ENGINEERING ROBOTIC CO-WORKERS

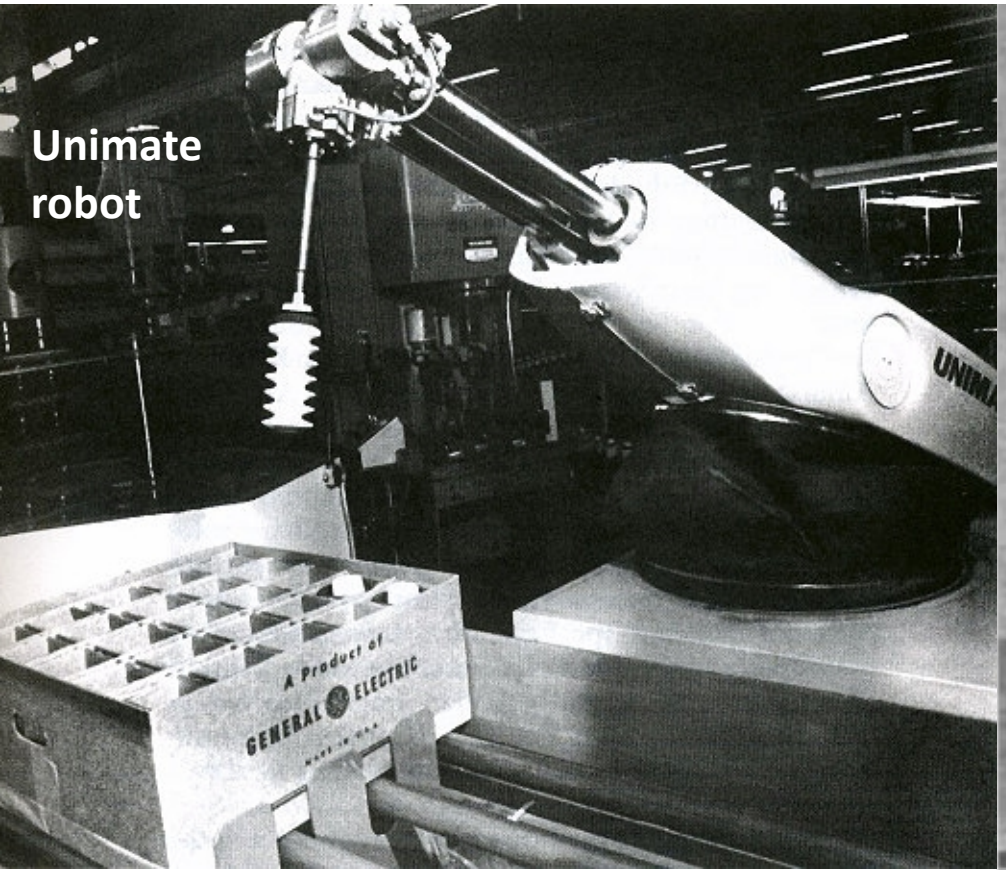
Waleed Farahat

Rethink Robotics Inc.

2017 German-American Frontiers of Engineering Symposium

April 1, 2017

HOW IT ALL STARTED…



Unimate robot

Devol & Engelberger

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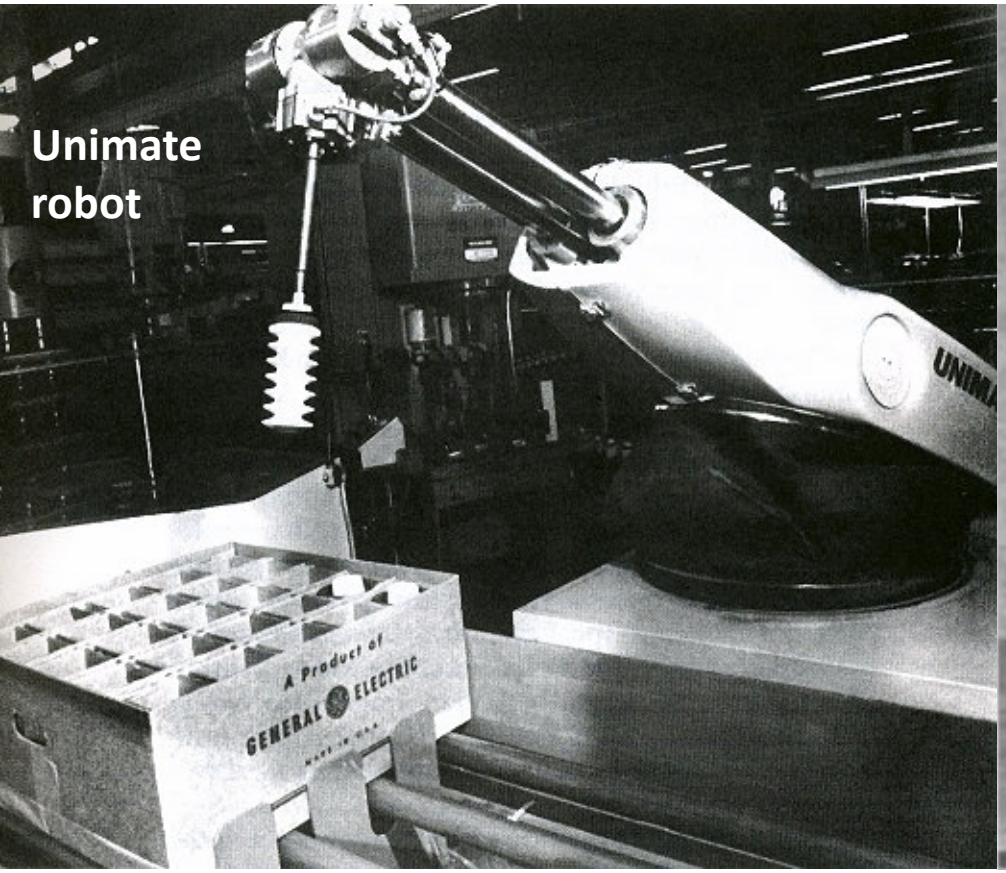
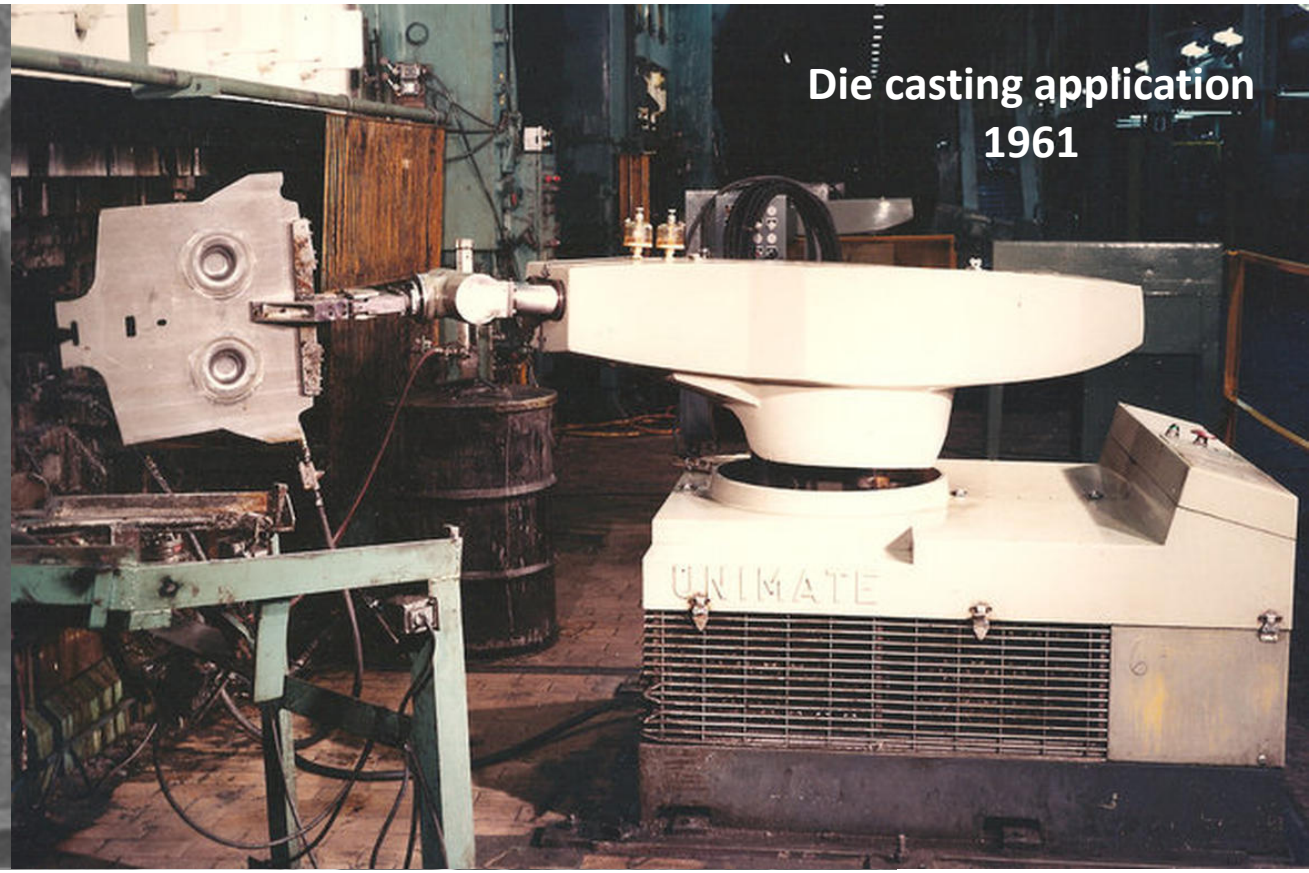


