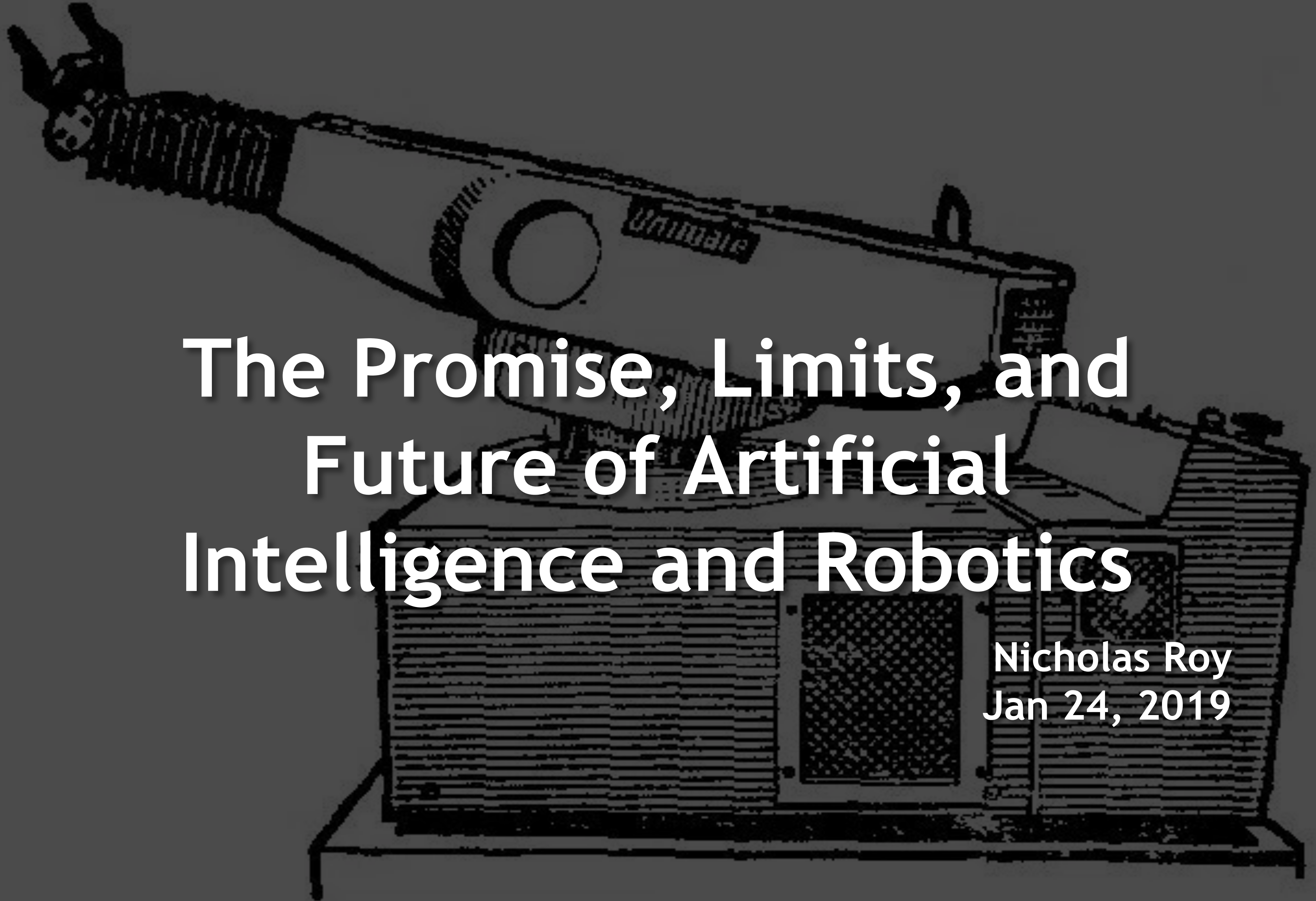


The Promise, Limits, and Future of Artificial Intelligence and Robotics

Nicholas Roy
Jan 24, 2019


WAYMO 01

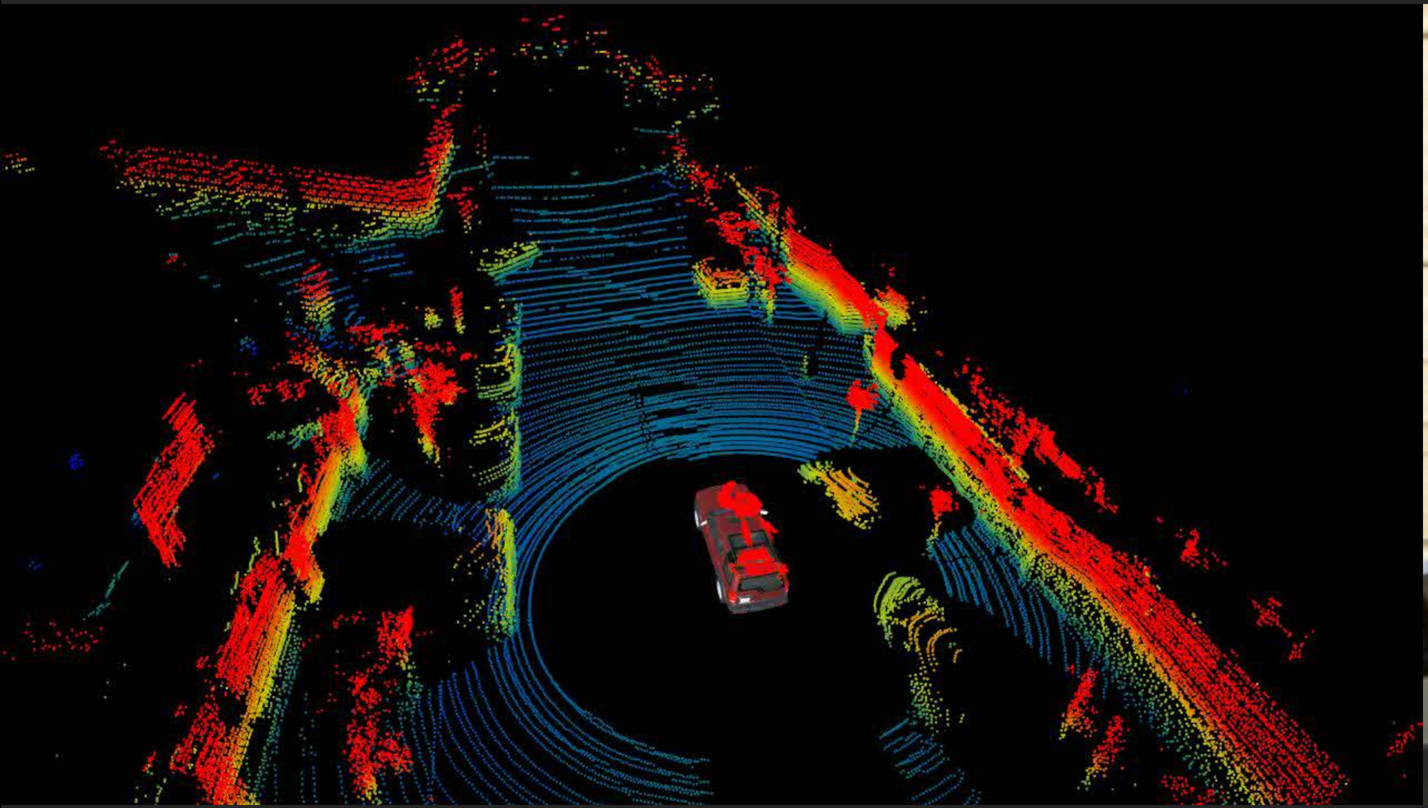

The Challenges of Autonomy

- Vehicles must know where they are
  - Signal processing and estimation theory
- Vehicles must know what is around them
  - Signal processing and estimation theory
- Vehicles must be able to plan what to do
  - Planning algorithms
- Vehicles must be able to react to the unexpected and adapt as the world changes
  - Machine learning

Major Hardware Advances Driving Modern Autonomous Robotics

- Low-cost, high-power micro-electronics
- Low-cost, high-power computation
- New generations of sensors

Velodyne (3D Laser Scanner)



