

# Mid-Cycle National Roadmap Update

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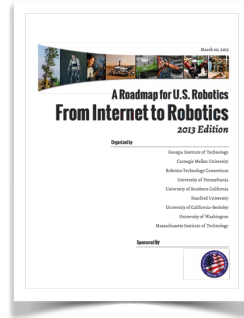
**Contextual Robotics Institute**

# Trying to Predict the Future

2009

Economic downturn?

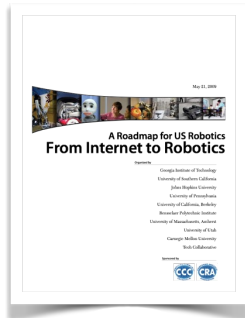
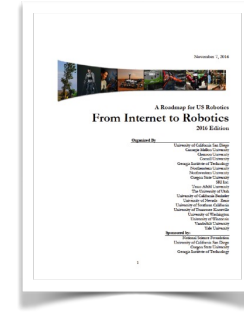
- Co-Robot



2016

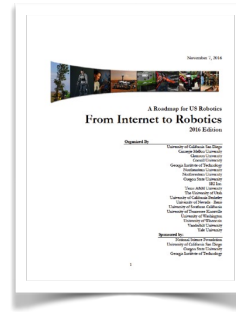
Globalization?

- High-mix / low volume



Fukushima?  
•Unstructured Environments

2013



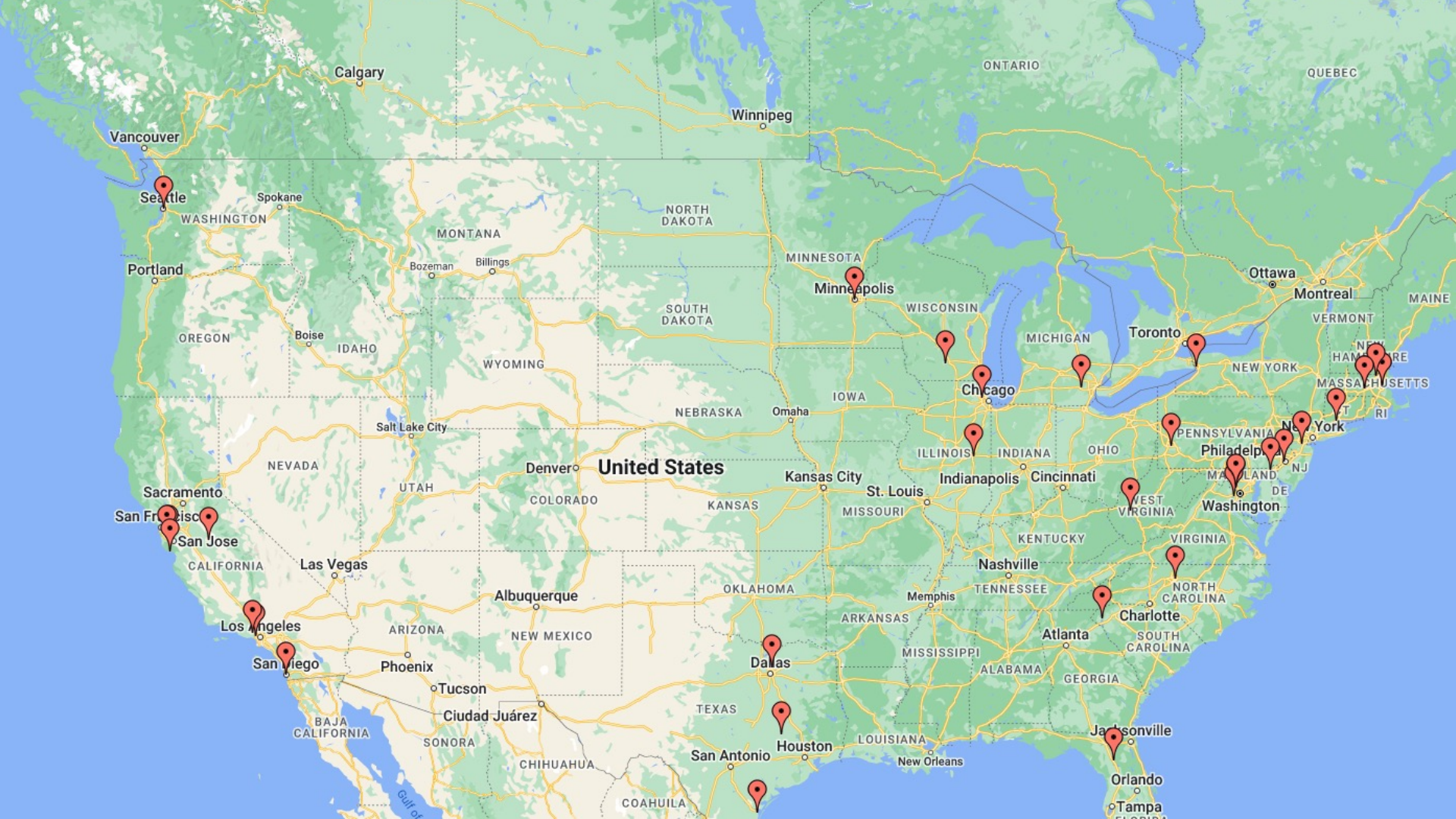
Post-Pandemic, ....  
Reshoring  
e-commerce

2020

# Mid-Cycle Update to Robotics Roadmap (H. Christensen & H. Yanco, eds.)

- Post-COVID
- Reshoring
- E-commerce
- New administration
- New FRR program, NRI sunsetted
- CCC sponsored update in cooperation with EVRA
- CfP (Dec 2022)
- 41 contributions (Jan 2023)
- AAI discussion (Feb 2023)
- Synthesis (Mar 2023)
- Review by contributors (Mar 2023)
- Publication (Apr 2023)

<https://cra.org/ccc/wp-content/uploads/sites/2/2023/04/Robotics-Mid-Cycle-White-Paper.pdf>



# Mid-cycle Update to the US National Robotics Roadmap<sup>1</sup>

Henrik I Christensen, UCSD & Holly Yanco, UML (Editors)

Version: 2023-04-02

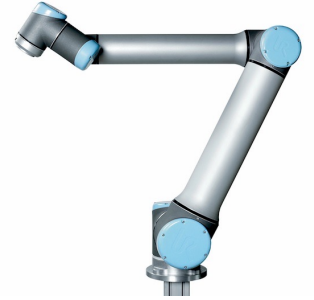
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Are we making progress?