Unimate robot



Die casting application 1961

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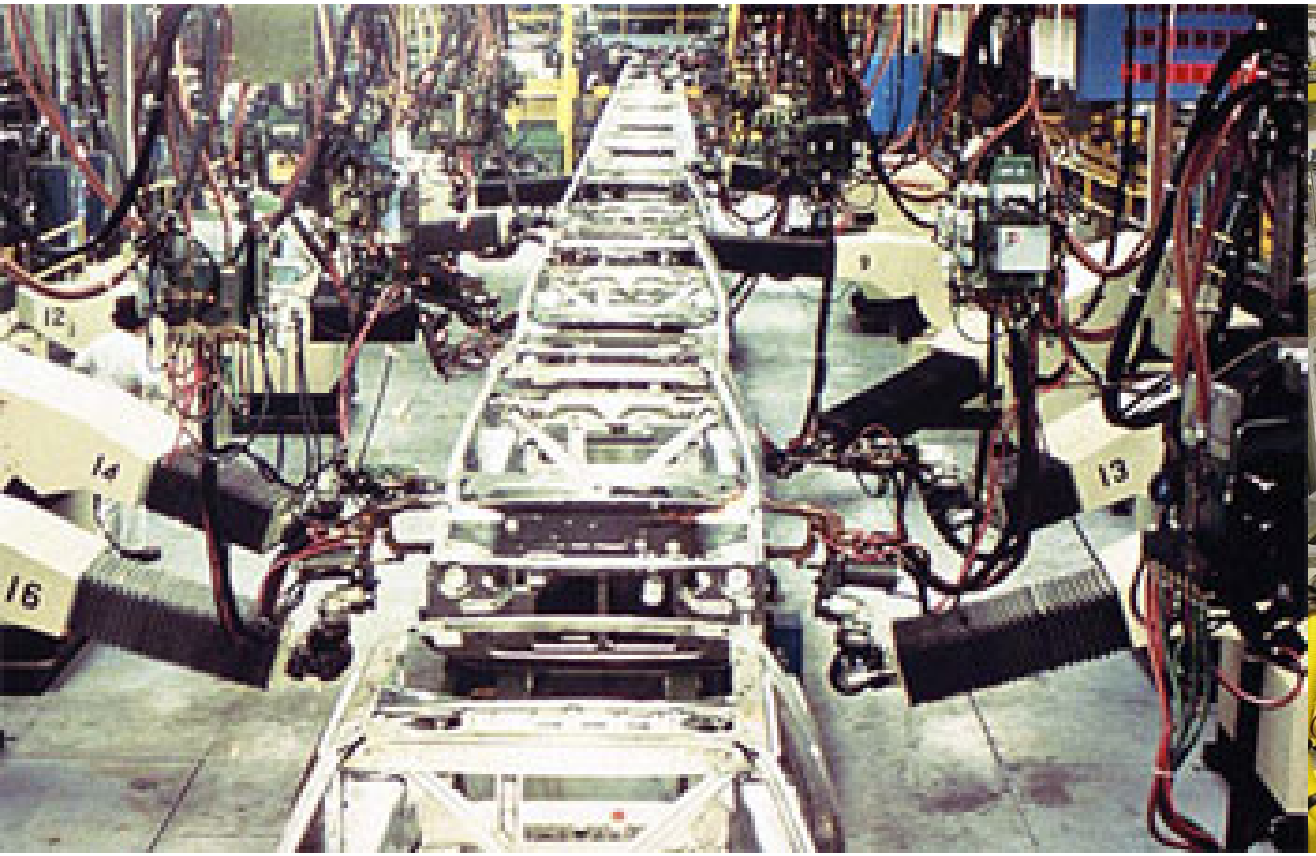