Slide courtesy of J. Leonard, MIT


HOKUYO
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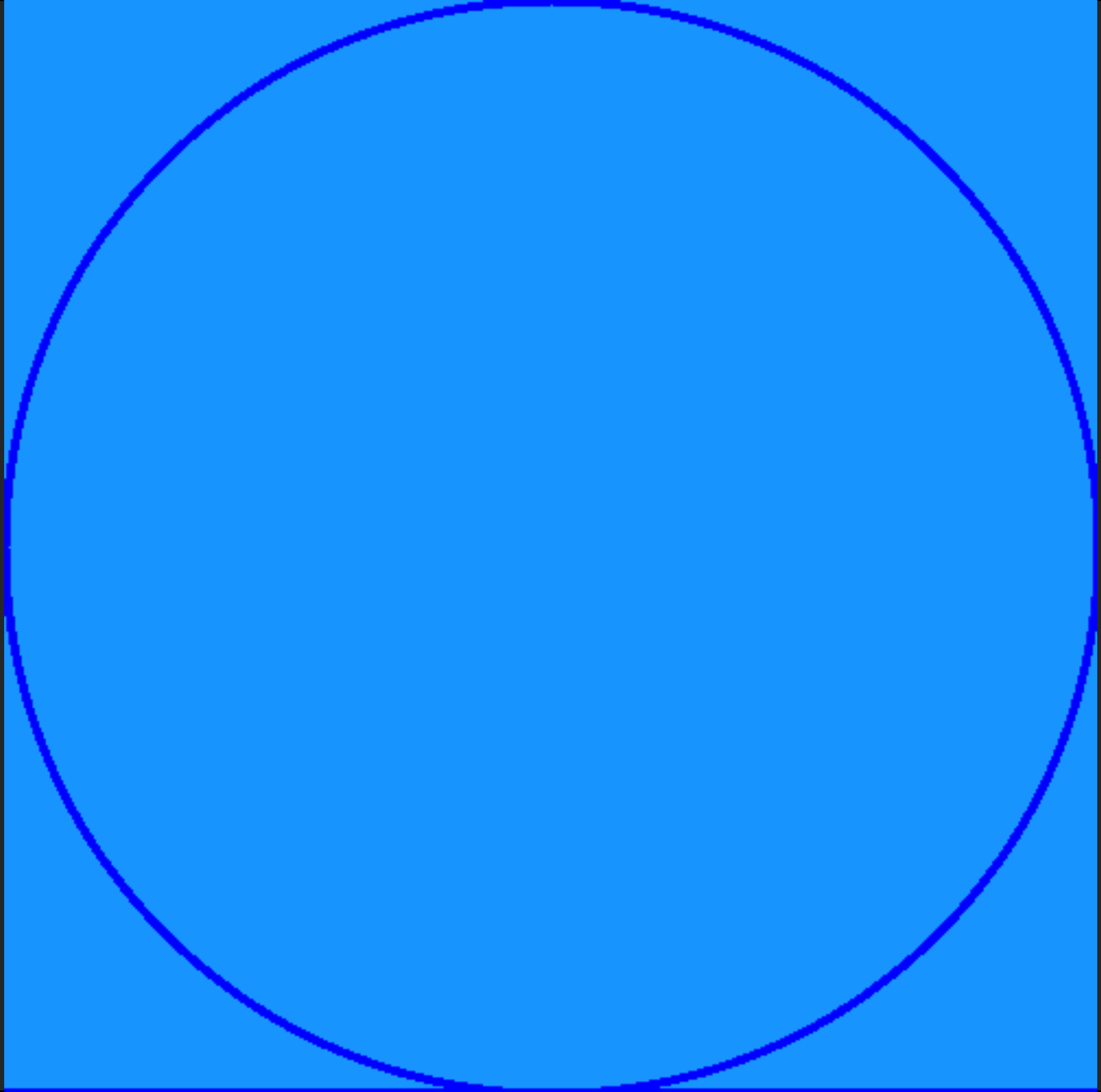
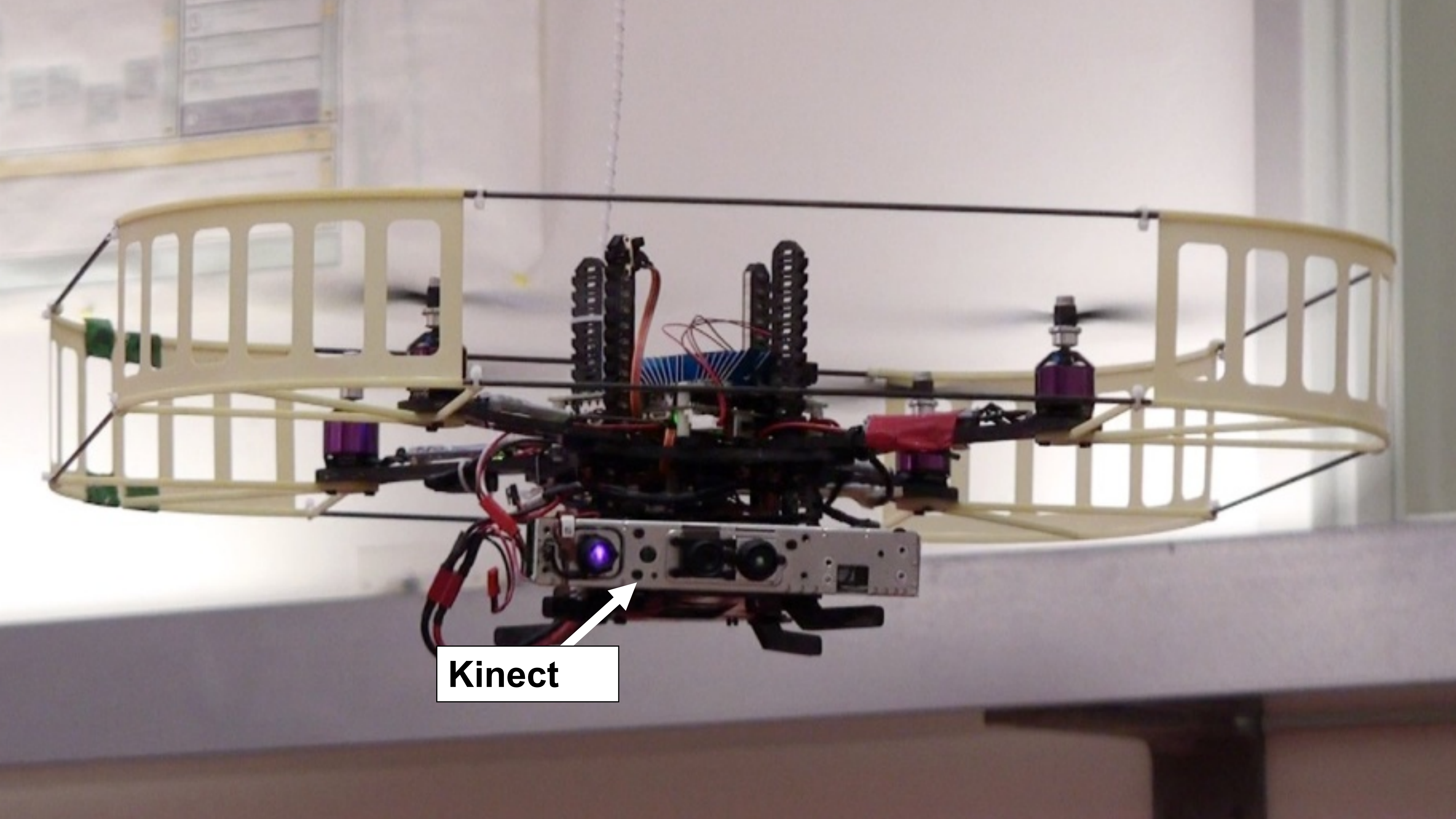
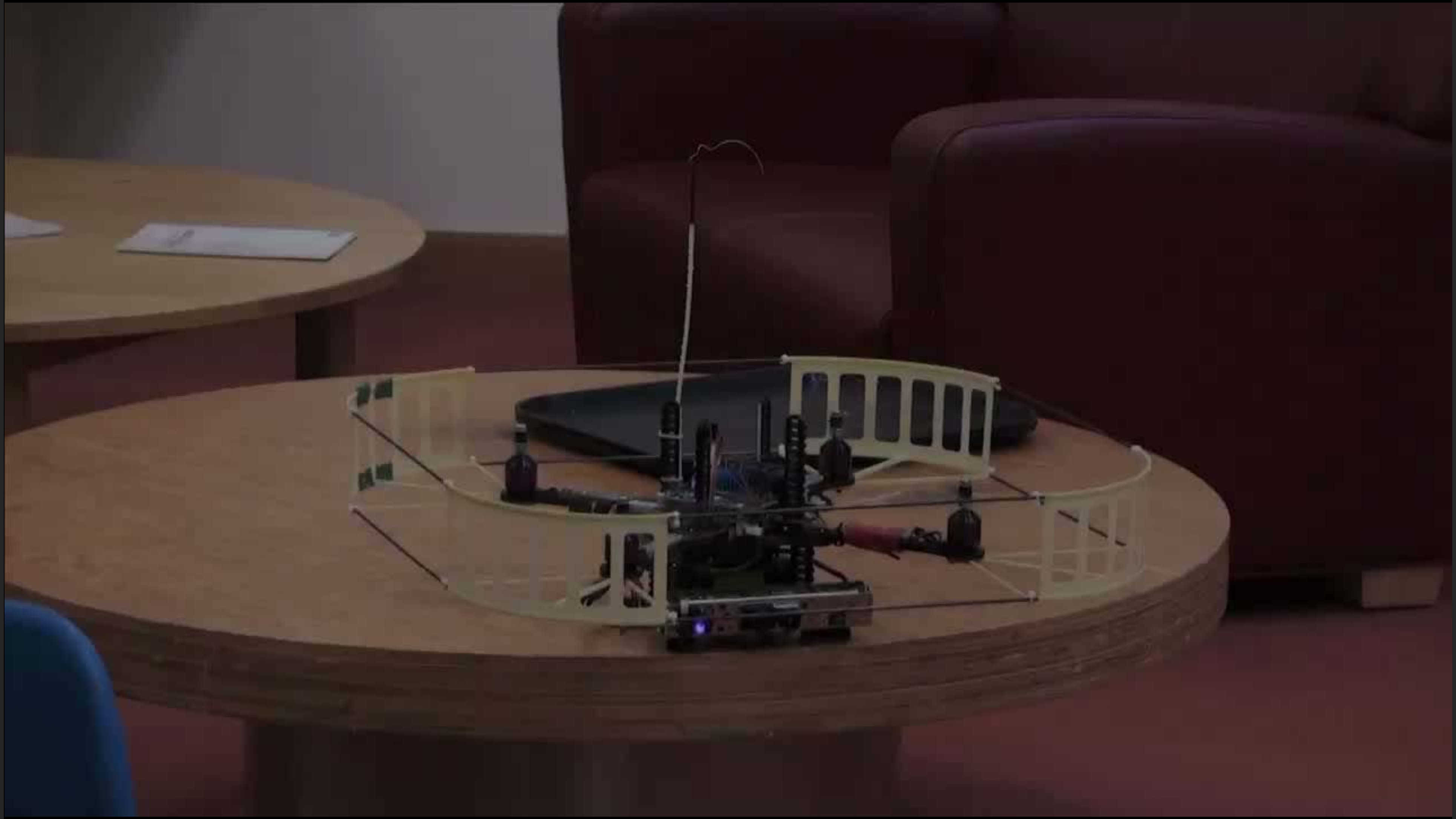