# 10-15 Years of Progress

- Co-Robots (2008/2004)
- Roomba (2002)
- E-commerce / Kiva (2004)



# 10-15 Years of Progress

- DARPA Challenge (2004-2007)
- Drones / DJI (2006)
- Spirit & Opportunity (2004)





MEGA – Trends?

# Some COVID Implications

- Logistics / home deliveries
- Tele-robotics (health, social)
- Automated screening of samples
- Food / item security
- Cleaning & disinfection
- Lack of (migrant) workforce



# Trade Dynamics

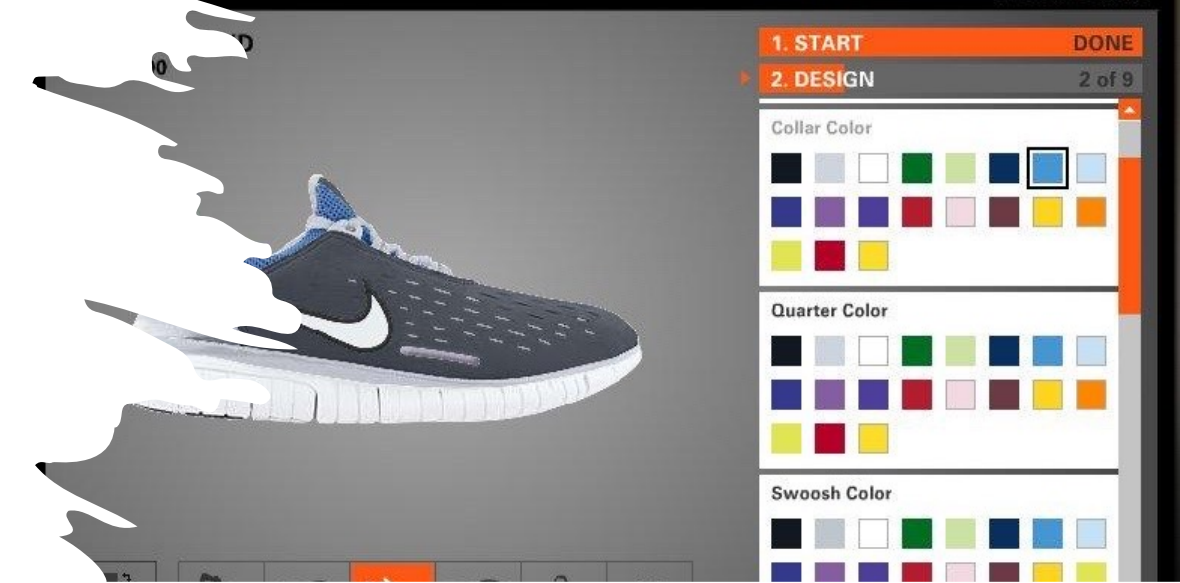
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- Manufacturing is gradually moving out of China
- Salary is a factor
- Increase productivity with robots?



# Mass Customization

- Everyone wants a one-off
- 3D printing, ... is an enabler
- Shipping (my product now!)

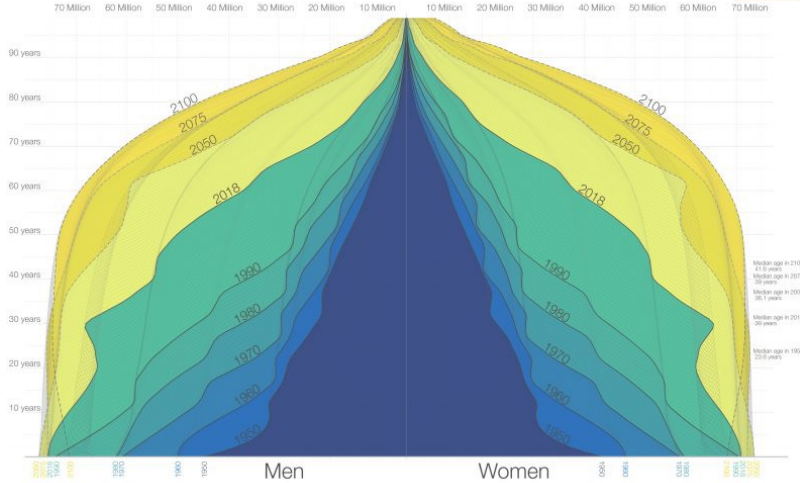


# Aging Society

## The Demography of the World Population from 1950 to 2100

Shown is the age distribution of the world population – by sex – from 1950 to 2018 and the UN Population Division's projection until 2100.

Our World  
in Data



Data source: United Nations Population Division – World Population Prospects 2017, Medium Variant.  
The data visualization is available at [OurWorldinData.org](https://ourworldindata.org), where you find more research on how the world is changing and why.

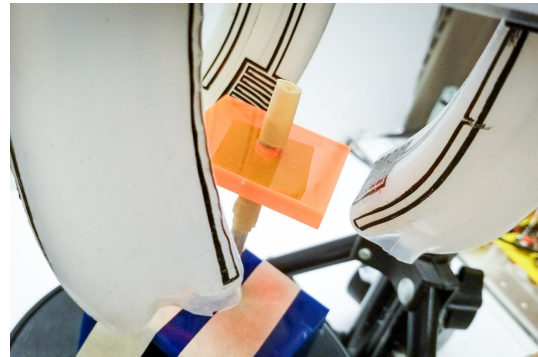
Licensed under CC-BY by the author Max Roser.



Technology Drivers?