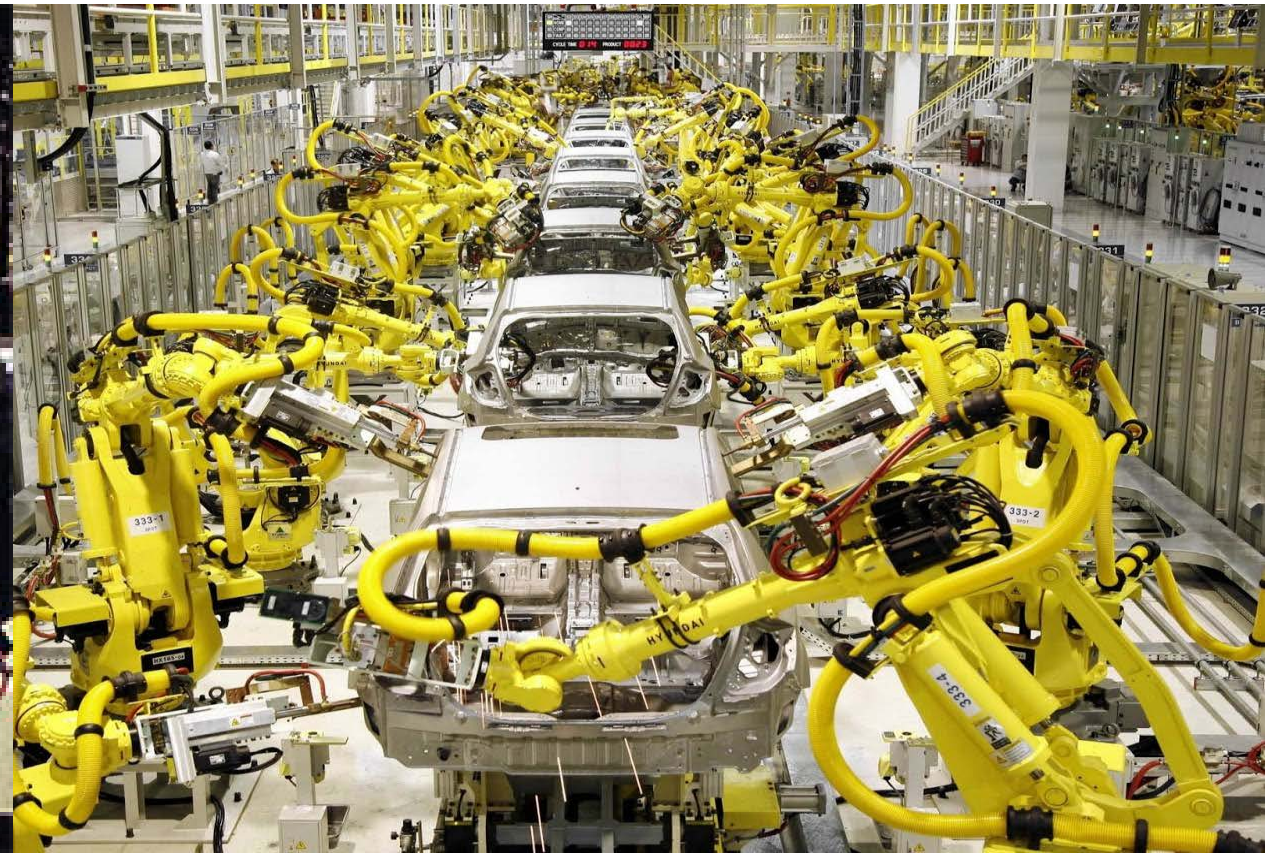

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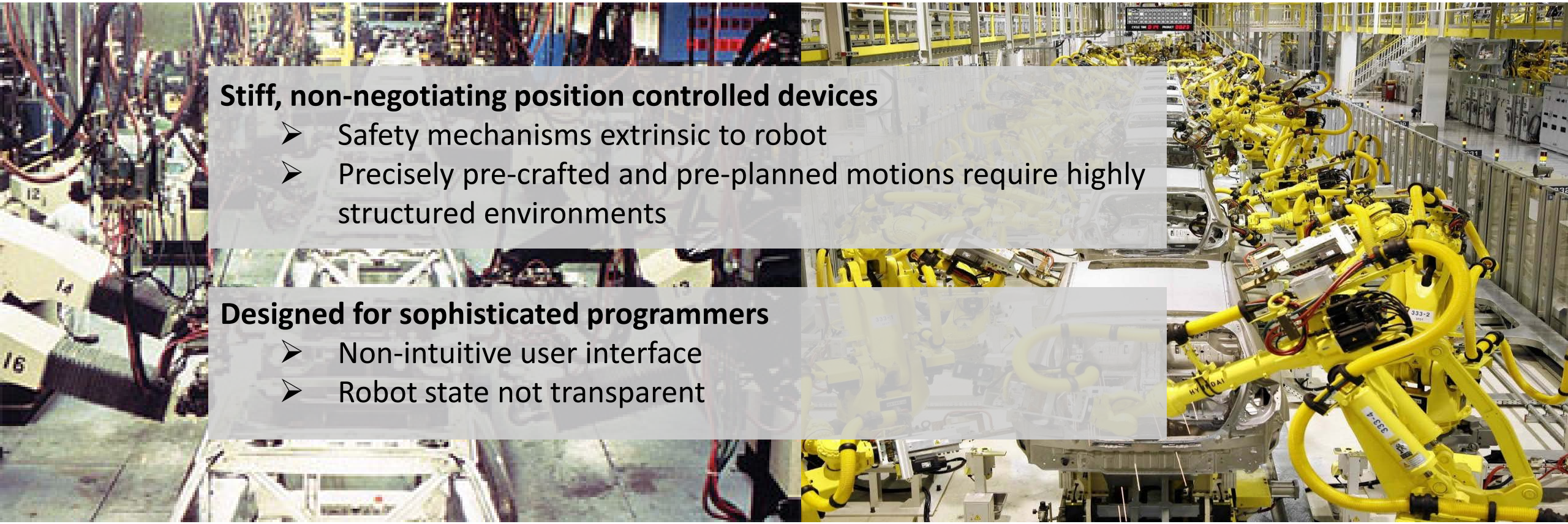
MODERN INDUSTRIAL ROBOTS ARE REINCARNATIONS OF THE UNIMATE



Stiff, non-negotiating position controlled devices

- Safety mechanisms extrinsic to robot
- Precisely pre-crafted and pre-planned motions require highly structured environments

Designed for sophisticated programmers

- Non-intuitive user interface
- Robot state not transparent

Return on investment of robotic automation becomes justified for a small set of high-value, high-throughput tasks.

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CONTRAST WITH…

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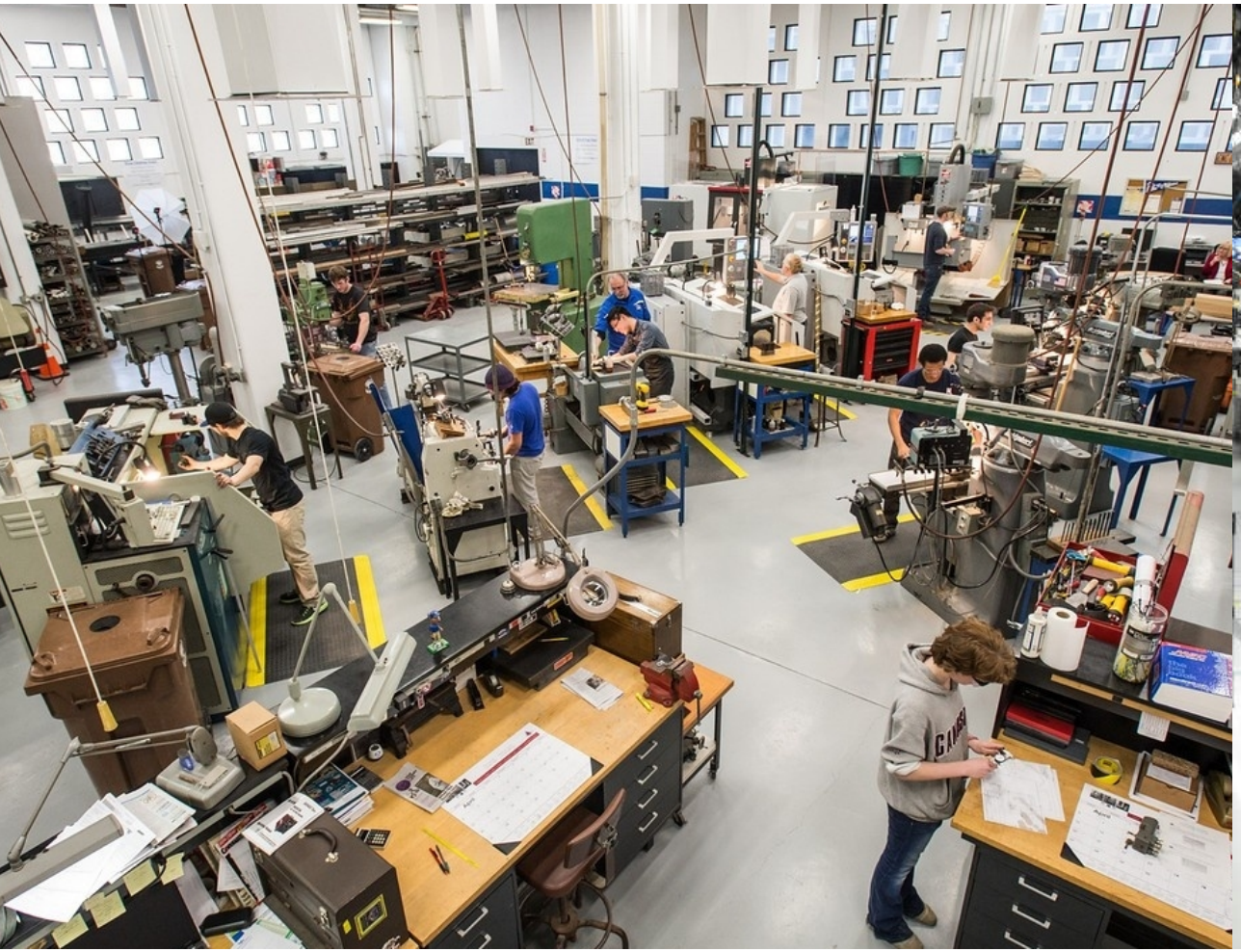