Autonomous
Navigation


Kinect



Advances in robotics now (mostly) from software

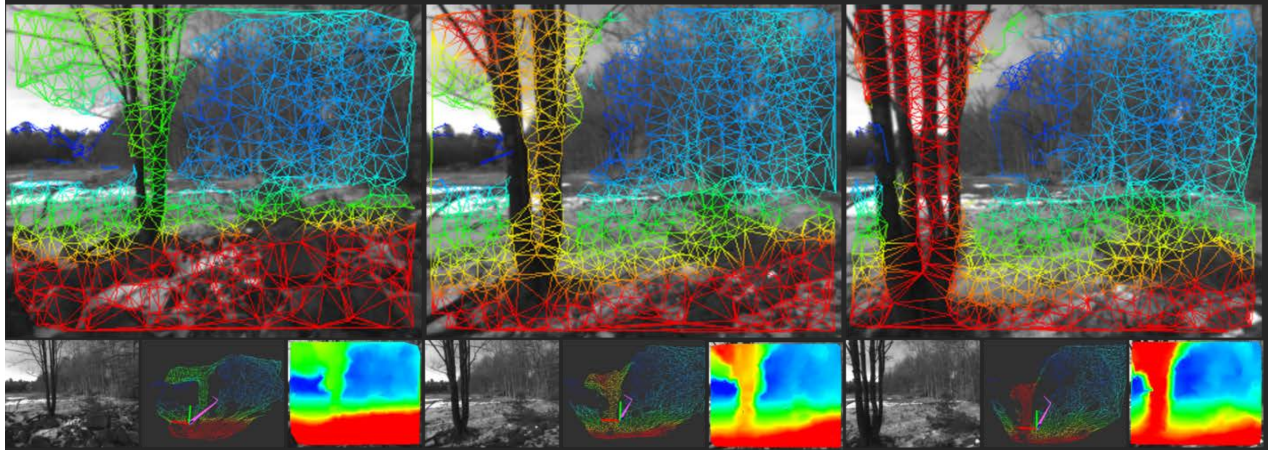
From Lasers to Cameras

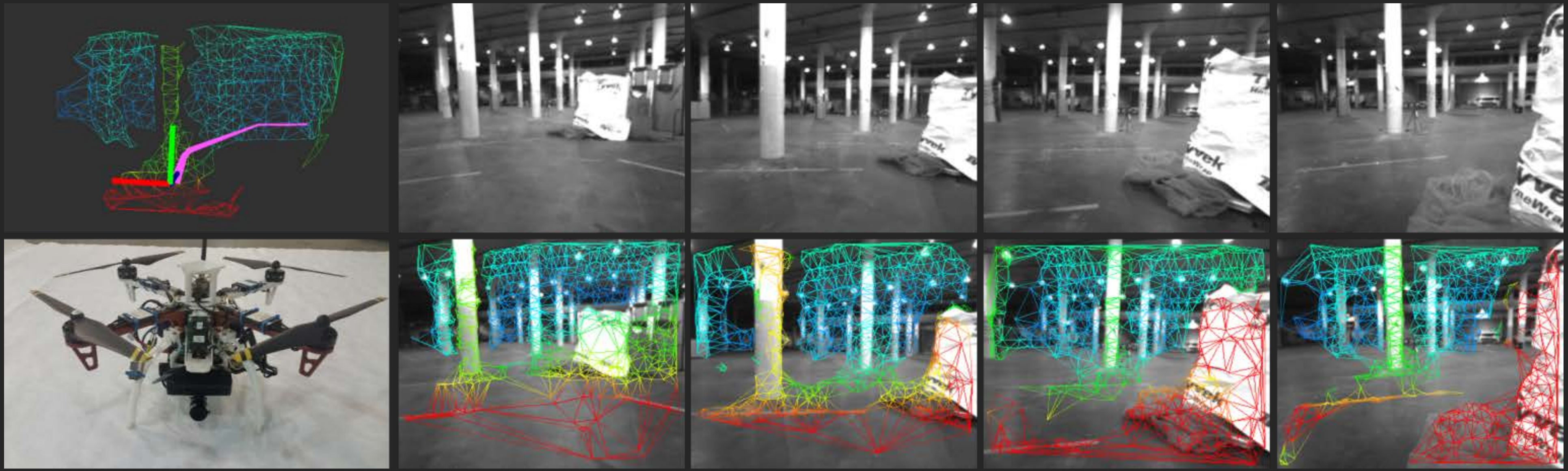
FLaME: Flight Results

Timing and Load on Autonomous MAV

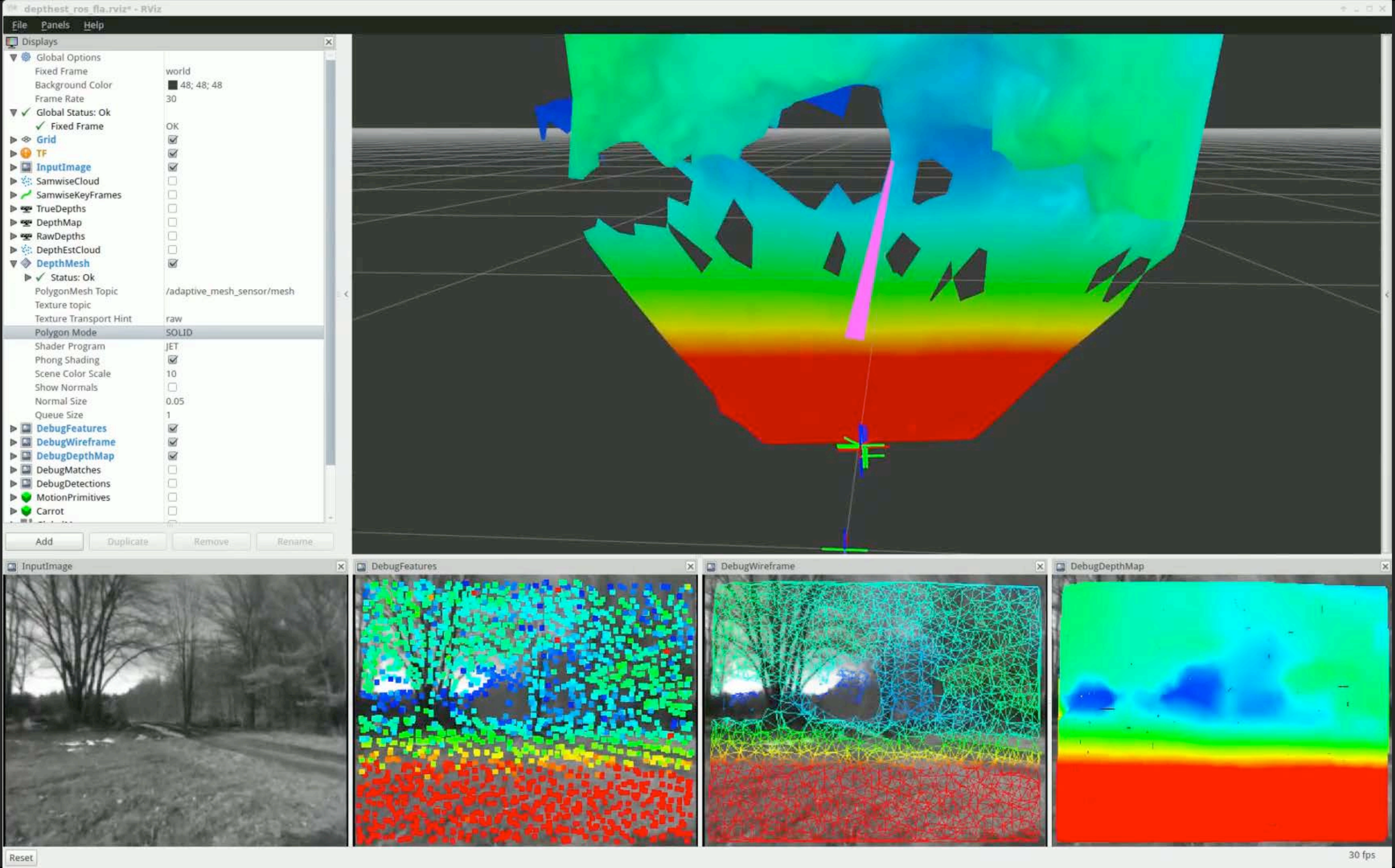
Metric	Indoor	Outdoor
Vehicle Speed [m/s]	2.5	3.5
Depthmaps	803	1046
Vertices / depthmap	1396	1620
Edges / depthmap	4170	4838
Density [%]	82	88
CPU Load [cores]	1.6	1.7
Runtime [ms]	9.4	11
Peak FPS [Hz]	106	91

Outdoor





Indoor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Frame Rate
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Global Status: Ok
Fixed Frame
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Grid
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InputImage
