Flexible integration of cobots in industrial environments: Programming by demonstration

Petit-Déjeuner Minalogic Robotique/Cobotique

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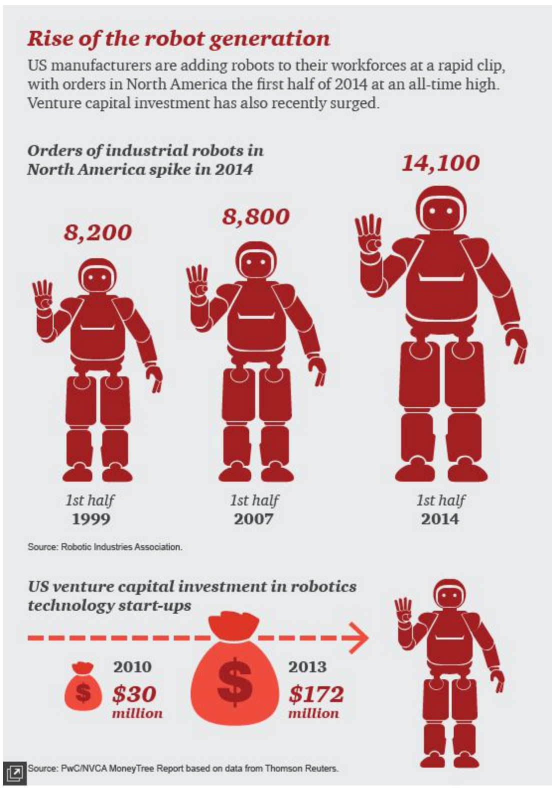
Robots rising

- Robots decidedly are on the rise, as demonstrated by the increasing demand for the technology, and the booming investment in robotics
- Yes, but . . .
  How can robots and humans work together ?



What is cobotics ?

Definition (Cobotics)

Cobotics is a neologism formed by the terms "colloborative" and "robotics" proposed first by Peshkin and Colgate to conceptualize the direct interaction between a robot and a human on a dedicated workstation.

- Cobots become more specialized, and engaged in jobs such as selecting, packaging, inspecting and assembling
- No longer confined to cages, more robots will require less physical space and can be more easily interconnected with other robots and employees ⇒ a hybrid human/robot manufacturing paradigm

Classification of cobotic system for industrial applications

To characterize a cobotic system, it is necessary to pay attention to:

1. The task that must be solved by the cobotics system
   - E.g., transporting, moving or carrying objects, assembling, etc.
2. The role of the human
   - E.g., operator, coworker, supervisor, bystander, subject, etc.
3. The human system interaction and the interaction frequency
   - E.g., physical, tactile, visual, sound, etc.
4. The cobot and its control system
   - E.g., robotic arms, mobile robots, exoskeletons etc.
5. The features of the environment
   - E.g., known, partially known, unknown

What does cobotics really look like in a workspace ?

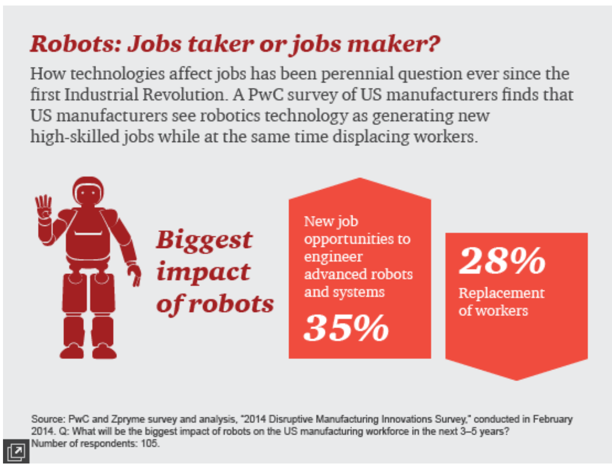







What keeps companies from fully embracing cobotics ?