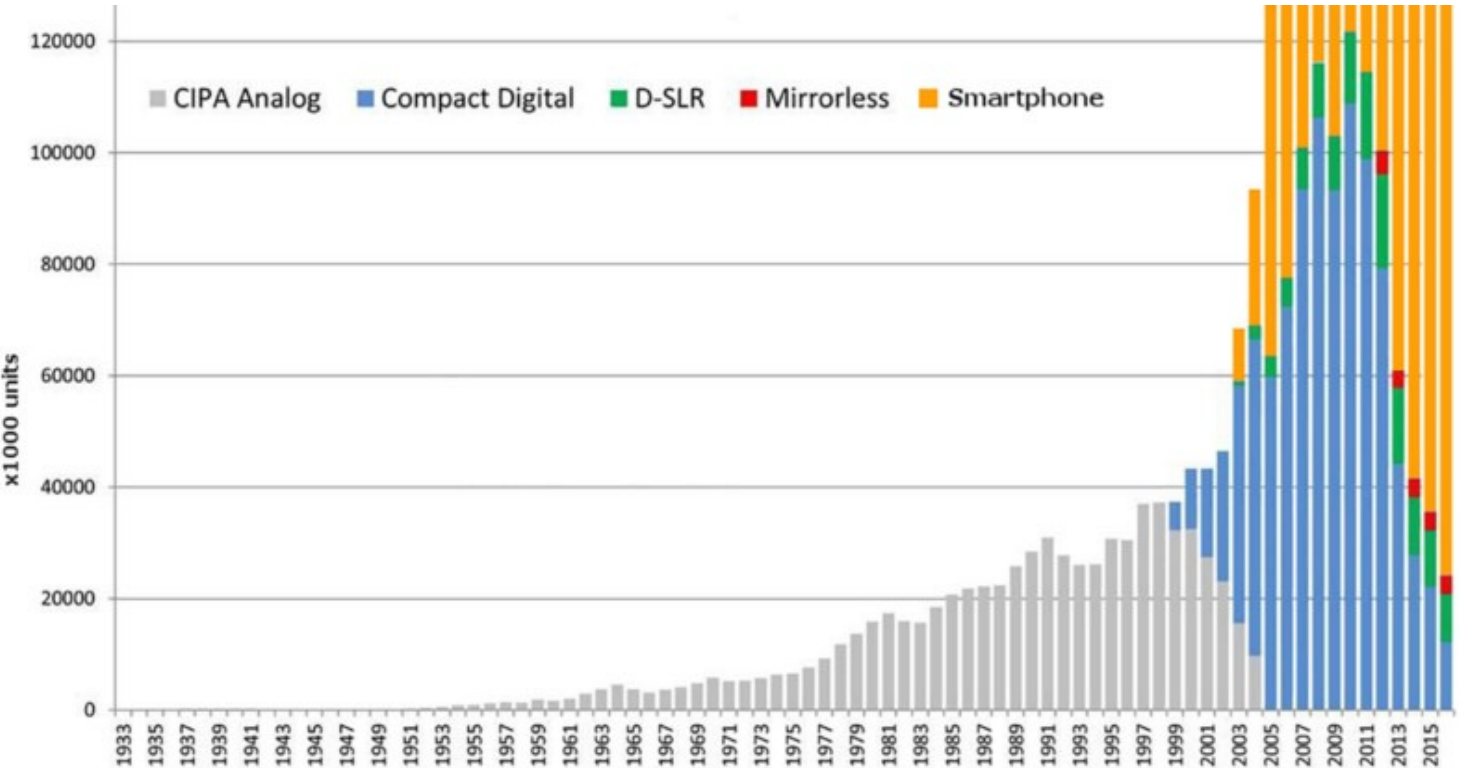
# New Materials

- Safer robots
- New grippers
- Mixed materials
- Printed to order



# Sensors

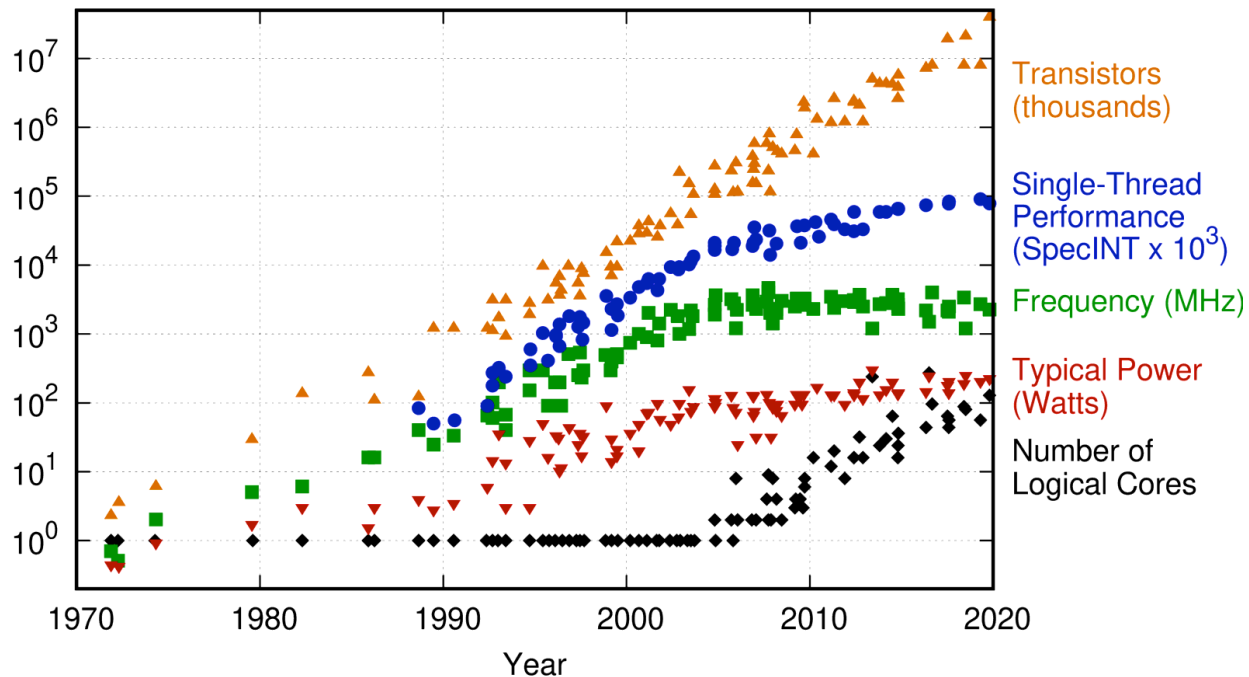
- Evolution in sensors





# Computing

48 Years of Microprocessor Trend Data



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten  
New plot and data collected for 2010-2019 by K. Rupp

# New computing architectures



# Societal Drivers?

- Manufacturing
- Logistics
- Transportation
- Feeding the planet
- Quality of life
- Healthcare
- Security & safety