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SamwiseKeyFrames
TrueDepths
DepthMap
RawDepths
DepthEstCloud
DepthMesh
Status: Ok
PolygonMesh Topic
/adaptive_mesh_sensor/mesh
Texture topic
Texture Transport Hint
raw
Polygon Mode
SOLID
Shader Program
JET
Phong Shading
Scene Color Scale
10
Show Normals
Normal Size
0.05
Queue Size
1
DebugFeatures
DebugWireframe
DebugDepthMap
DebugMatches
DebugDetections
MotionPrimitives
Carrot
Add
Duplicate
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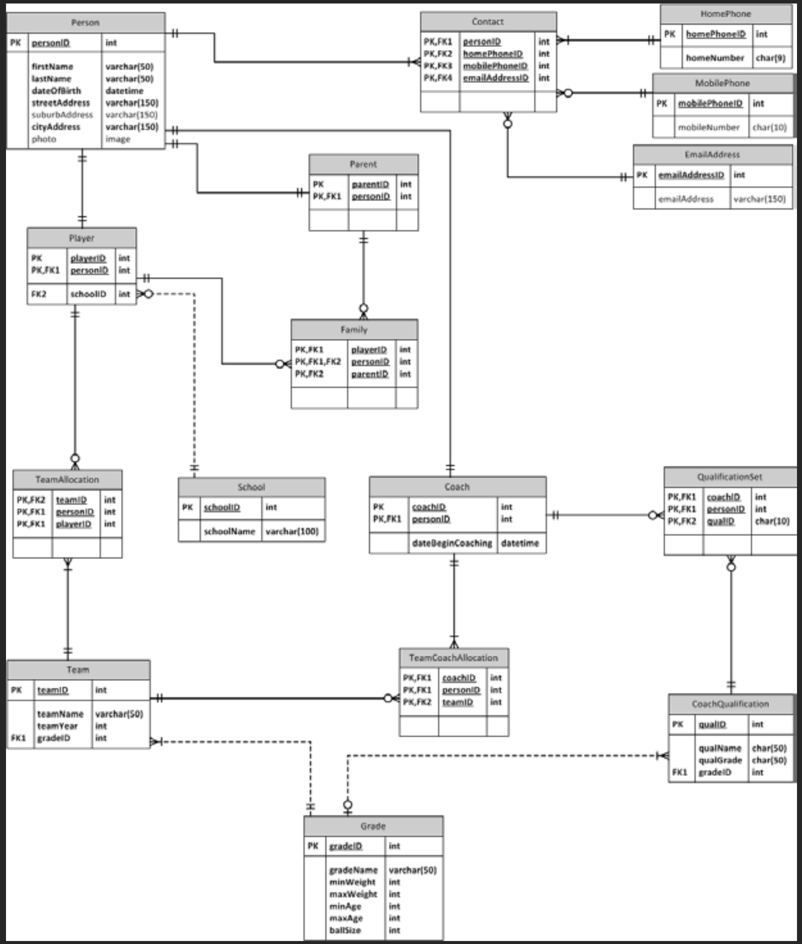
Rename
InputImage
DebugFeatures
DebugWireframe
DebugDepthMap
Reset
30 fps

Representing Knowledge in Robotics



In Defense of Probability

Peter Cheeseman
SRI International
333 Ravenswood Ave., Menlo Park, California 94025

