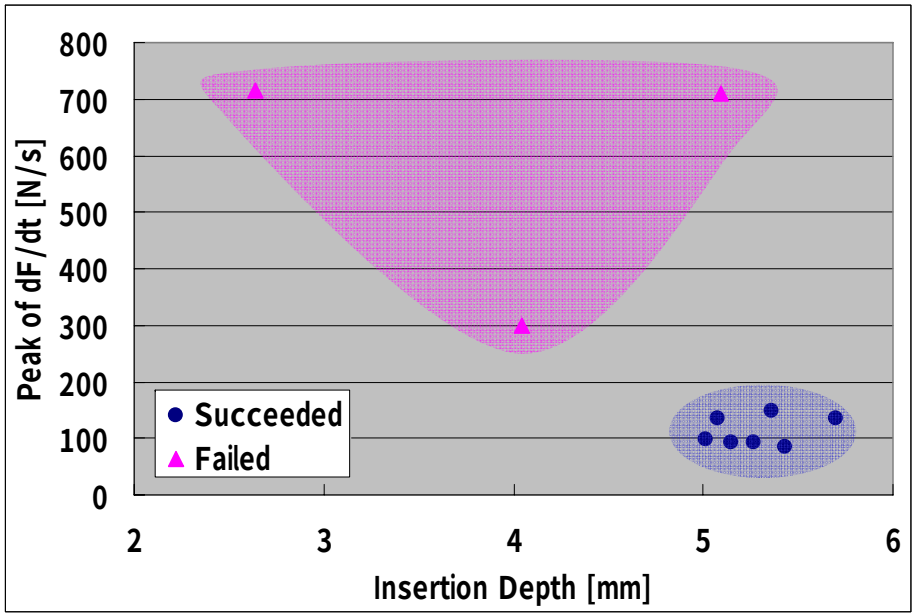
Insertion Depth = Position.B − Position.A
(calculated from joint angle sensors)



How to deal Recognition Problem (2/2)

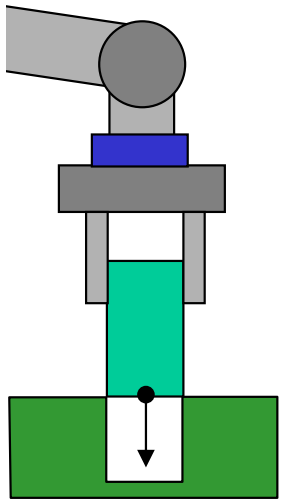
- Difficult to precisely decide success or failure
  - Sometimes, insertion depth is insufficient to clearly distinguish success from failure (see left-sided figure)
  - By introducing another feature (ex. peak of dF/dt), it becomes clearer to distinguish success from failure (see right-sided figure)



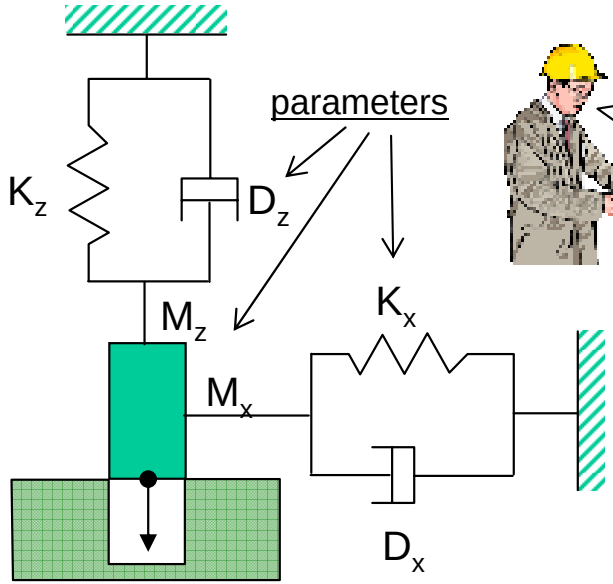


How to deal Tuning Problem (1/3)