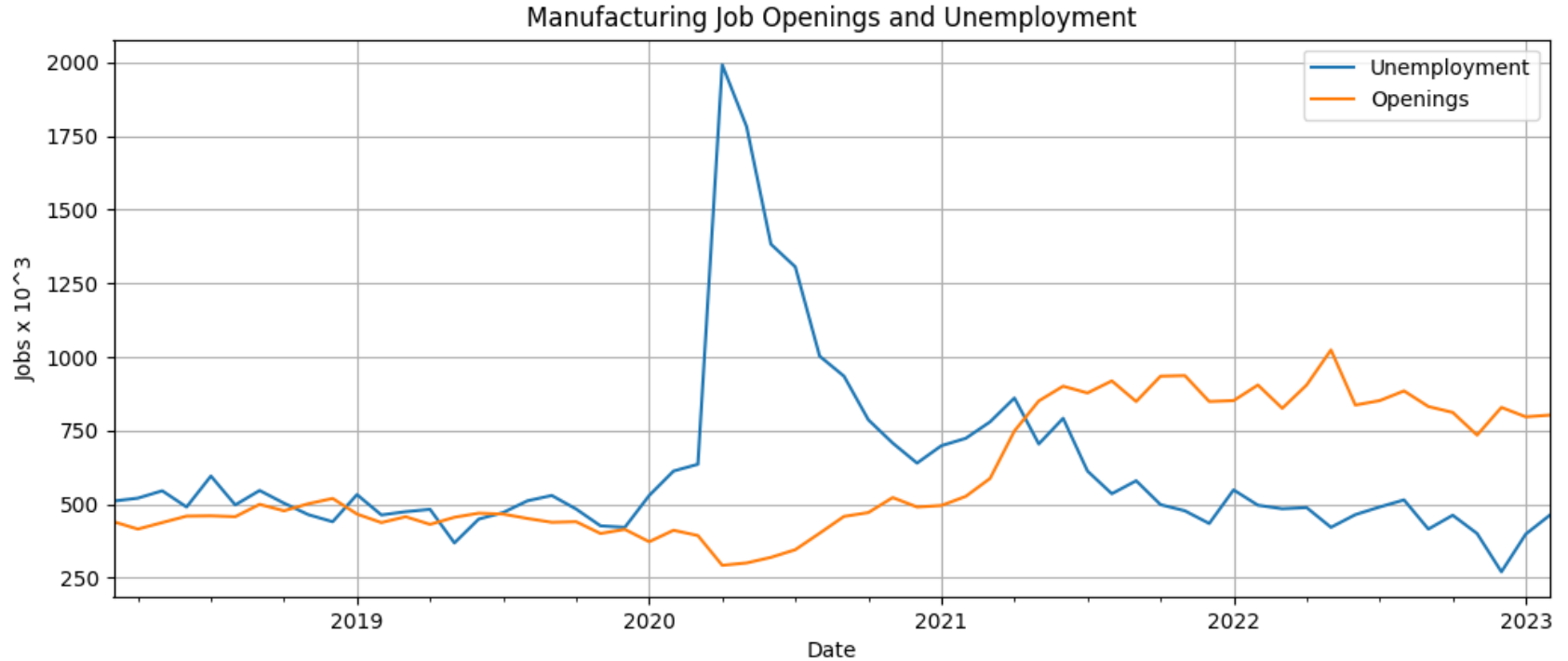
# Manufacturing

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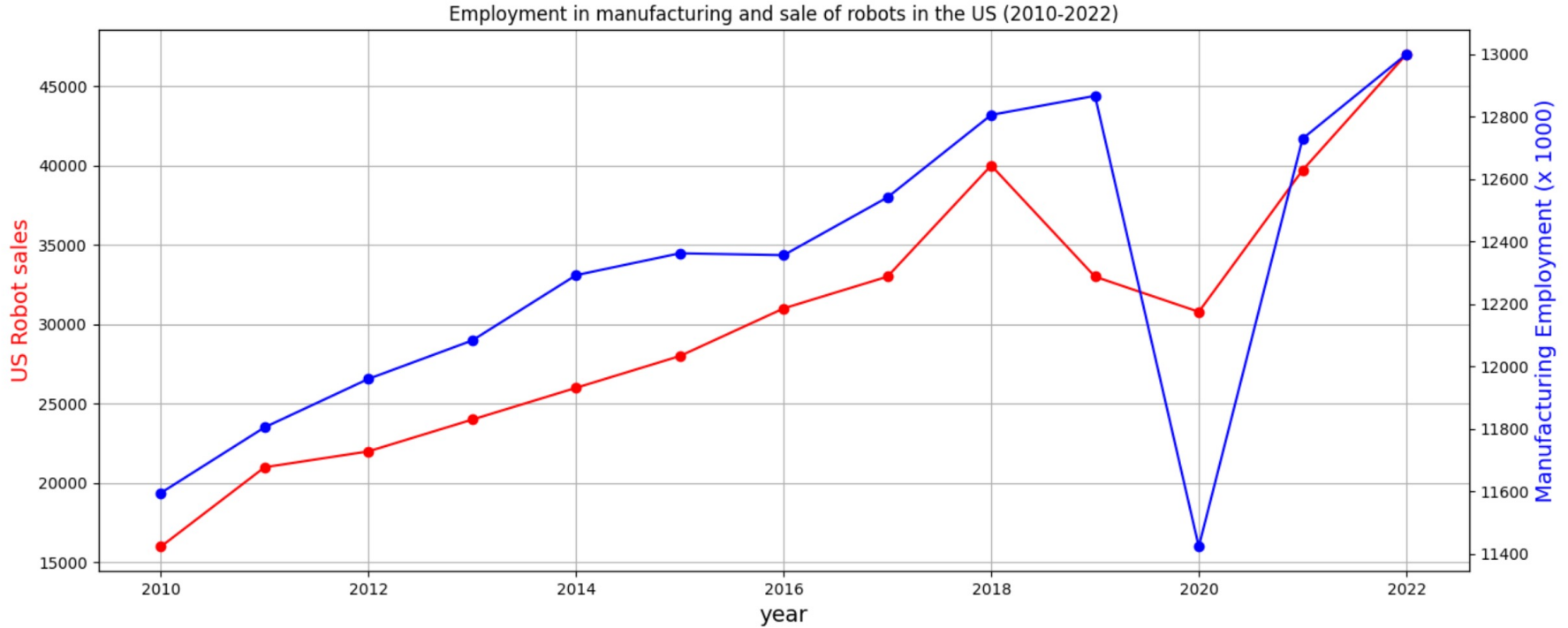
- Cost
- Flexibility
- Mix
- Lotsize-1
- Programming