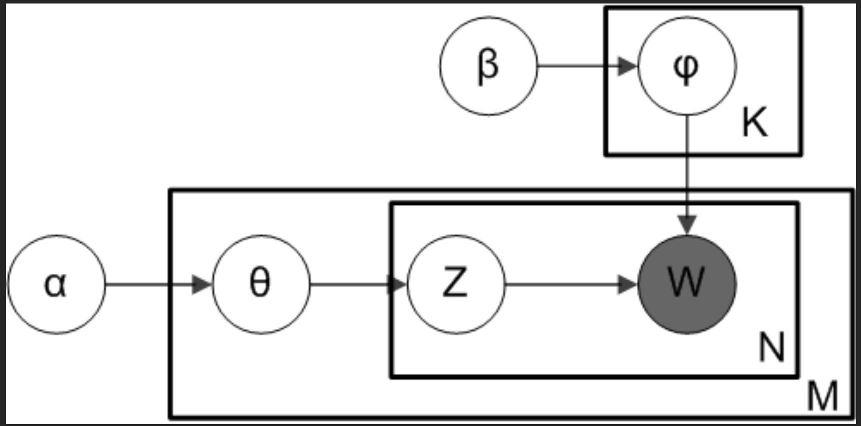
Abstract

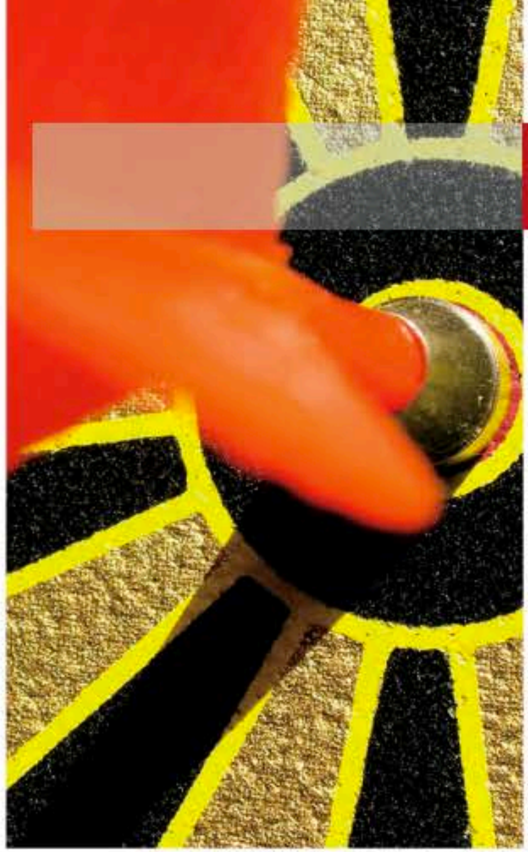
In this paper, it is argued that probability theory, when used correctly, is suffrcient for the task of reasoning under uncertainty. Since numerous authors have rejected probability as inadequate for various reasons, the bulk of the paper is aimed at refuting these claims and indicating the scources of error. In particular, the definition of probability as a measure of belief rather than a frequency ratio is advocated, since a frequency interpretation of probability dras-

ference is that in probabilistic inference all the relevant inference paths ("proofs") connecting the evidence to the hypothesis of interest must be examined and "combined", while in logic it is sufficient to establish a single path between the axioms and the theorem of interest. Also, the output is different, the former includes at least one numerical measure, the latter simply true or false.

Unfortunately, the logical style of reasoning is so prevalent in AI that many have attempted to force intrinsically probabilistic situations into a logical straight-jacket with