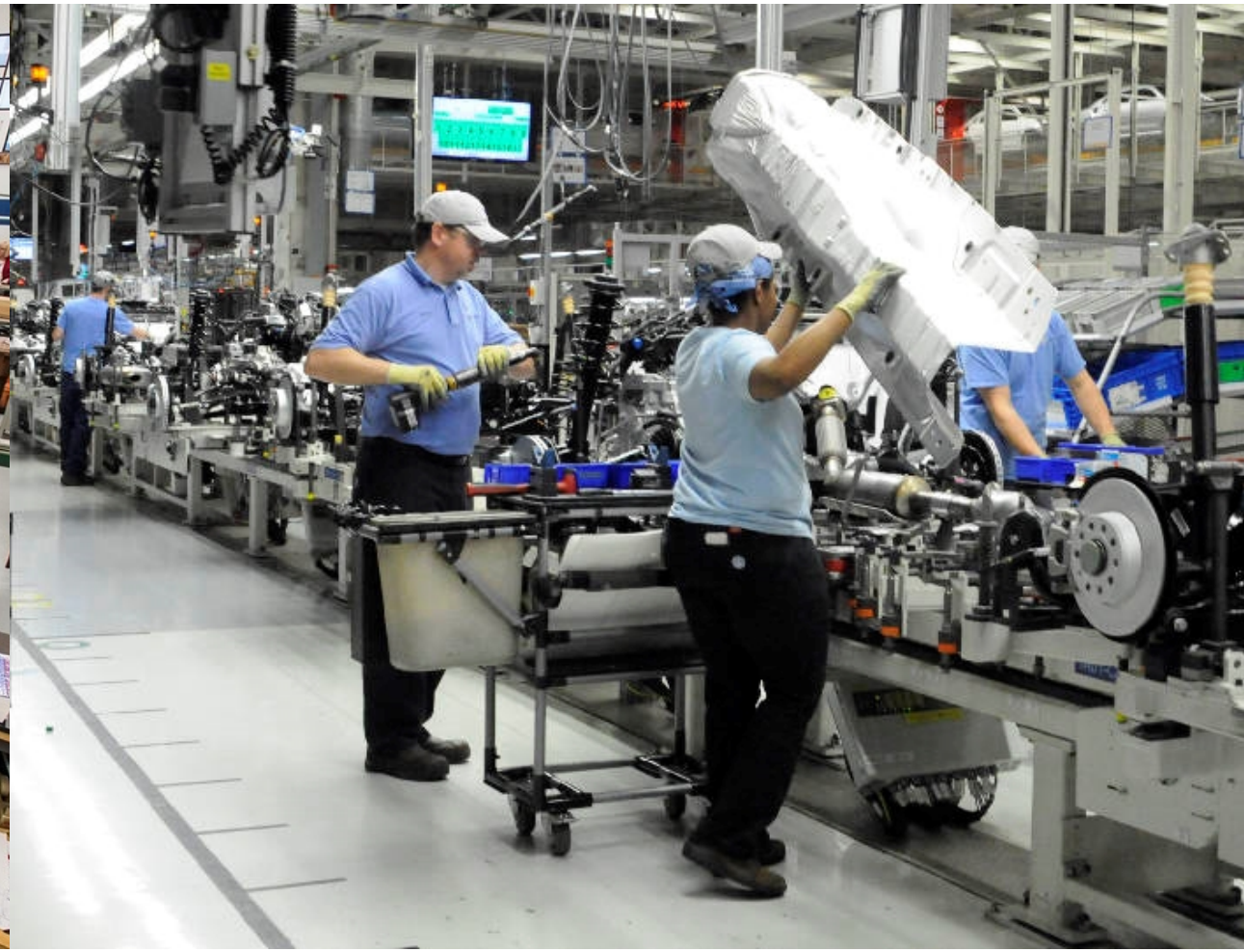

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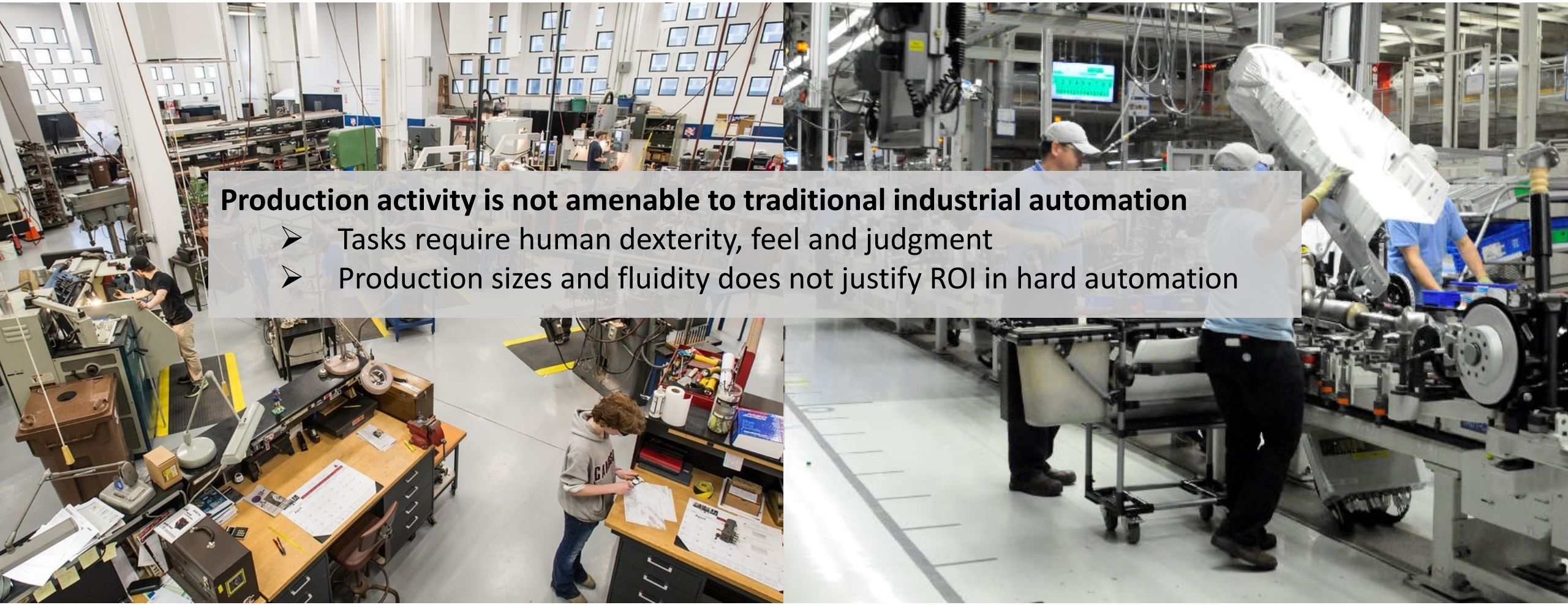
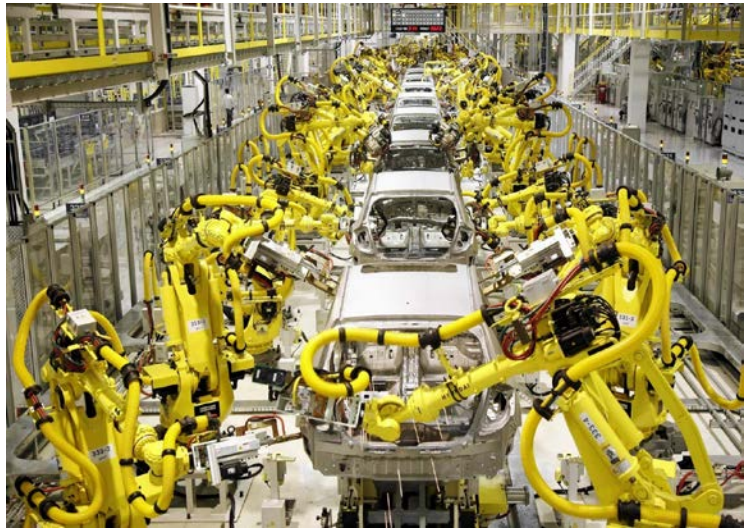


Production activity is not amenable to traditional industrial automation

- Tasks require human dexterity, feel and judgment
- Production sizes and fluidity does not justify ROI in hard automation

A TALE OF TWO CITIES

- Human skill and judgement essential
- Fluid, reconfigurable production settings



- High-value, high-throughput
- Little flexibility
- Automation as an all-or-nothing approach

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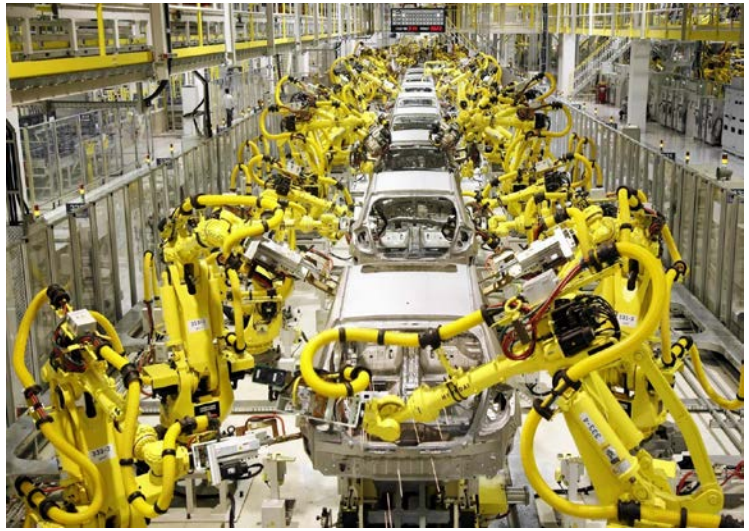
COLLABORATIVE ROBOTS AIM AT BREAKING TRADEOFFS

- Human skill and judgement essential
- Fluid, reconfigurable production settings

- Opportunities for human robot collaboration



- High-value, high-throughput
- Little flexibility
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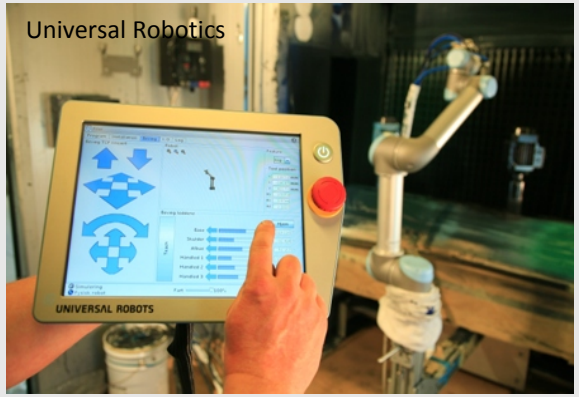
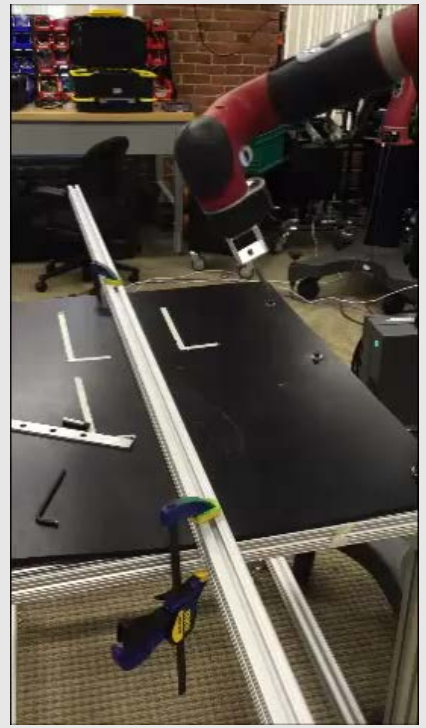
WHAT MAKES A ROBOT COLLABORATIVE?