# Lack of a Workforce



# Robots or Jobs?



# Logistics

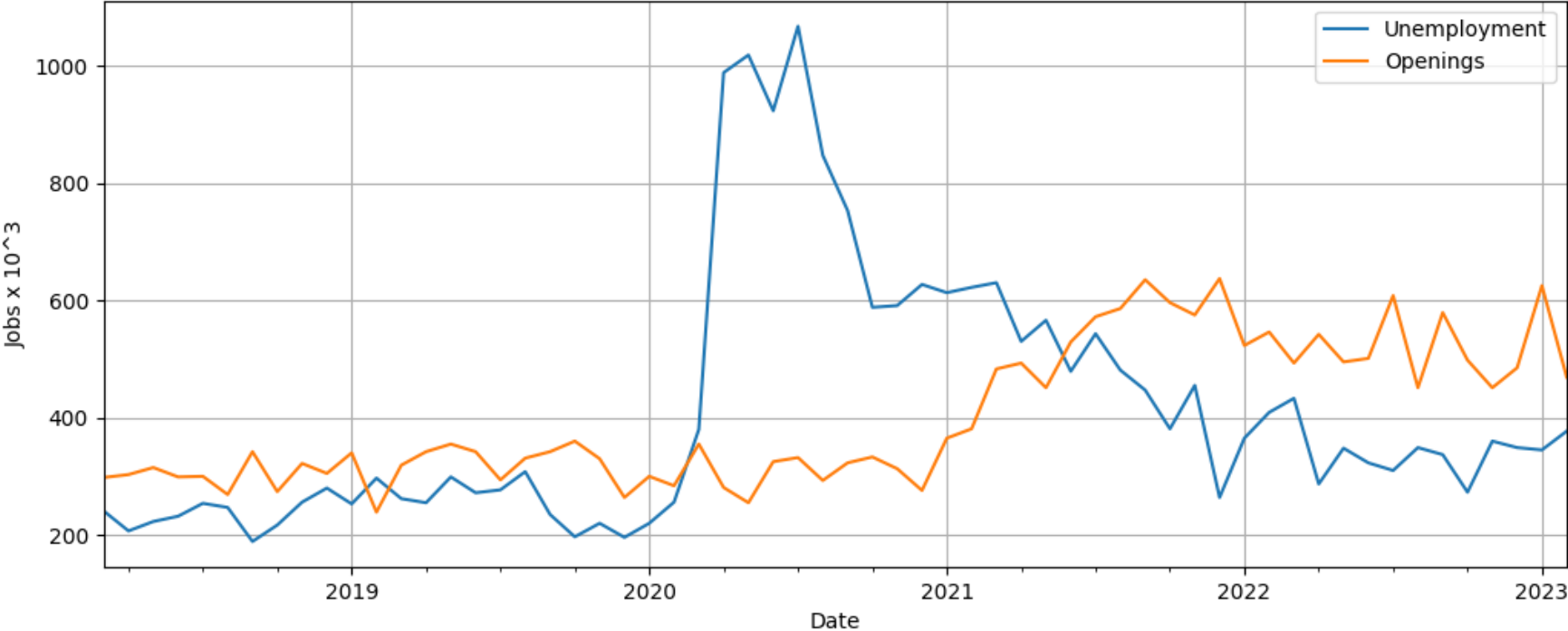
- Scale
- Multi-modal
- Flexible
- Agility

## DISTRIBUTION CENTERS



# Workforce still a major issue

Warehousing Job Openings and Unemployment







Grocery Store – 45k+ SKUs



# Transportation

- Autonomy
- Inclusion
- People
- Material
- Beyond highway



# Autonomous Vehicles





Amazon Scout – Certification is hard

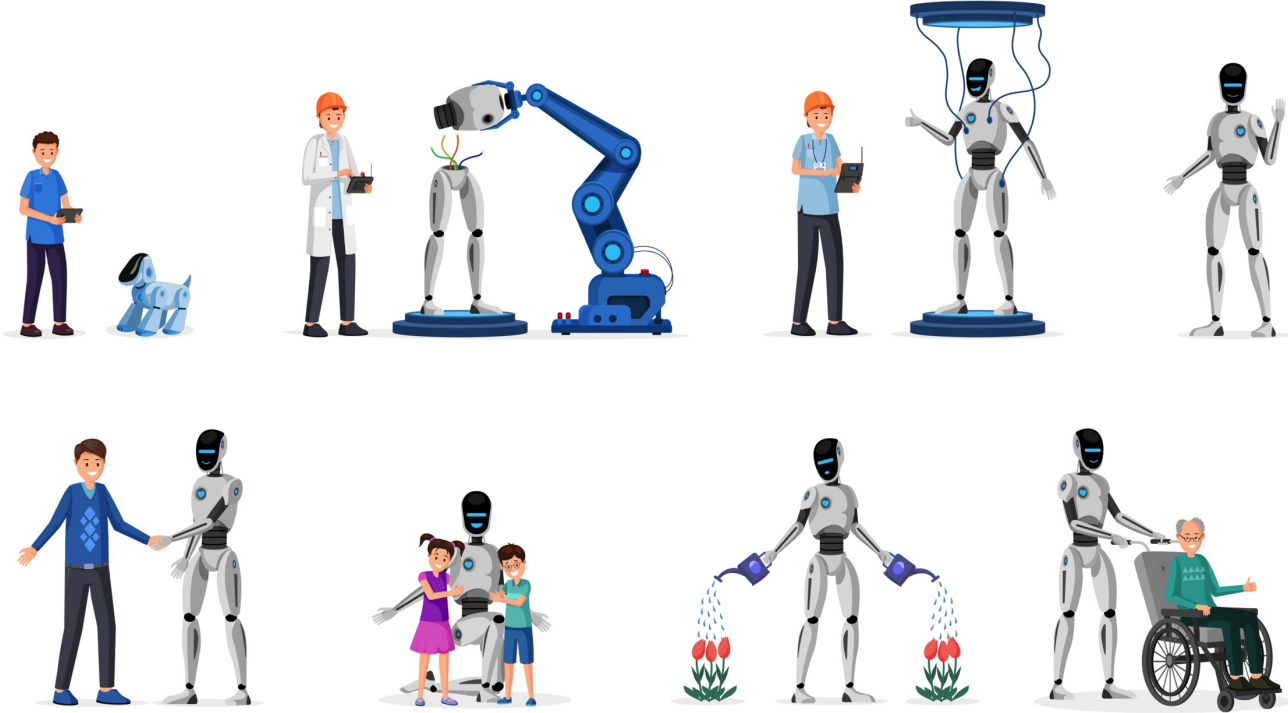
# Feeding the Planet

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- Small scale
- Robust
- Simple program
- Cost
- Vertical farming
- Environment



# Quality of Life





# Healthcare

- 1-off
- Access
- Integration
- Physical
- Rehabilitation
- Psychological

An aerial, high-angle view of a multi-lane highway with several cars and a police car. A large, semi-transparent white drone is overlaid in the center of the image. The text "Security & Safety" is written in white, sans-serif font across the middle of the drone's body.