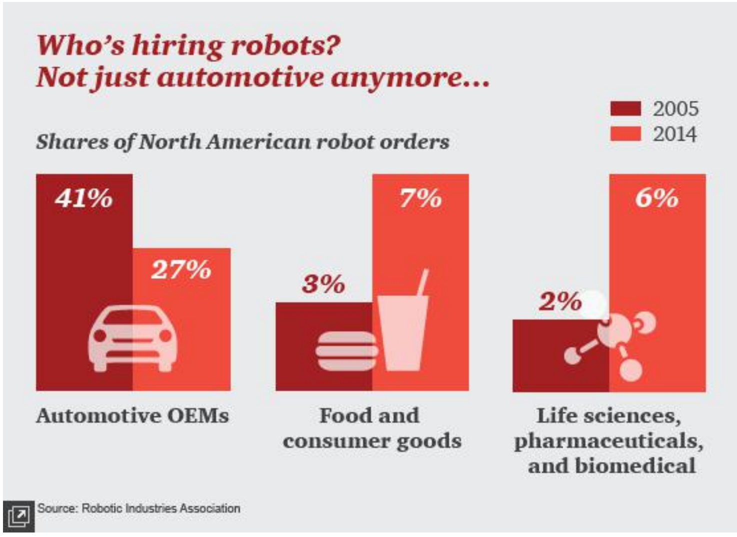
⇒ Manufacturers point to obstacles including cost, the lack of need and the absence of skills and experience needed to properly exploits robots



⇒ Companies have been slow to adopt robotics technology for a variety of reason, including fears that robots could replace human workers

Cobots are landing new jobs . . . in new industries

- The expected boom can benefit manufacturers and other types of companies
- More efficient production of even small quantities of goods

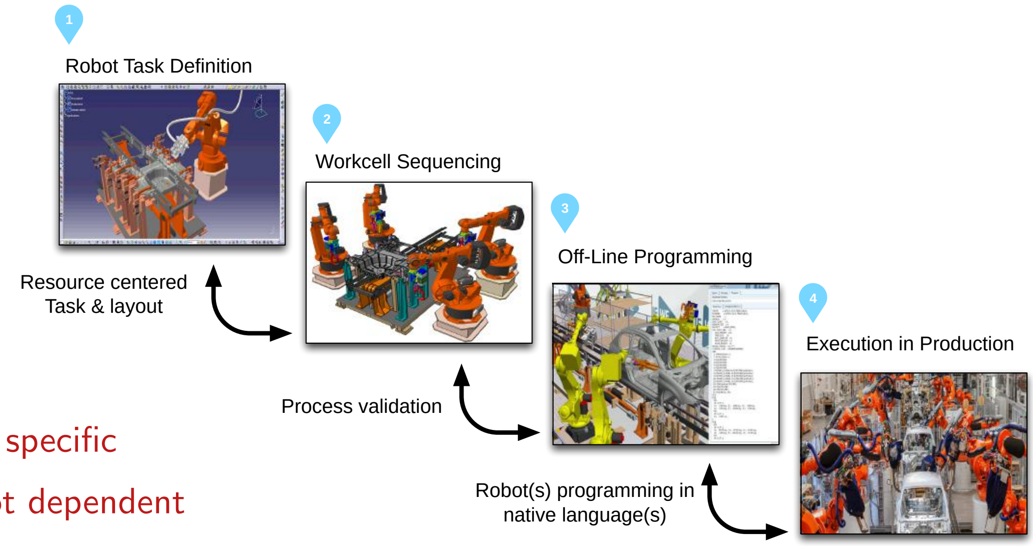


Cobotics issues

- Economic issues
  - Evolution of the manufacturing production from mass to small production
  - Increasing the personalisation of manufacturing products
  - Flexibility of manufactoring production
  - Increasing the SMB competivity

- Social issues
  - Reduce the drudgery of work
  - Reduce the physical constraints related to the work
    - Ex: Handling heavy loads, strain physical postures, mechanical vibrations
  - Reduce the exposure to dangerous environments
    - Ex: Chemical agent, excessively variable temperatures, noise
  - Certain paces of work
    - Ex: Night work, work in shifts, repetitive work

