Human-like Assembly Robots in Factories

8th June 2011
YASKAWA ELECTRIC CORPORATION
Corporate R&D Center
Robotics Technology R&D Group
Shingo Ando
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
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
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
Current Applications and Control
- Welding, painting, handling…
- Only position is controlled

Even now, assembly process are done by human workers
- Force control is needed to realize assembly task by robots
- 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
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
Human-like Industrial Robots
- Redundant degrees of freedom
- Dual arm
- Almost same size as human

Human-like Assembly Robots are in the spotlight
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?
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)
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 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)
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
- Tuning problem: how to easily tune parameters of force control
  - Experimental data of parameter vs. settling time
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.
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...
Thank you for listening.