SAFE, CHEAP AND SMART: COLLABORATIVE ROBOTS IN MANUFACTURING

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FOE

July 2014
SUMMARY

- What is a collaborative robot?
- Where does a collaborative robot fit in factory automation
  - Properties of collaborative technology
  - Economic landscape
- Examples of collaborative robots
- Rethink robot technology
WHAT IS A COLLABORATIVE ROBOT?

- Robots that are
  - Safe – work alongside humans without cages
  - Inexpensive (cheap) – buy ($25k-$50k) and deploy
  - Smart – easy to train and deploy

- Compare with industrial robot
  - Dangerous – need safety cages ($$$, floor space, safety rated controls)
  - Expensive
  - Training requires skills
WHY POPULAR? WHY NOW?

- Why popular?
  - Economic and market trends

- Why now?
  - Technology maturing
  - Cost being driven down by other industries
    - Computation
    - Sensing
ECONOMIC LANDSCAPE II: US MANUFACTURING OUTPUT INCREASED 3.7% PER YEAR WITH 60 YEAR MOSTLY FLAT EMPLOYMENT

Source: Federal Reserve Bank of Chicago, Oct. 2007
ECONOMIC LANDSCAPE I: US MANUFACTURING PRODUCTIVITY HAS INCREASED FASTER THAN OTHER PRODUCTIVITY

Source: Federal Reserve Bank of Chicago, Oct. 2007
AUTOMATION HAS DRIVEN PRODUCTIVITY

- Different types:
  - Fixed
    - $$$ to design and create
    - $ to run
    - inflexible
  - Machines
    - $$ to implement
    - $$ to run
    - flexible
- (Robotics)
  - $$ to implement
  - $ to run
  - Inflexible
- Offshoring
  - Long lead times
  - Inflexible supply chain
BUT THERE IS A NEED FOR FLEXIBILITY

- Customers demand
  - Choice
  - Customized products
- Businesses want to be responsive to market
- Push for
  - Smaller batches
  - Flexible manufacturing
- But
  - Existing automation methods expensive and inflexible

From: Manufacturing in the Age of Innovation
http://innovate.typepad.com/innovation/advanced_manufacturing/
ENTER COLLABORATIVE ROBOTS

- Safe, cheap, smart means
  - low capital cost
  - Low integration cost
  - Low maintenance/programming cost
- Works with existing automation

- Enables lower value applications
  - Stuff not yet automated
  - Machine tending
  - Packaging
- Enables flexible manufacturing
  - Easy to train, repurpose

Parts transfer – to/from a machine, conveyor, etc.

Packing – into boxes, cases, containers or bags

Kitting/order fulfillment – multiple parts and locations

Line loading - moving parts from another line/location
COLLABORATIVE ROBOTS I: UNIVERSAL ROBOTS

- Universal robots
- UR5, UR10
- Lightweight
- Easy to program
  - Language
  - wizards
- Inexpensive
COLLABORATIVE ROBOTS II

Precise Automation
- Inexpensive SCARA arm
- Safety system reduces forces
- Lead to teach

Kuka Iiwa lightweight robot
- Integrated force sensing
- High performance
- Expensive
RETHINK ROBOTICS

- Baxter robot
- Two arms, face
- Innovative programming
- Integrated force sensing/cameras
- 2Kg payload
- Inexpensive ($28k)
BAXTER TECHNOLOGY

- Video
- Series Elastic Actuator
- UX
  - Programming by demonstration
  - Declarative task
- Integrated sensing
SERIES ELASTIC ACTUATOR

- SEA invented at MIT in 1993
  - Pratt and Williamson (1995)
- Inexpensive way to get good force control
  - Make robots that are compliant, good at tasks, safer around humans, good in unstructured environments etc.
- Spring in series with gearbox
- Turn force control problem into position control
- Spring filters gearbox nonlinearities, gives smooth output torque
- Gain in compliance, sacrifice bandwidth
BAXTER AND SEA

- Safe
  - Inherently compliant – less forces on impact
  - Closed loop position control is not stiff
  - Force sensing for collisions

- Inexpensive
  - Effective way to deal with gearbox deficiencies caused by low cost, e.g. backlash

- Smart
  - Good force controls enables programming by demonstration
  - Force sensing for e.g. contact detection
CONCLUSION

- Automation drives productivity in manufacturing
- Business needs drives flexibility
- Current approaches to manufacturing:
  - Fixed automation
  - Machines + people
  - (Robots)
- Collaborative robots
  - Safe, inexpensive, smart
  - Reduced cost of installation
  - Enable low value applications
  - Enable more flexible manufacturing