Classical Robot Programming Process

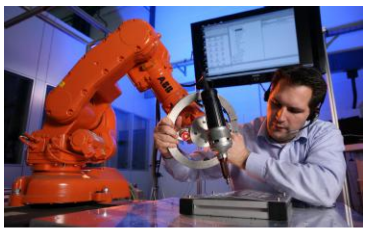


- Task specific
- Robot dependent
- Require specific programming expertise
- Limited to structured working environment
- Time consuming and cost intensive solutions (programming expert, facility, time consuming)

Robot Programming by Demonstration

Definition (Robot programming by demonstration)

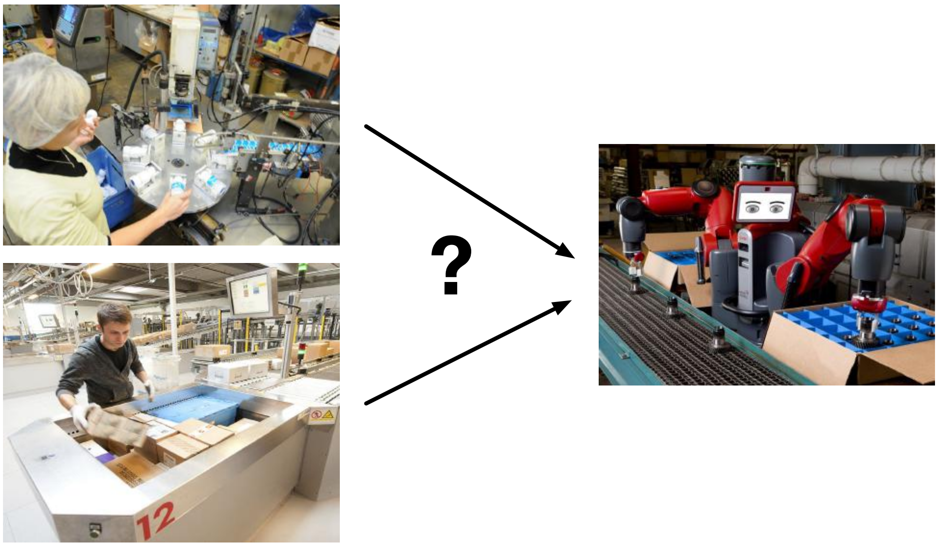
Robot programming by demonstration (PbD) refers to the transfer of skills to robots by providing solutions for the required performance through demonstrations



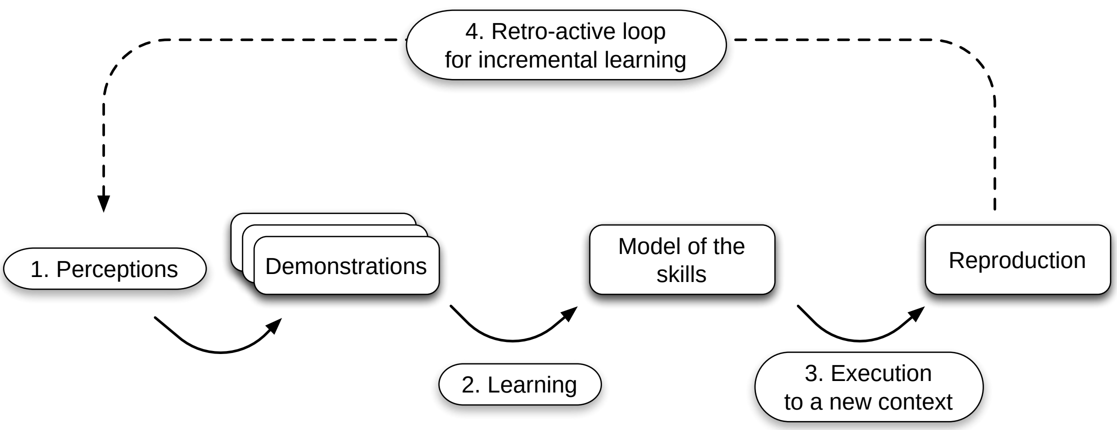
- Adaptive for different tasks
- Independent of the robot platform
- Intuitive, quick programming approach
- Provides framework for service robotics applications
- Reduces costs for development of industrial applications
- Continually refine performance with repetition of demonstrations