- Safe and sensitive physical interaction with humans surroundings

- Ease of programming by non-experts



- Adaptiveness to alleviate need for perfectly structured environments



- Accessibility through lower cost of acquisition and integration

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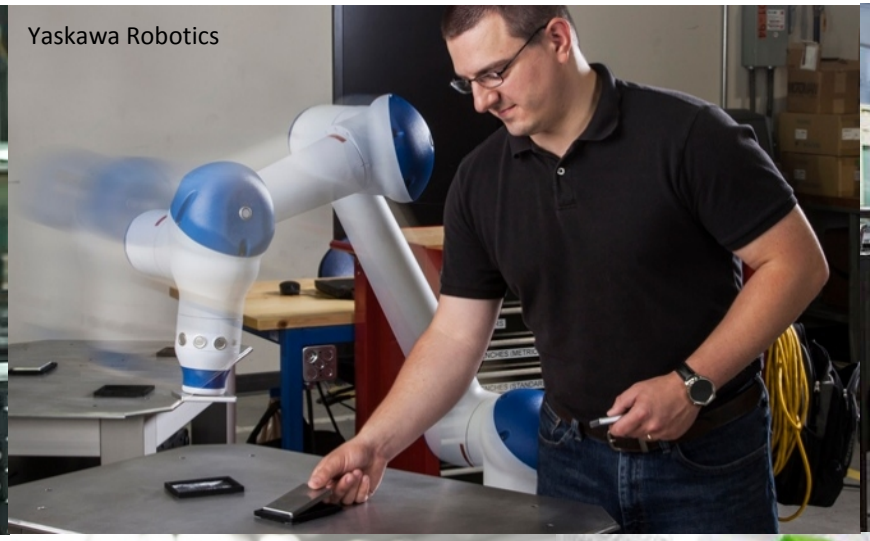
RAPID GROWTH IN COLLABORATIVE OFFERINGS

- Collaborative robots you can deploy in ~2011

RAPID GROWTH IN COLLABORATIVE OFFERINGS

- Collaborative robots you can deploy in ~2017



RAPID GROWTH IN COLLABORATIVE OFFERINGS

- Collaborative robots you can deploy in 2017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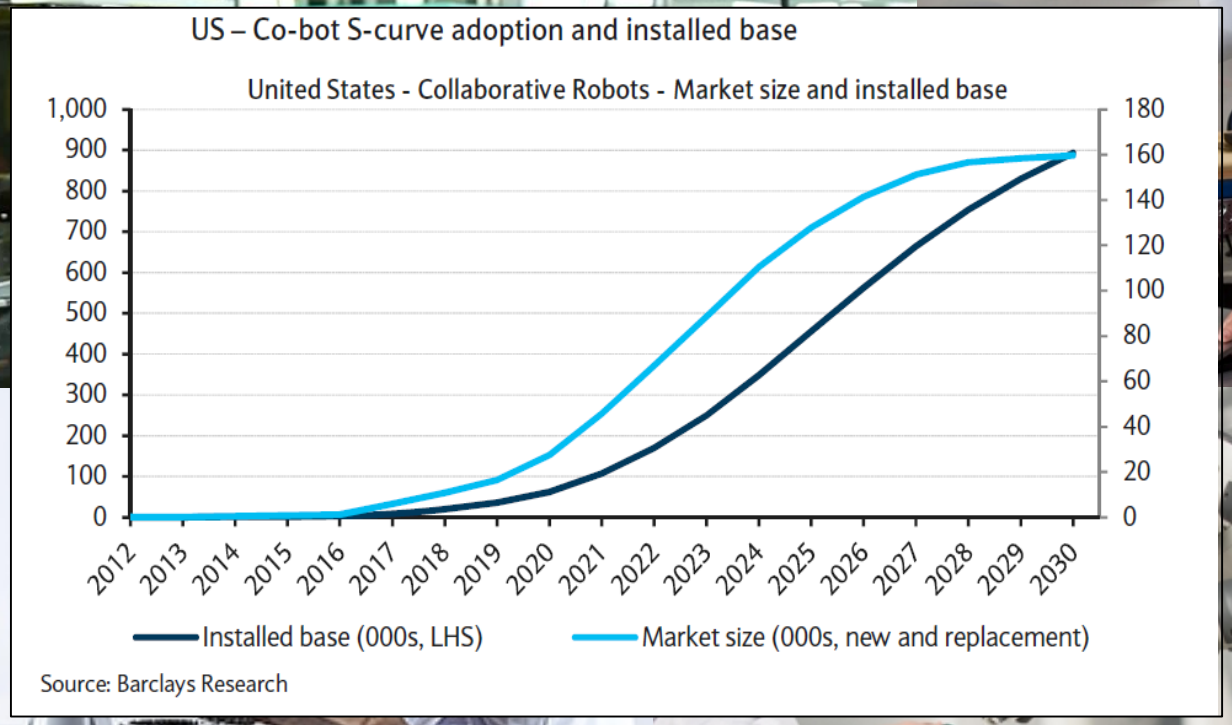
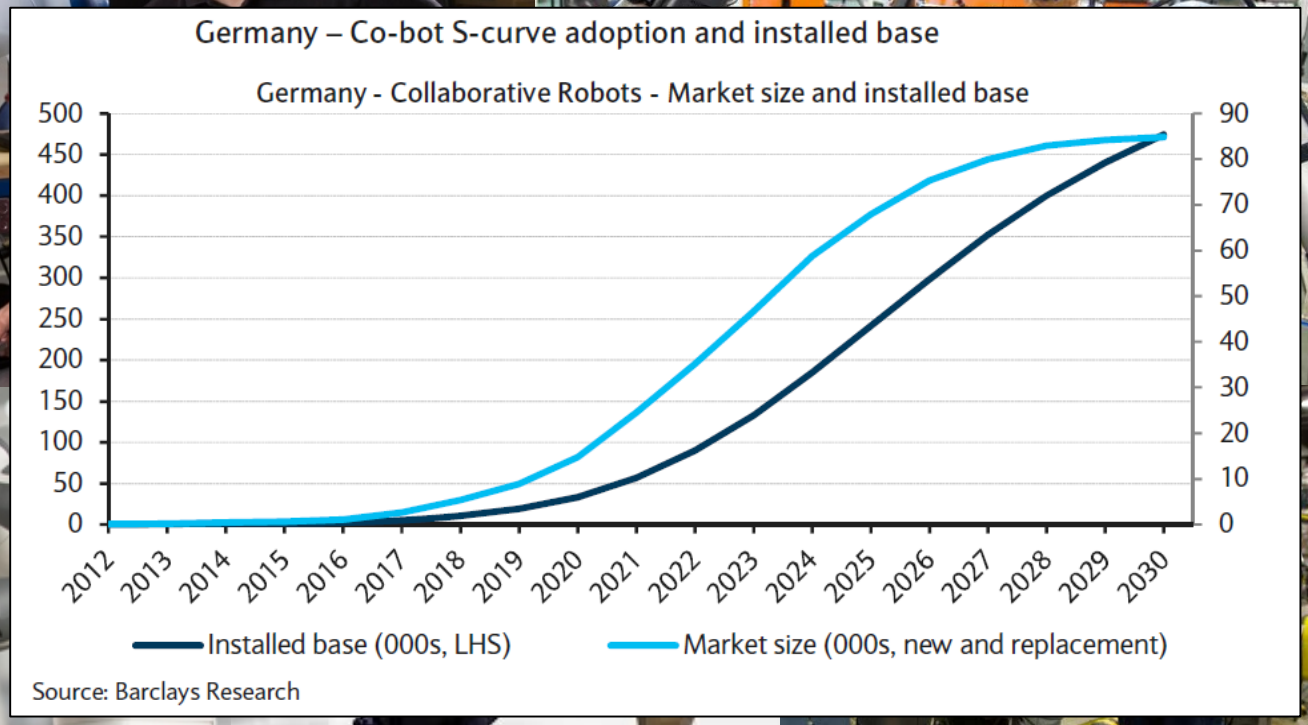
Yaskawa Robotics