Security & Safety



A pair of black-rimmed glasses is resting on an open book. A red bookmark is visible on the left page. The background is softly blurred, showing more of the book and a wooden surface.

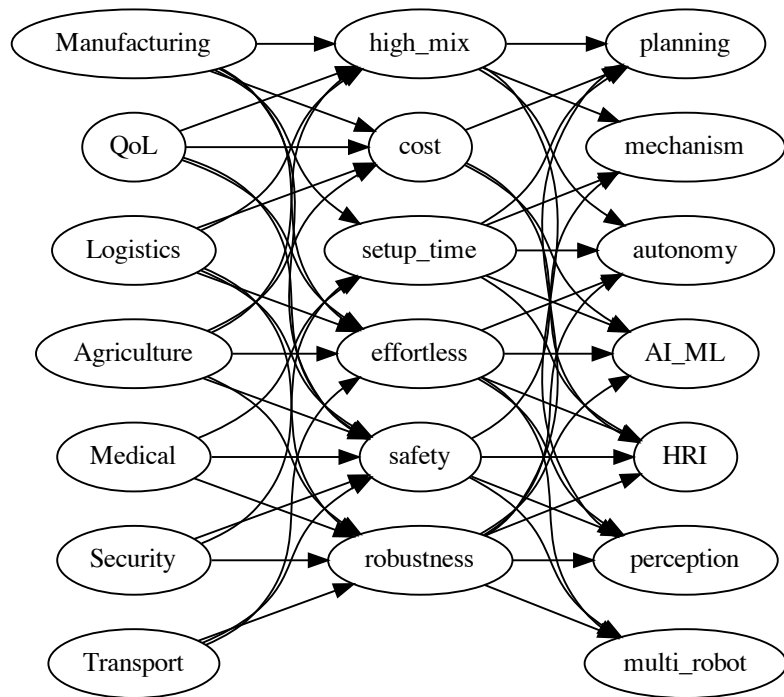
Overall obstacles?  
Research challenges?

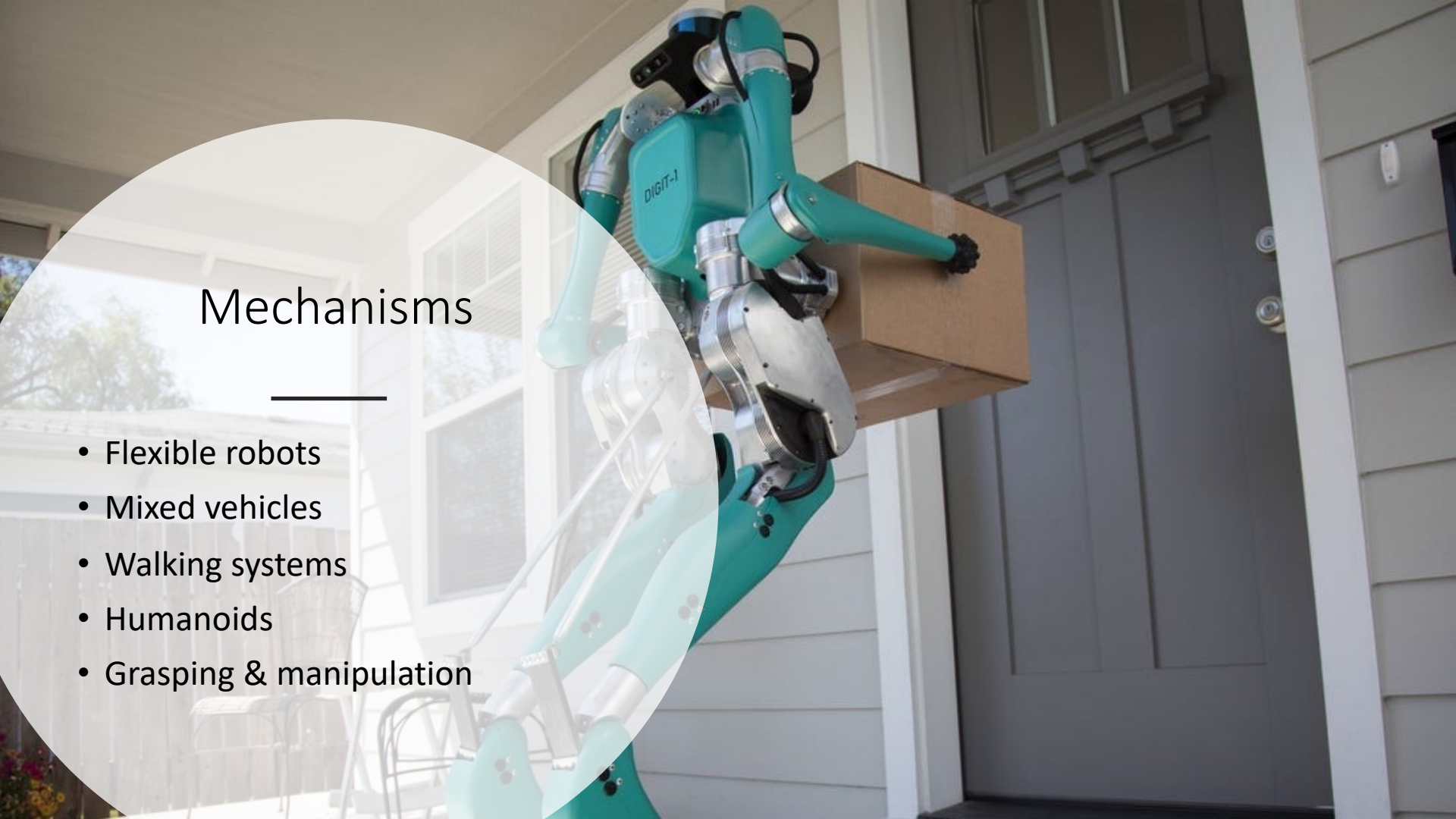
```
mirror_mod = modifier_ob.  
    set mirror object to mirror  
    mirror_mod.mirror_object  
    operation == "MIRROR_X":  
    mirror_mod.use_x = True  
    mirror_mod.use_y = False  
    mirror_mod.use_z = False  
    operation == "MIRROR_Y":  
    mirror_mod.use_x = False  
    mirror_mod.use_y = True  
    mirror_mod.use_z = False  
    operation == "MIRROR_Z":  
    mirror_mod.use_x = False  
    mirror_mod.use_y = False  
    mirror_mod.use_z = True  
  
    #selection at the end -add  
    mirror_ob.select= 1  
    modifier_ob.select=1  
    context.scene.objects.active  
    ("Selected" + str(modifier  
    mirror_ob.select = 0  
    = bpy.context.selected_obj  
    .data.objects[one.name].se  
  
    print("please select exactly  
  
    ----- OPERATOR CLASSES -----  
  
    types.Operator):  
    X mirror to the selected  
    object.mirror_mirror_x"  
    mirror X"  
  
    context):  
    context.active_object is not
```