Technological lock to be lifted

How can an operator without programming knowledge program by kinesthetic manipulations and control by objective a cobot to perform tasks in an industrial environment ?



PbD Principle Overview



Problem Statement

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Create a framework that allows human operators to:

1. Teach skill to a cobot in a comprehensive automated planning representation
2. Enable a cobot to use the learned actions models to be controlled with a goal oriented approach based on automated planning technique

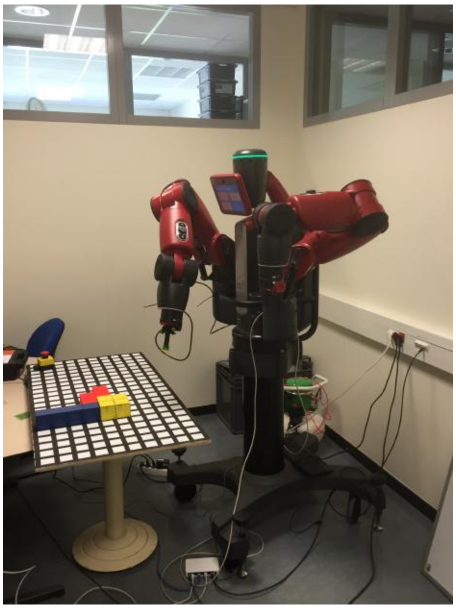
- Hypothesis:
  → User without any programming knowledge should be able to teach Baxter actions to fulfill the task

Example (Skill pick-up)

(**:action** move-block
:parameters (yellow - block A B - position)
:precondition (and (at-block yellow A)
(at-gripper A)
(free-gripper))
:effect (and (at-block yellow B)
(not (at-block yellow A))
(at-gripper B))
(not (at-gripper A)))

Experimental Context

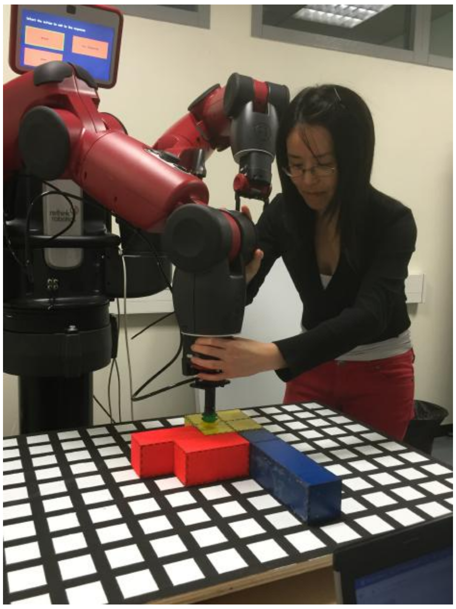
- A classical manipulation task in a manufacturing context
- Skills to teach : pick-up, move, put-down, rotate, etc.