- How to easily tune parameters of force control
  - Smaller M_k and D_k, Faster the arm follow the direction of force (that means robots may finish insertion task faster)
  - Too small M_k and D_k may lead contact unstable
  - Too large M_k and D_k lead the task to failure
  - Currently, parameters M_k, D_k and K_k are manually decided (tuned) by trial & error (manual tuning is time consuming)



Force control

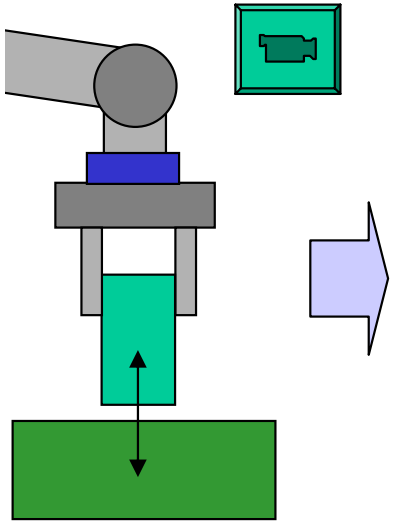


Virtual mechanical impedance

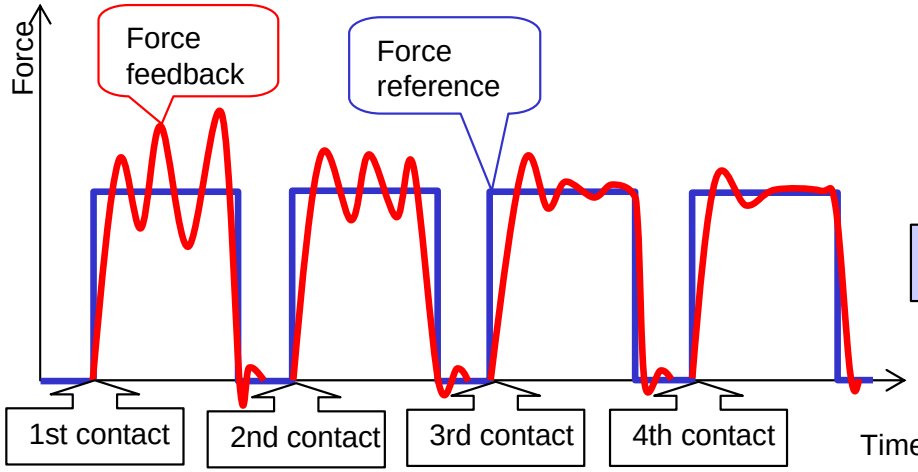
Parameters are manually decided by trial and error
→ Takes long time
→ Performance depends on human skills
→ Special technical knowledge is necessary (Almost all the workers don't have it)

How to deal Tuning Problem (2/3)

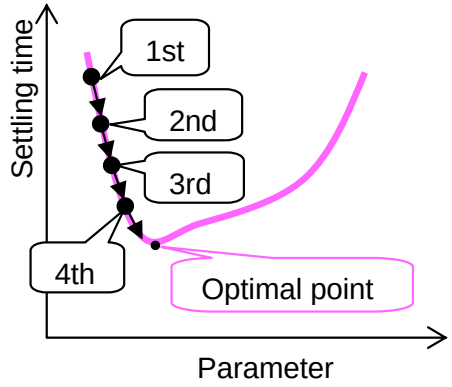
- How to easily tune parameters of force control
  - Automatic parameter tuning for each direction
    1. While making grasped work piece contact repeatedly,
    2. Search parameters so that force feedback can be good responses.
    3. End searching when settling time becomes almost minimum.