# Overall obstacles

- Robustness
- Scaling Up / Flexibility
- Safety & Certification
- 1-off execution
- Training & Programming
- Ethics, Privacy, Policy ...

# Mapping: \$ -> Challenges -> R&D



A teal robot arm, labeled 'DIGIT-1', is shown holding a brown cardboard box. The robot is positioned in front of a grey door on a house with light-colored siding. The background shows a porch with a white railing and some outdoor furniture. A large, semi-transparent white circle is overlaid on the left side of the image, containing text.

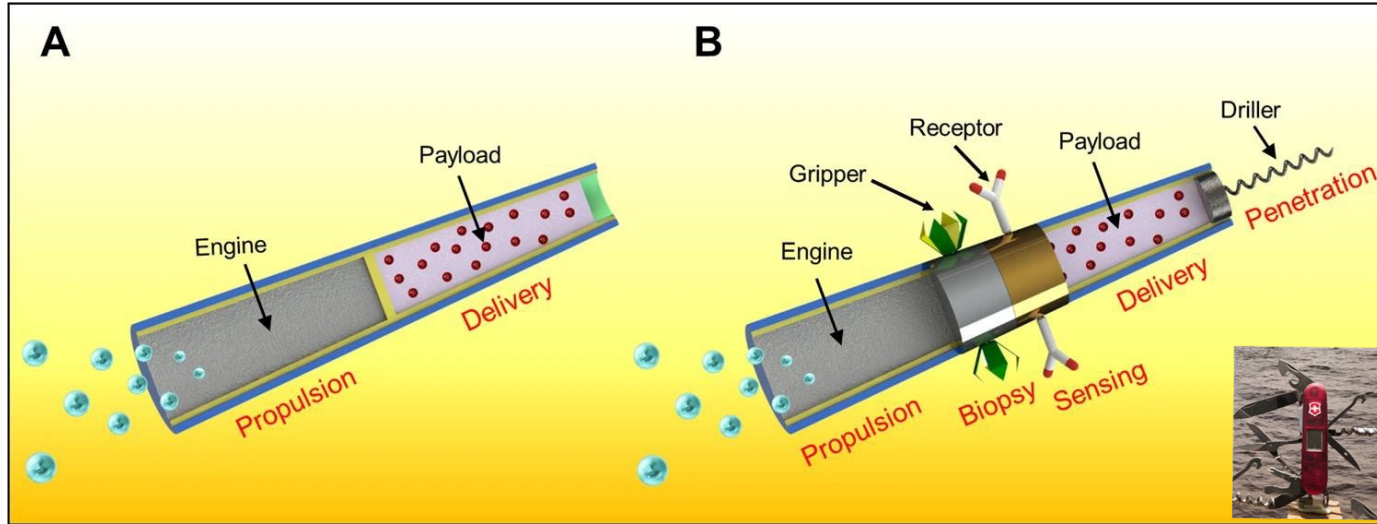
# Mechanisms

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- Flexible robots
- Mixed vehicles
- Walking systems
- Humanoids
- Grasping & manipulation

# Fabrication

**Simplicity versus complexity: special-purpose or general-purpose microbots?**



**Task-specific customized micromachines**

**Multi-purpose "all in one" vehicles**

**Relying on bottom-up fabrication for building the desired robotic microstructures that break the symmetry for generating active propulsion**