⇐ vacuum gripper

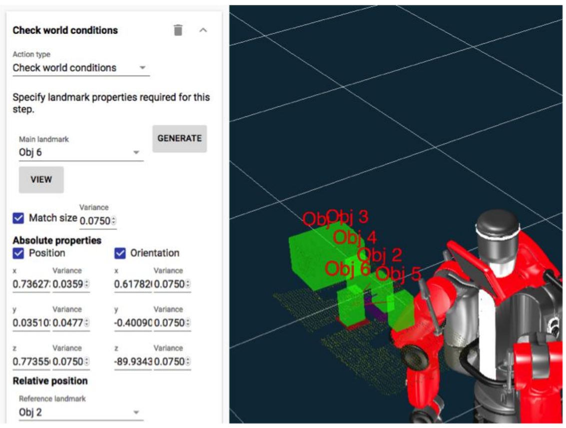
Experimental Approach

- How a cobot learns a new skill from the user by demonstration
  - **Step 1:** The cobot records the movement and the properties of the world that are modified, e.g. the new location of a block
  - **Step 2:** The cobot induces a representation of the skill based on planning representation and validates the skill's semantic with the human operator
  - **Step 3:** The cobot replays the skill to check the learning skill induced
  - if Baxter's replay fails it goes back to step 1

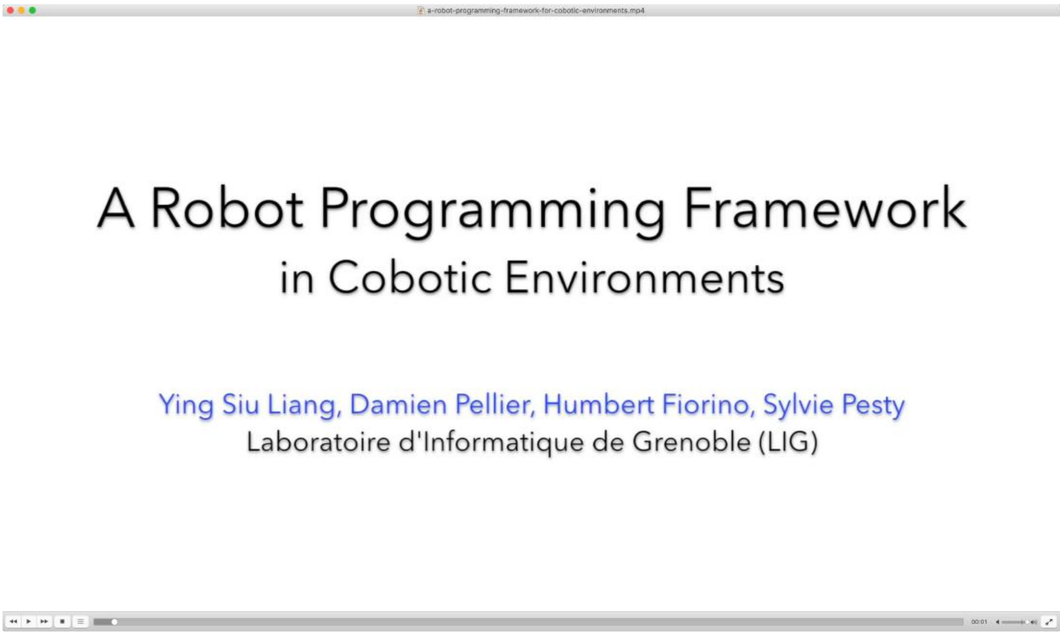


Towards an integrated development environment

- A complex integrated development environment:
  1. the cobot is an integral part of the interface
  2. A more classical interface with a language (PDDL) and a simulated representation of the cobot
- Collaboration with ergonomists and human-machine interface specialists



A video

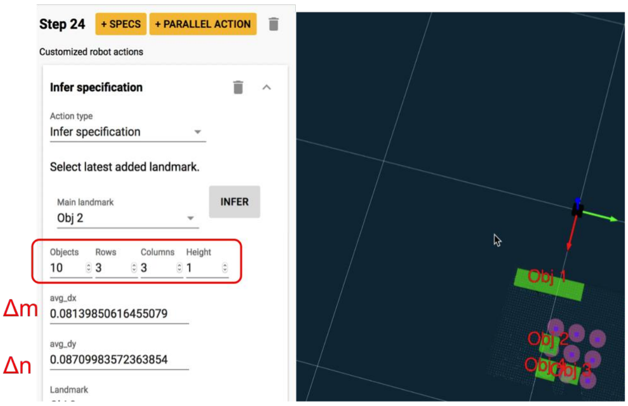


A particular problem: to specify to the cobot its objective

- Many repetitive tasks consist of stacking and packaging manufactured goods
- How can we simply specify by demonstration to the cobot how to carry out such packaging?
- Given a D demonstration set, how infer:
  1. the distance between objects Δ_m and Δ_n
  2. the specification of the objective (the size of the grid) $s = m \times n$