Representing Knowledge in Robotics





Contact Editor: **Brian Brannon,** bbrannon@computer.org

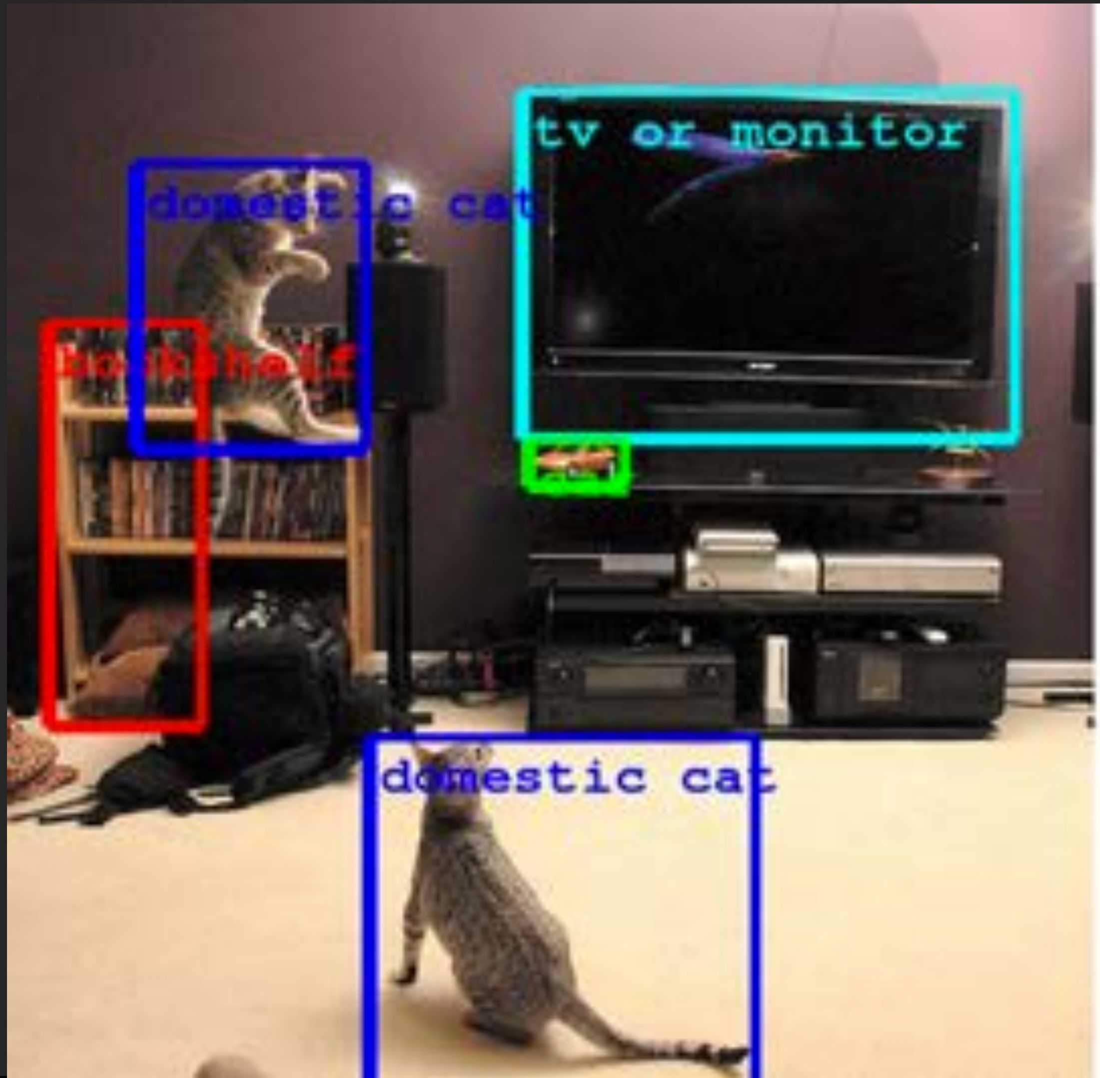
The Unreasonable Effectiveness of Data

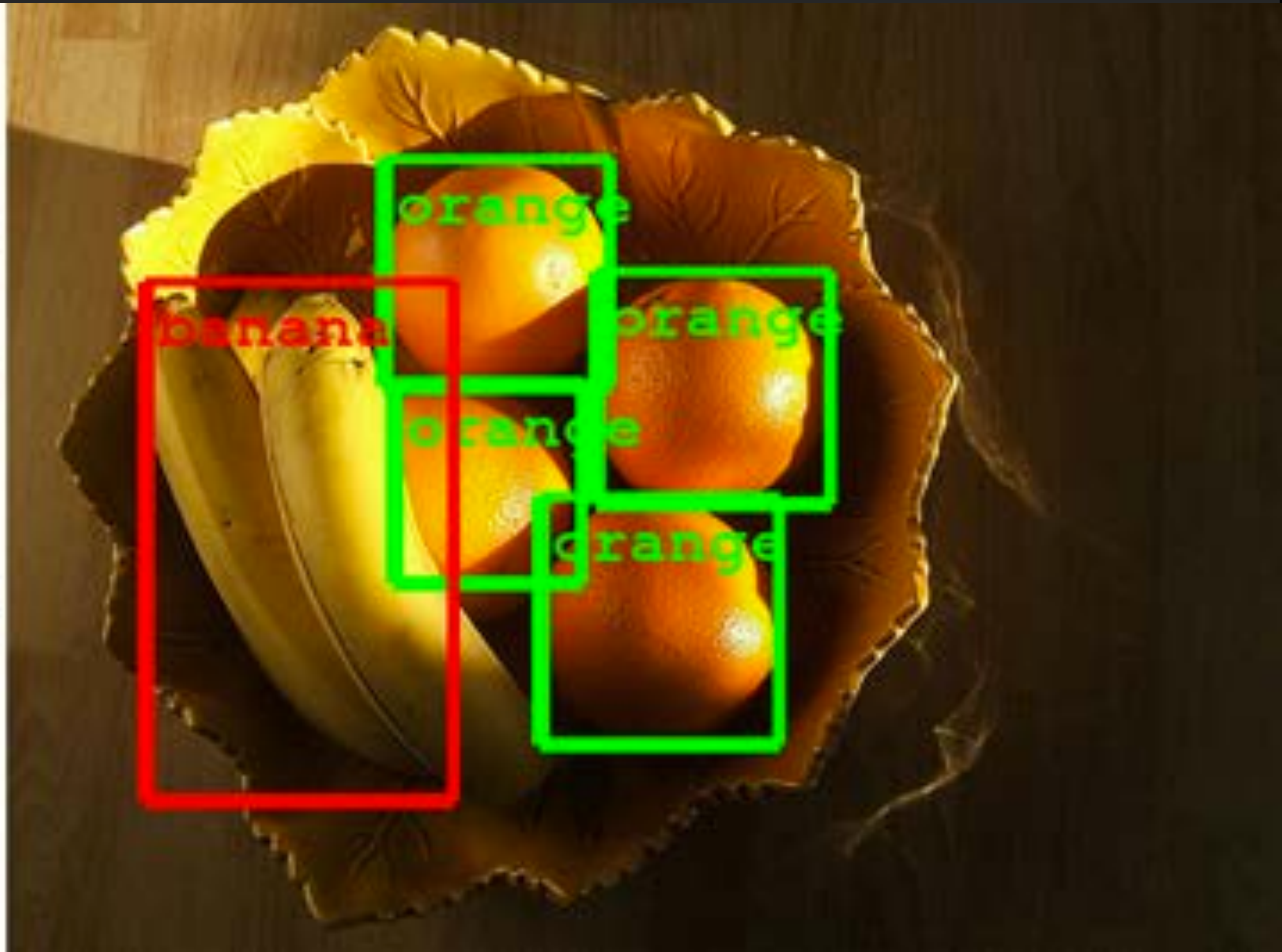
Alon Halevy, Peter Norvig, and Fernando Pereira, ***Google***

Eugene Wigner's article "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"[1] examines why so much of physics can be

behavior. So, this corpus could serve as the basis of a complete model for certain tasks—if only we knew how to extract the model from the data.