1. Repeated contact



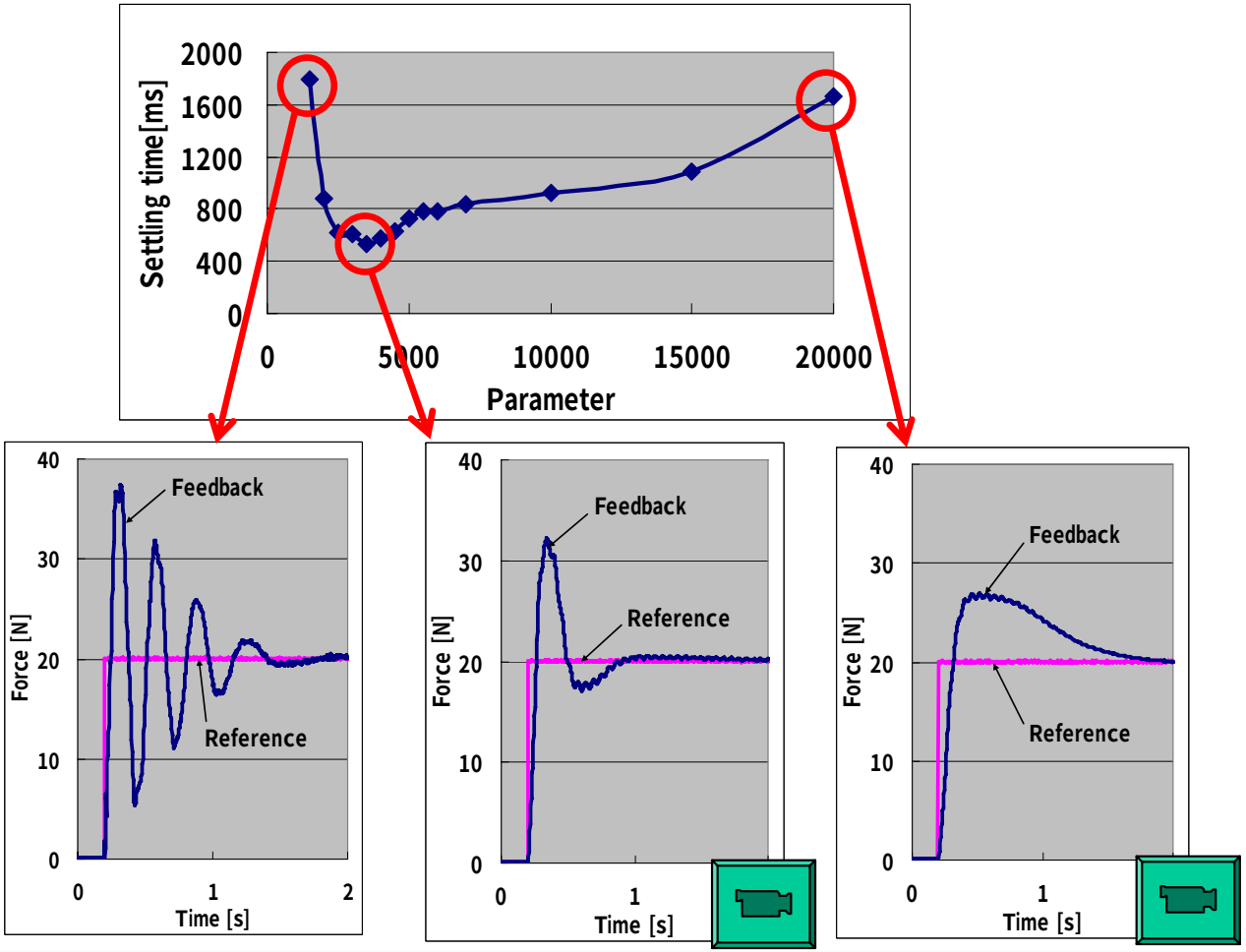
2. Parameter search



3. End searching

How to deal Tuning Problem (3/3)

- Tuning problem: how to easily tune parameters of force control
  - Experimental data of parameter vs. settling time



Future Challenges and Directions (1/2)

- By solving the technical problems, Yaskawa expects that assembly robots will be widely spread into following manufacturing fields:
  - Step1. Automobile and its related parts
  - Step2. Home electronics
  - Step3. Medical equipment
- Safety becomes more important, because assembly robots are expected to work with human workers in flexible manufacturing cells.

Future Challenges and Directions (2/2)

- Industrial robots will be safer and as dexterous as human by force control and its related technologies
- Then industrial robots will expand out of factories
  - Farms
  - Theme parks, Restaurants…Many possibilities will be tested

Ice cream serving robot

Apple paring robot
(just for entertainment…)

YASKAWA

Thank you for listening.

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