Goal inference, visualization and evaluation

- The inference is based on a probabilistic calculation updated with each new demonstration
- The visualization is carried out via an interface
- The evaluation
    - use of Amazon Mechanical Turk's benchmark
    - 25 different product classes
    - 25 specifications for different purposes
    - The approach covers 90% of indutrial cases



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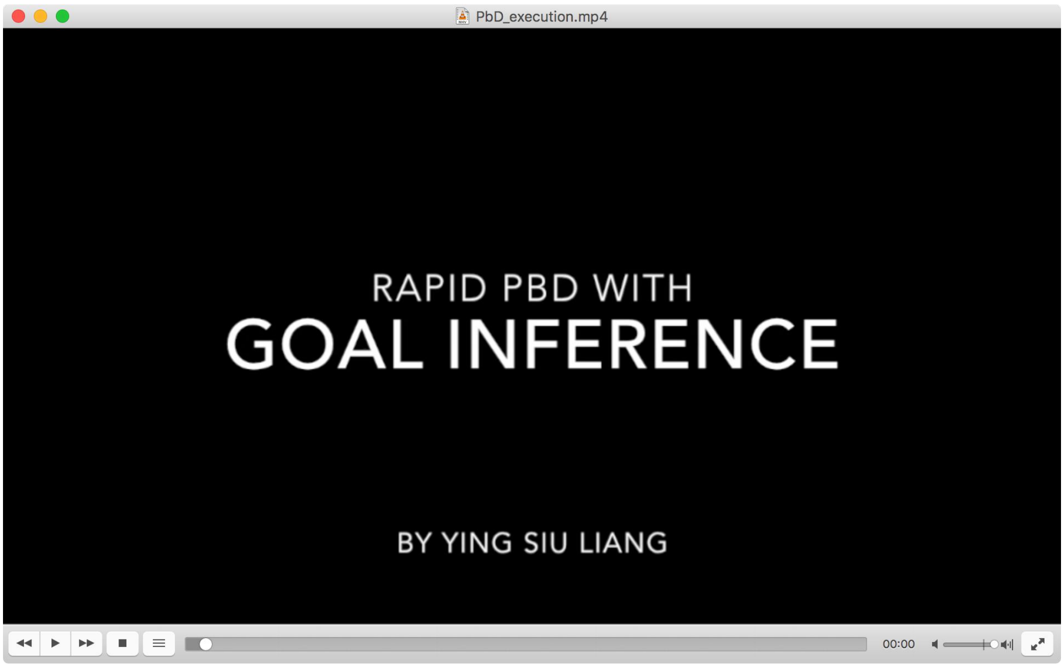
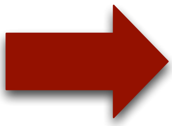


Conclusion



1. Collaborative Robotics " cobotics" is coming ...
2. Programming by demonstration is a promising research field to address the cobotics problems for teaching new skills to robots
3. Mixing programming by demonstration and AI techniques opens an easy way to programm cobots without robotic expert knowledge

Concrètement comment collaborer ?

Types de financements possibles:

- CIFRE (Conventions Industrielles de Formation par la REcherche) (3 ans)
- Chaire industrielle (18 mois ou plus)
- Transferts technologiques directs sous la forme de
  - Prestations et d'expertises (sans dure)
  - Licence logicielle sur la brique logicielle
- Dépot de projets: ANR, Européen, FUI, etc.

Remarque: Les investissements réalisés dans le cadre des dispositifs présentés sont éligibles au crédit impôt recherche et défiscalisation
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