Kuka Robotics


ABB


Fanuc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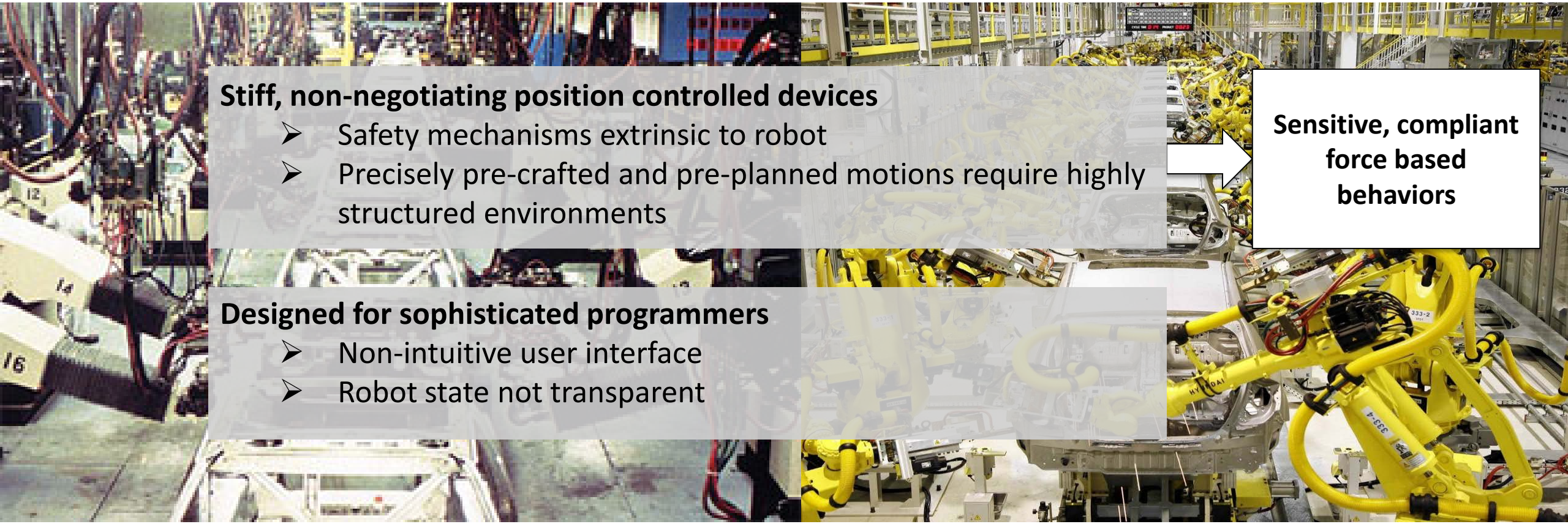
MODERN INDUSTRIAL ROBOTS ARE REINCARNATIONS OF THE UNIMATE



Stiff, non-negotiating position controlled devices

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Designed for sophisticated programmers

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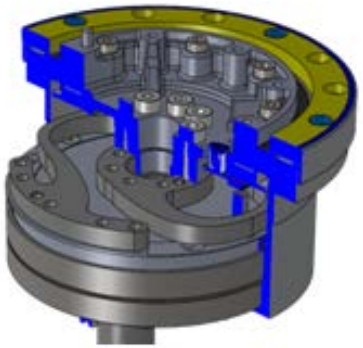
- Robot state not transparent

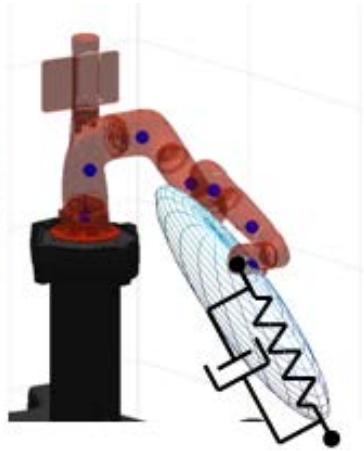
Sensitive, compliant force based behaviors

PHYSICAL COMPLIANCE DRIVES FORCE SENSITIVITY

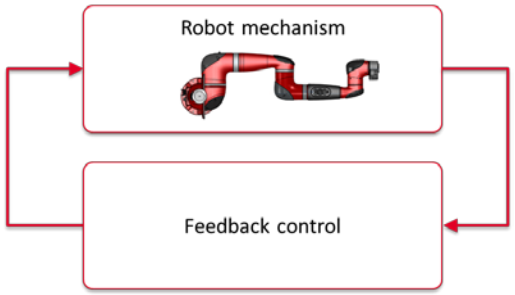
Rigid robot mechanisms

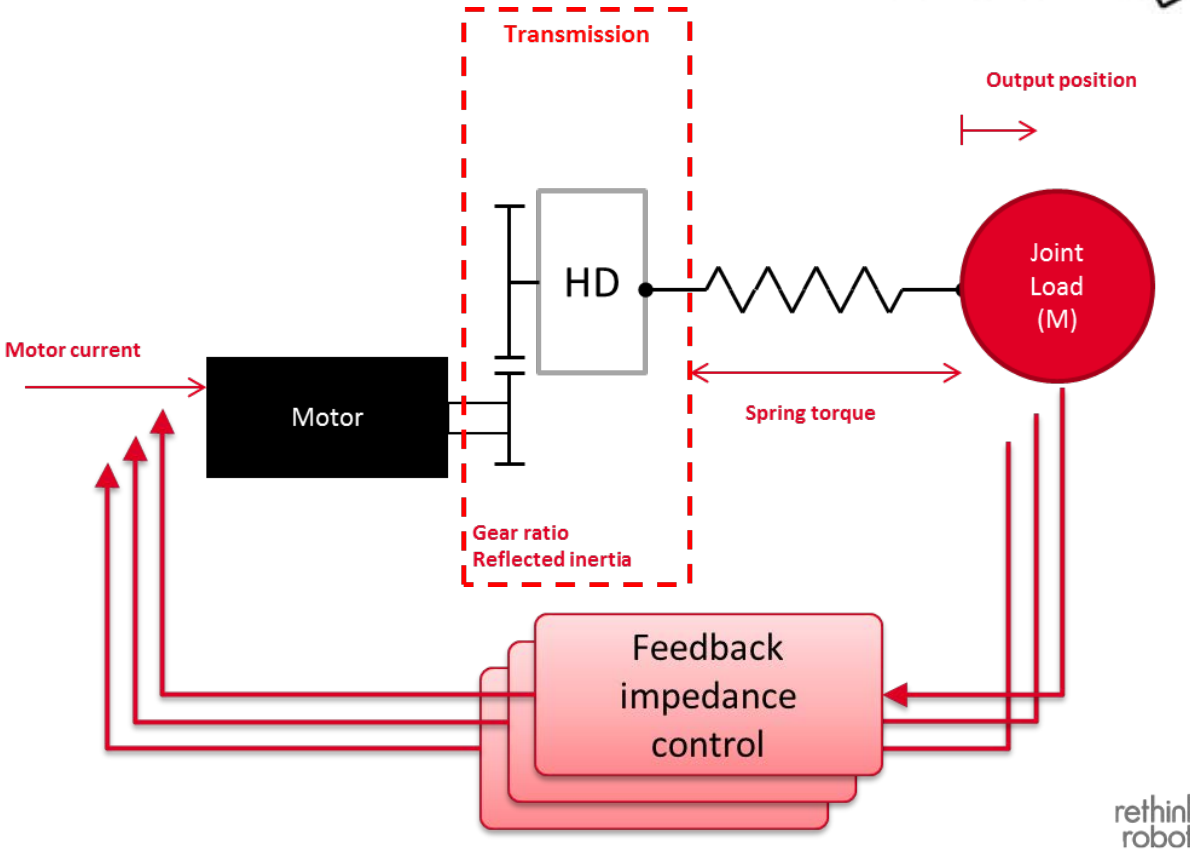
Soft Robotics





Compliance optimized for industrial needs





Soft robot mechanisms

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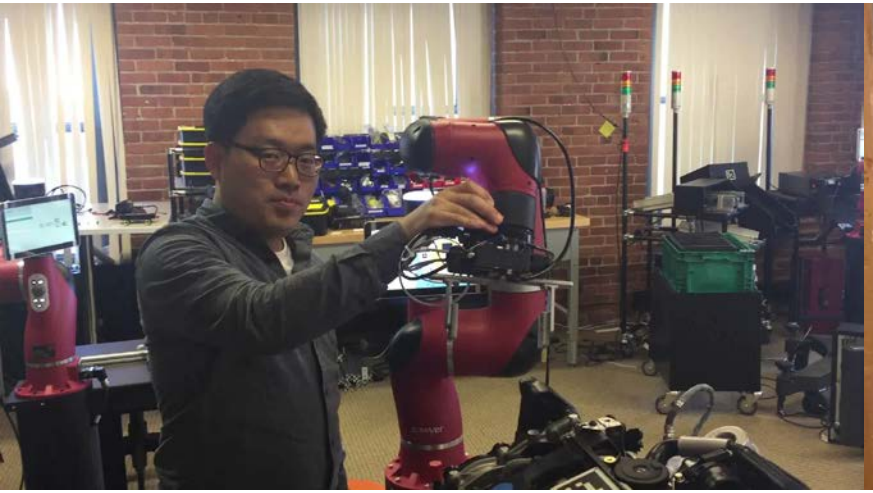
FORCE BASED PRIMITIVES