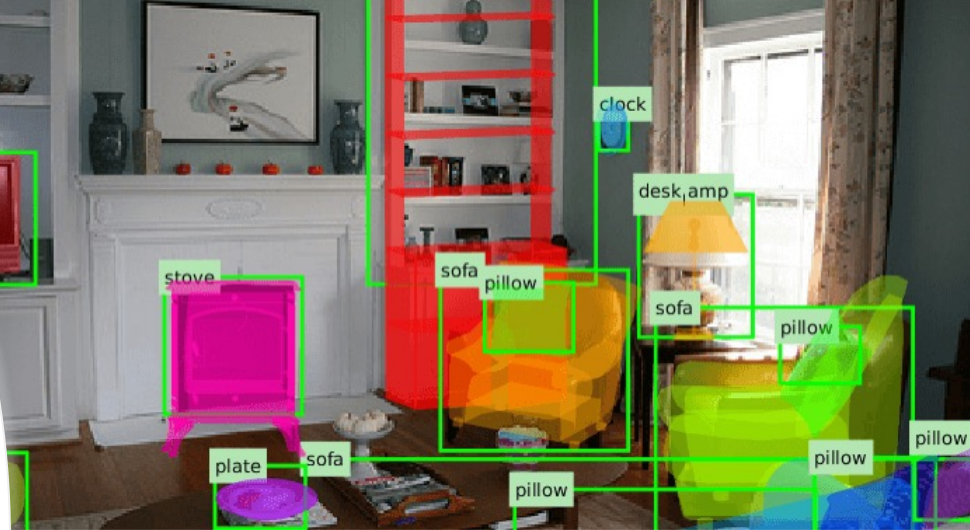
# Grasping & Manipulation

- Beyond Models
- Scaling
- Flexibility
- Safety
- Soft Systems
- Sensorized

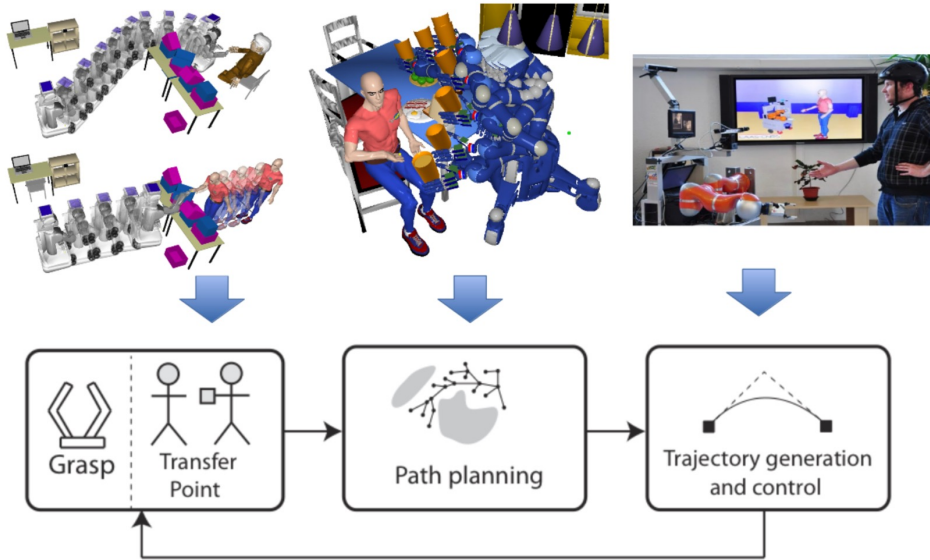




# Sensing / Perception

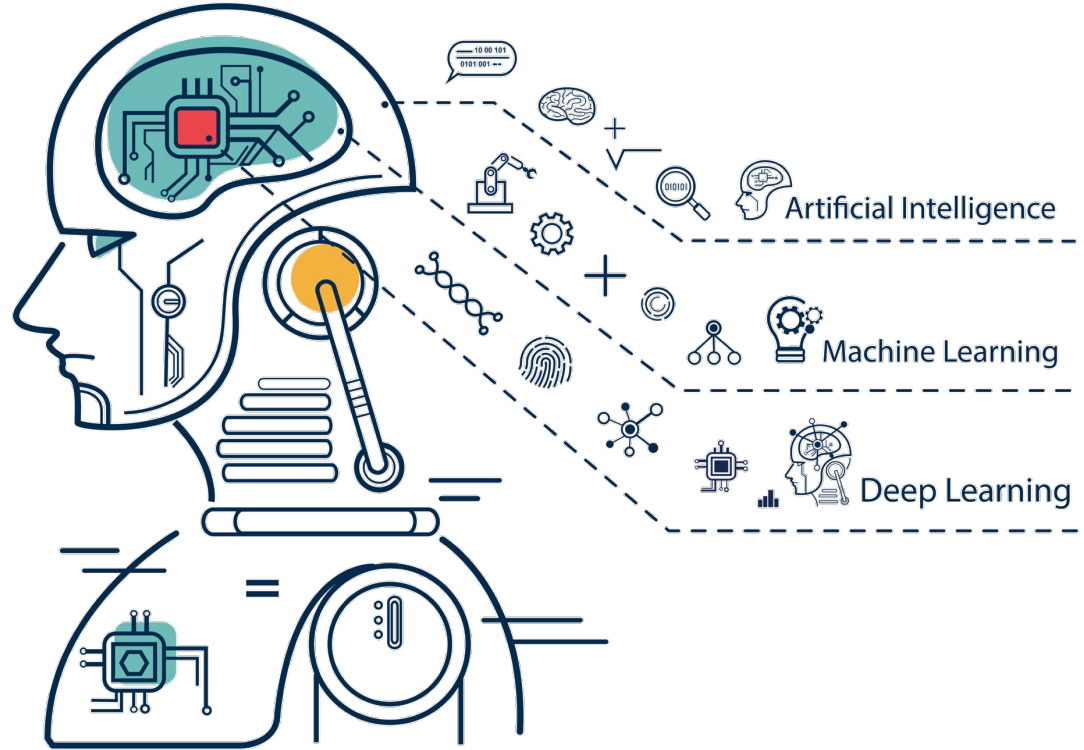


# Planning and Control





# Learning and adaptation





# Human-Robot Interaction

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- Multi-Modal
- Zero-Barrier
- Physical Interaction
- Cognitive Connection

# Architecture & Design

- Re-envisioning cyber-physical system-architectures
- Engineering the data-interface to/from the analog/digital domains
- Real-time robotic digital information architectures
- Multifunctional modular integration
- New manufacturing techniques
- A science of integration

# Workforce Considerations

- Workforce changes are happening
- Training will be required at all levels
- K-12 -> Trade Schools -> College
- Continuing education / Lifelong Education
  
- Robotics is a key enabler for STEM education

# Recommendations

- US is falling behind (big-time)
  - Need a stronger investment in R&D
  - A unified program to simplify access, success rate, ...
  - Coverage from component technologies to systems
  - A full pipeline from basic research to translation
  - Investments in infrastructure / test facilities
  - Consideration of legal framework to ensure deployment

# Summary

- The world is adopting robot systems to
  - Increase quality of life
  - Enable increased flexibility and autonomy
  - Empower access to food, cleaner world, economic growth & sustainability
- The robot economy is growing 15-18% annually
- Basic R&D is falling behind (and so is translation)

September 9, 2020



**A Roadmap for US Robotics**  
**From Internet to Robotics**  
2020 Edition

**Organized By**

University of California San Diego  
University of Illinois Urbana Champaign  
University of Massachusetts Lowell  
University of Southern California  
Carnegie Mellon University  
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Cornell University  
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University of Southern California

# Roadmap

- Updated every 4 years
- Trying to be an accurate estimator of how robots are used / deployed / ....
- Document is available in public domain

<https://cra.org/cc/visioning/robotics-roadmap>

# Next Roadmap Update

Date	Activity
June 2023	Call for White Papers
July 2023	Submission Deadline
Sep – Nov 2023	Three workshops (East, Mid, West)
Jan 2024	Synthesis Workshop (~15 people)
Mar 2024	Initial Draft
Jun 2024	Roadmap Published

Please contribute white papers, attend workshops, .... It is YOUR roadmap



# Next Roadmap Update: Starts Today!

Fundamental Challenges in Robotics Workshop, today, 3-5pm

- Organizers: Holly Yanco, Henrik Christensen, and Ann Drobniš
- Challenges posed by panelists, then by attendees



Dorsa Sadigh  
Stanford



Hadas  
Kress-Gazit  
Cornell



Jake Abbott  
Utah



Joydeep Biswas  
UT Austin



Marynel Vázquez  
Yale



SK Gupta  
USC