Robotics Evolution: From Production Rate to Human Productivity

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YASKAWA ELECTRIC CORPORATION

Largest supplier of industrial mechatronic automation

Dedicated focus on three core competencies:
- Robotics
- Motion control
- Environment and energy

CUMULATIVE GLOBAL SALES

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>360,000</td>
<td>ROBOTS</td>
</tr>
<tr>
<td>10 MILLION</td>
<td>SERVOS</td>
</tr>
<tr>
<td>18 MILLION</td>
<td>INVERTER DRIVES</td>
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Success

Technology

Challenges

Future
Success

<table>
<thead>
<tr>
<th>1950s BEGINNING</th>
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<tbody>
<tr>
<td>1954: Patented by George Devol</td>
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<tr>
<td>1957: Commercialized by Joseph Engelberger</td>
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<tr>
<td>1959: First deployed at General Motors</td>
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<td>1969: First robotic welding line at GM doubled production to 110 cars/hour</td>
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Made in USA
“Every time the cost of labor goes up a dollar an hour, a thousand more robots become economical.”

– Roger Smith, GM CEO

1980s EUPHORIA

A new robot company every month:
Robot and Automotive
Both Grow at a
Similar Rate of 3%

<table>
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<th>1985 – 2000</th>
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<tr>
<td>Steady, but limited growth</td>
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<tr>
<td>Robot implementation costs become an impediment to industry growth</td>
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<td>Robots used more as dedicated automation devices</td>
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<td>Most American robot companies disappear</td>
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<td>Japan becomes the leading robot producer and user</td>
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China becomes largest buyer

RESURGENCE

248,000 units sold in 2016

Growth outside of automotive:

- Electrical/electronics industry
- Metals industry
- Rubber and plastics industry
- New emerging markets
No Robot – No Car

- Automotive: 43%
- Electronics: 22%
- Metals: 9%
- Material/Chemicals: 8%
- Food: 3%
- Others: 4%
- Unspecified: 11%
Robot Reliability and Life

- **Honda Civic**
- **5,000 hours**
- **1970**
- **80,000 hours**
- **2010**

Industrial Robot

Honda Civic
Precision and Smoothness
Integration and Coordination
Sense and Act
Safety through Separation

LIMITED WORKER INTERACTION

- Physical or sensor fencing around robots
- Inflexible use of space
- Task has to be fully automated
- Increases cost of redeploying robots
Application Data is Key

CLOUD CONNECTED

Improve robot performance and uptime
Predict failure, schedule service, monitor operations

Additional sensing
Vision, touch, sound

Inter-connected robots
Leverage experience of sensory perception and action across robot fleets

Shared knowledge
Use data to train deep learning models
Disseminate updated capabilities to robots
### Robot End-Effectors

<table>
<thead>
<tr>
<th>NO UNIVERSAL ROBOT HAND</th>
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<tr>
<td>Custom based on part robot is handling</td>
</tr>
<tr>
<td>Could be electric, pneumatic, magnetic, etc.</td>
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<tr>
<td>Far from human hand capabilities</td>
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Complex Assembly

FULLY AUTOMATED SOLUTION

- Uses fixtures
  Hold parts in fixed known places

- Complex pre-programming
  Expert robot programmer codes sequences of motions for play-back

- Highly specific
  Even small changes to the chair model parts would require some reprogramming

- Not collaborative
  Humans can’t help – just stay out of the way
Where is Manufacturing Today?

FULLY AUTOMATED
- Low product mix
- Low product customization
- 5-year product life

FULLY MANUAL
- High product mix
- High product customization
- 2-year product life
Autonomous Car versus Complex Assembly

- Thy shall not make contact
- Available street view, maps and GPS
- Coarse sensing resolution
- Enormous amounts of data available

- Discern between good and bad contact
- Potentially use IKEA instructions
- Precise physical interaction
- Challenges acquiring data
2015 DARPA Robotics Challenge Winner - KAIST
YASKAWA VISION
Automation for humans and robots to coexist and cooperate

from…
Mechatronics

to…
Humatronics
Collaborative Automation

WORKING ALONSIDE

WORKING TOGETHER
What Makes This Challenging

SAFETY
coexist with the worker

DIFFICULTY
programmable by the worker

CAPABILITY
cooperate with worker
Capability: Mobile and Flexible
Capability: Mobile and Flexible
Capability: Augment Human Perception

Heavy Lifting and MotionPerformed by Robot. Human Out of Workspace.
Making it Safe
Making it Safe
Safety is More than Collisions
From Co-existence to Cooperation

Operator Easily Teaches Robot

Robot Cooperates with Operator
Operator Easily Teaches Robot
Making it Cooperate
Improving Operator-Robot Cooperation

Robot should maintain a 3D world model
- Use 3D perception to recognize/label equipment in work area
- See and track movement of people and objects in detail
- Dynamically avoid collisions

Robot should learn by observation
- Watches operator behavior to understand context
- Adapts by anticipating future behavior

Robot should recover from errors
- Use task knowledge and context
Improve Robot Ease of Use and Capability

Increase Worker Training and Ownership
NEXT 10 YEARS

Robot as a tool for worker productivity
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