Gravity compensation, hand guiding

Collision detection

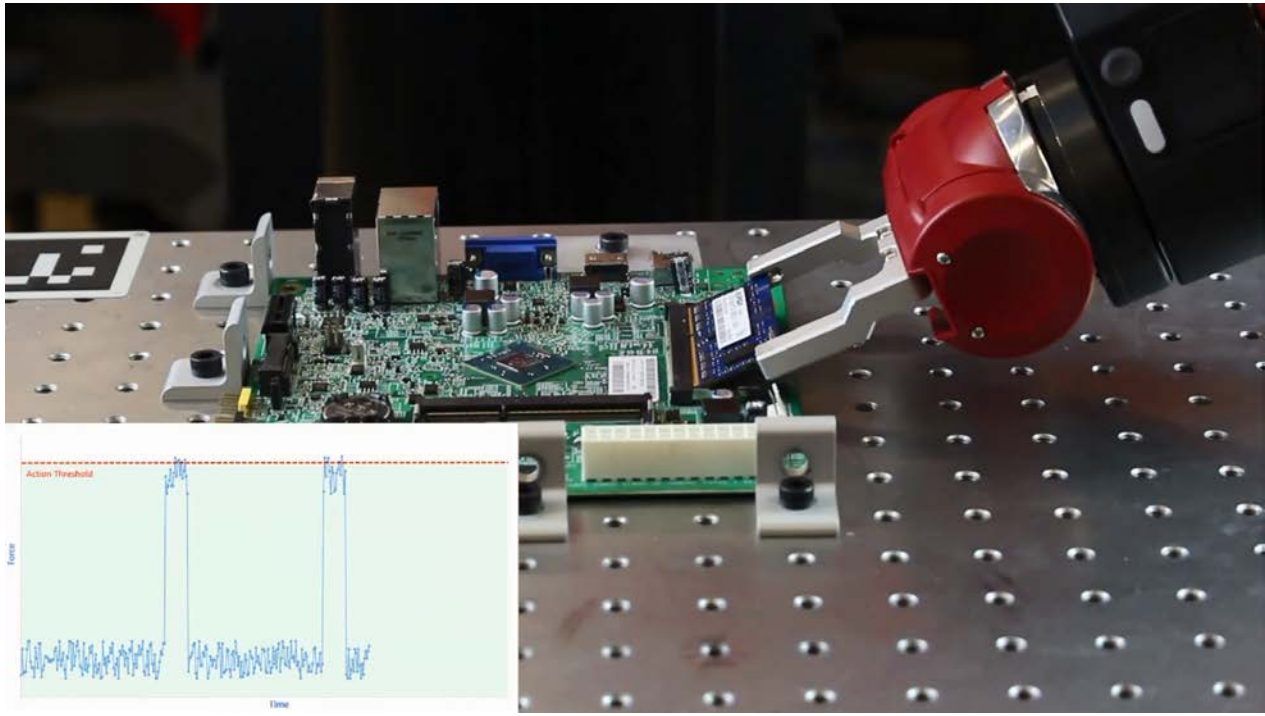
Yielding and back drivability

Collision avoidance

Directional compliance

Constrained gravity compensation

NEGOTIATING POSITIONAL PRECISION AND FORCE SENSITIVITY



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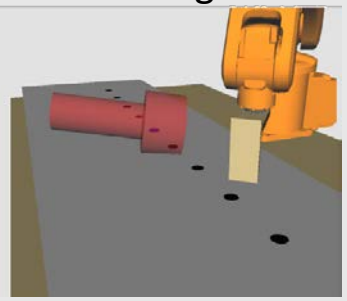
MULTI-FACETED APPROACHES TO ROBOT SAFETY

Power and speed limiting by inherent design
- Low payloads & robot inertia
- Limited speeds, low bus voltage
- Direct drive, low reflected inertias

Safety rated control systems
- Redundant sensing, processing
- Consistency checks
- Safety rated monitoring systems
- Network & access safety

Perception based collision avoidance
- People & environment perception
- Real-time planning & collision checking


Shah et al, 2014



Increasing payload, speed, momentum requires increased safety measures

Ergonomic designs, soft padding, avoiding pinch points
- Ergonomic and HF designs


ABB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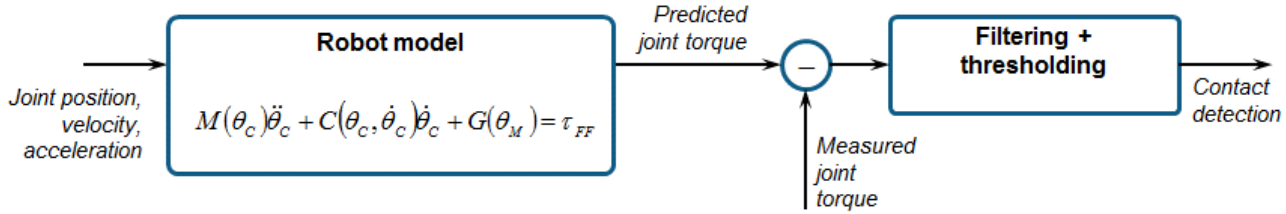
Collision detection & software-based back-drivability



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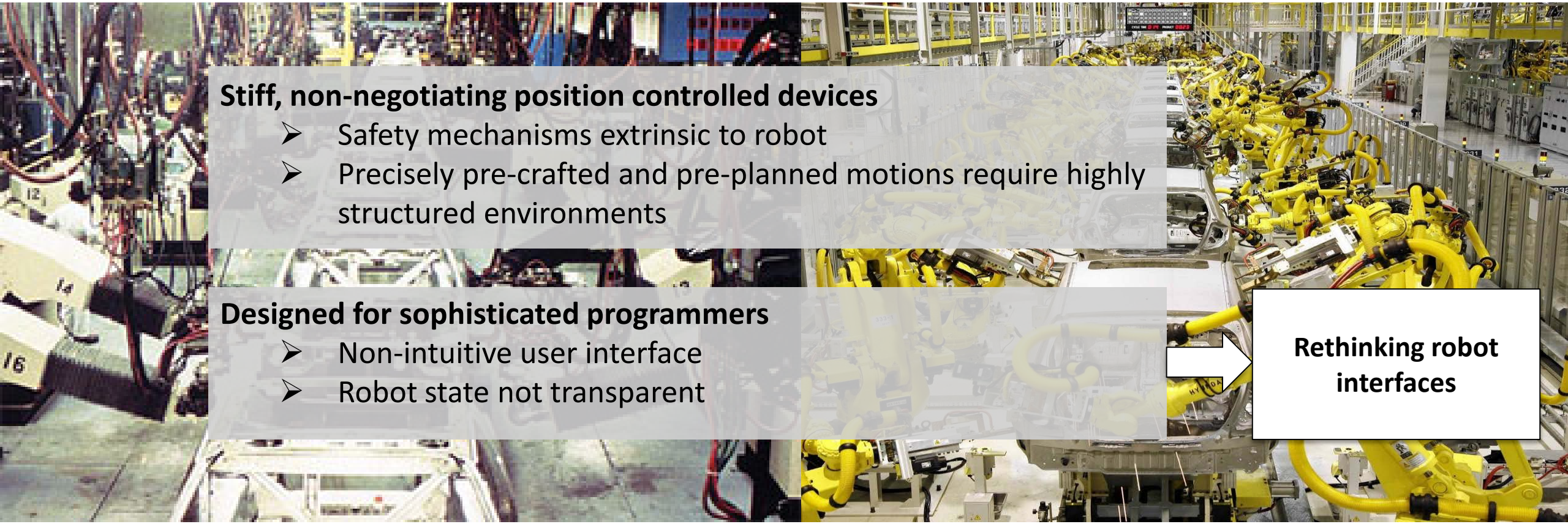

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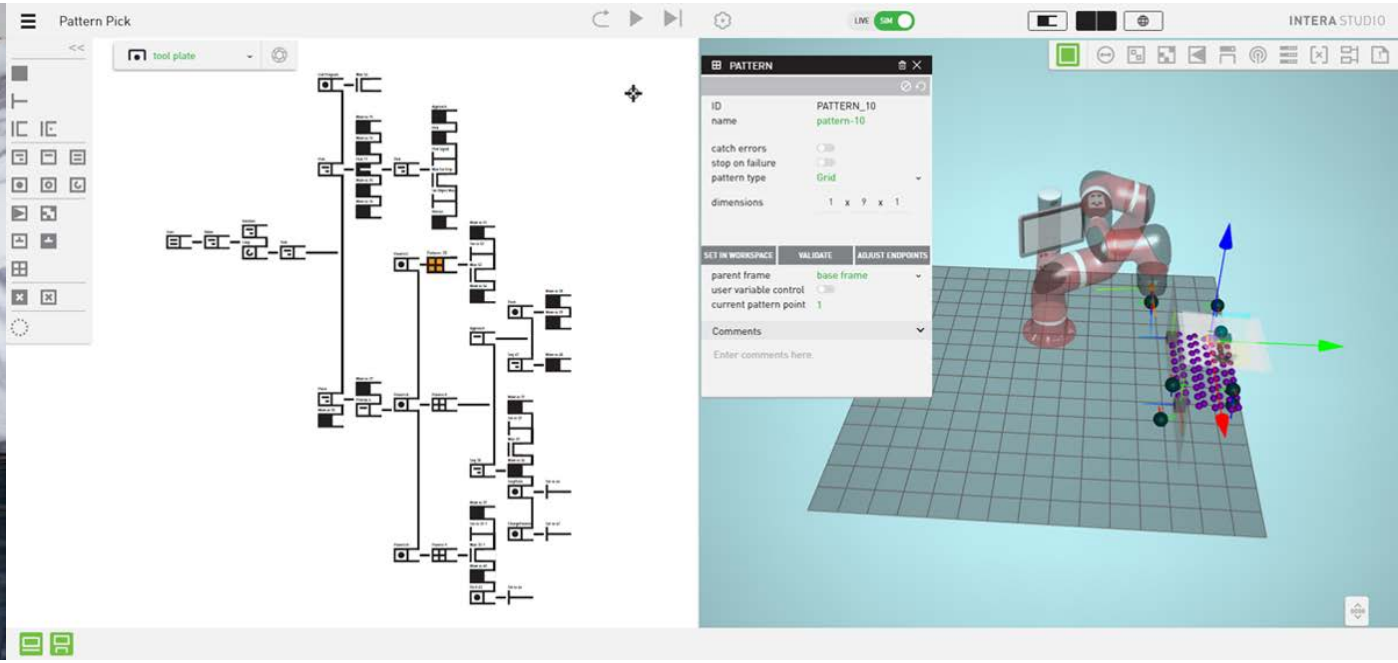
Rethinking robot interfaces

COMBINING INTUITIVE INTERFACES WITH FULL PROGRAMMATIC CONTROL

"Training simple tasks should be simple, complex tasks possible"

- Training by demonstration
- Full programmatic control via behavior trees



Hello World!

Programming actions, logic, flow. Encapsulation, shared data, debugging tools & temporal control.

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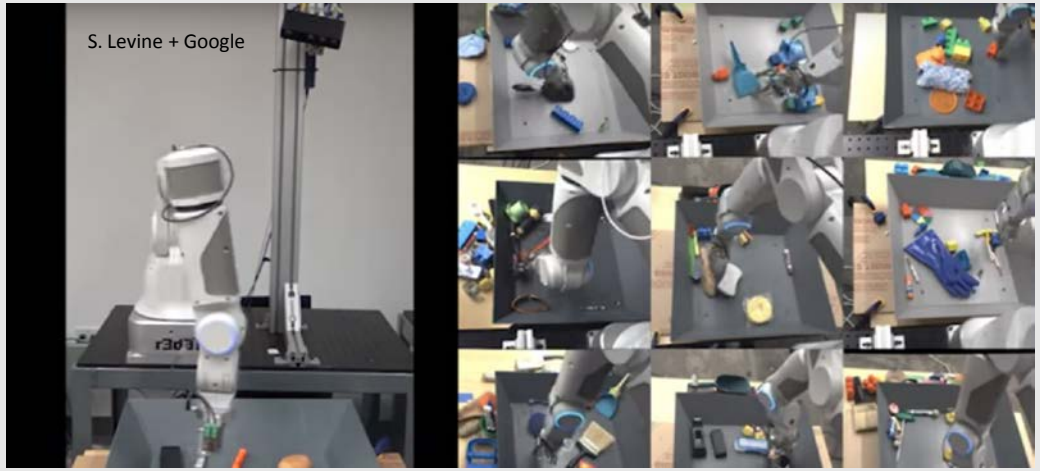
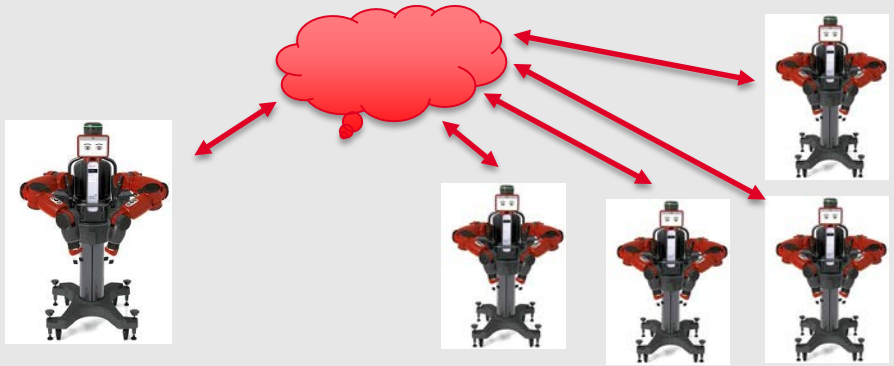
COLLABORATIVE ROBOTS ARE AT THEIR INFANCY

Expert Demos + Machine Learning + Robotic Manipulation



Connected Robots

- Computationally expensive learning off-loaded to the cloud
- Populations sharing learning data and models

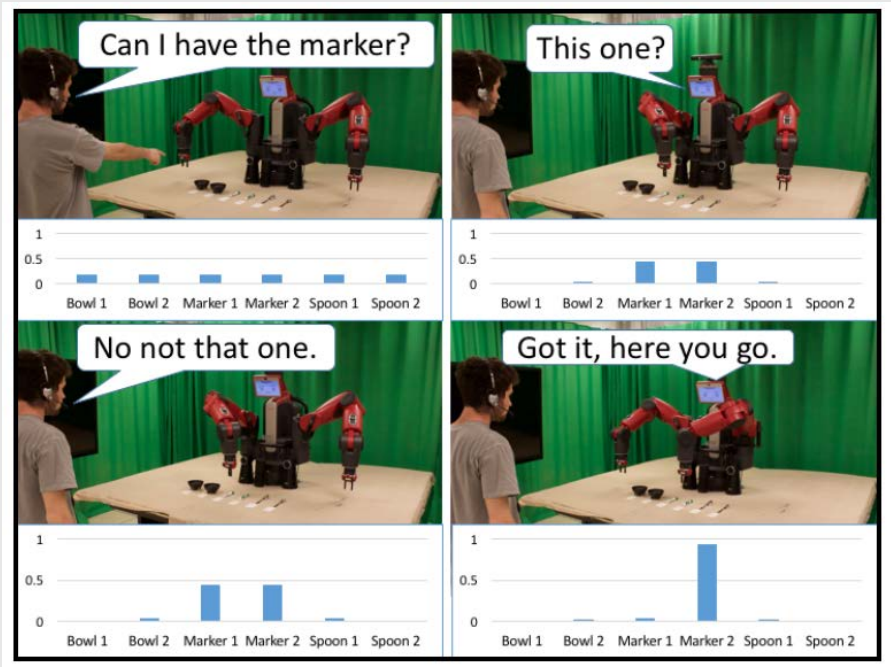


Understanding human intentions

- Natural language processing
- Gesture interpretations
- Social cues

⇨

- Faster robot learning
- Resolving uncertainty



S. Tellex et al

Hardware and algorithmic advances

- Mobile computing platforms fueling low cost robotic integration
- Innovative mechanisms and actuation technolgies
- Algorithmic advances

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