Object Recognition






MERC
MERCER ENGINEERING RESEARCH CENTER
Feb 27,2018 11:28:08AM


File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point
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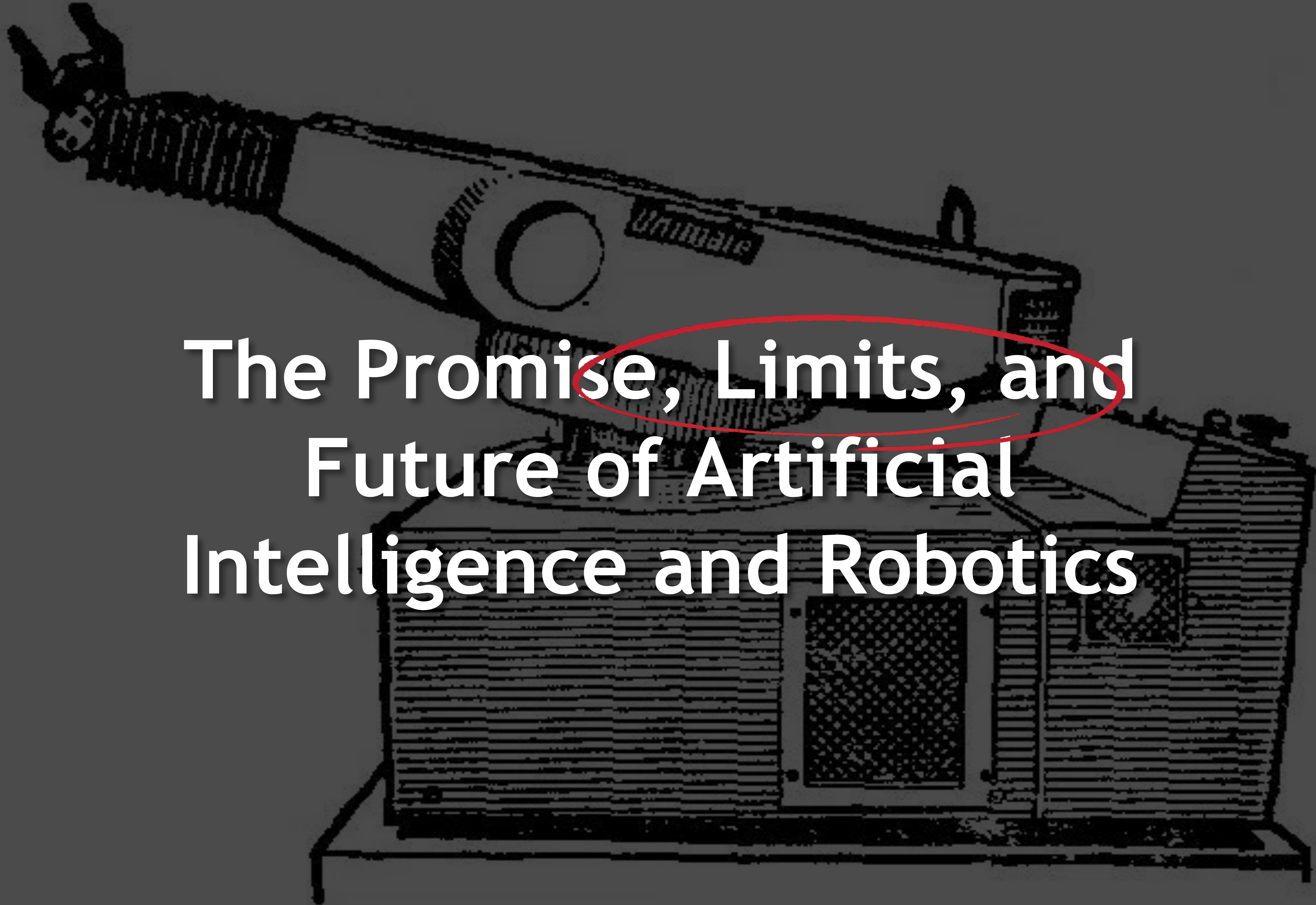
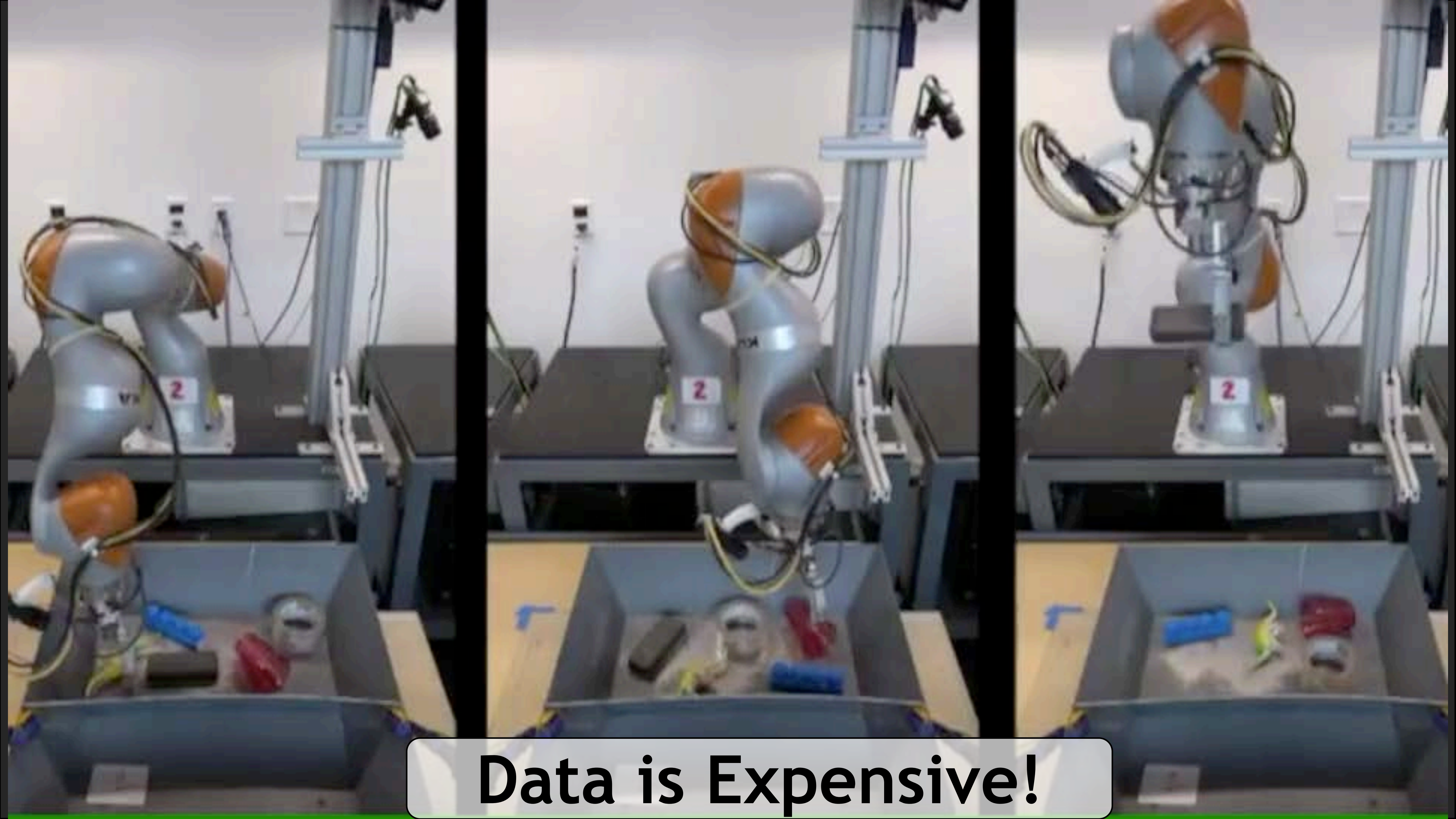
Reset
31 fps



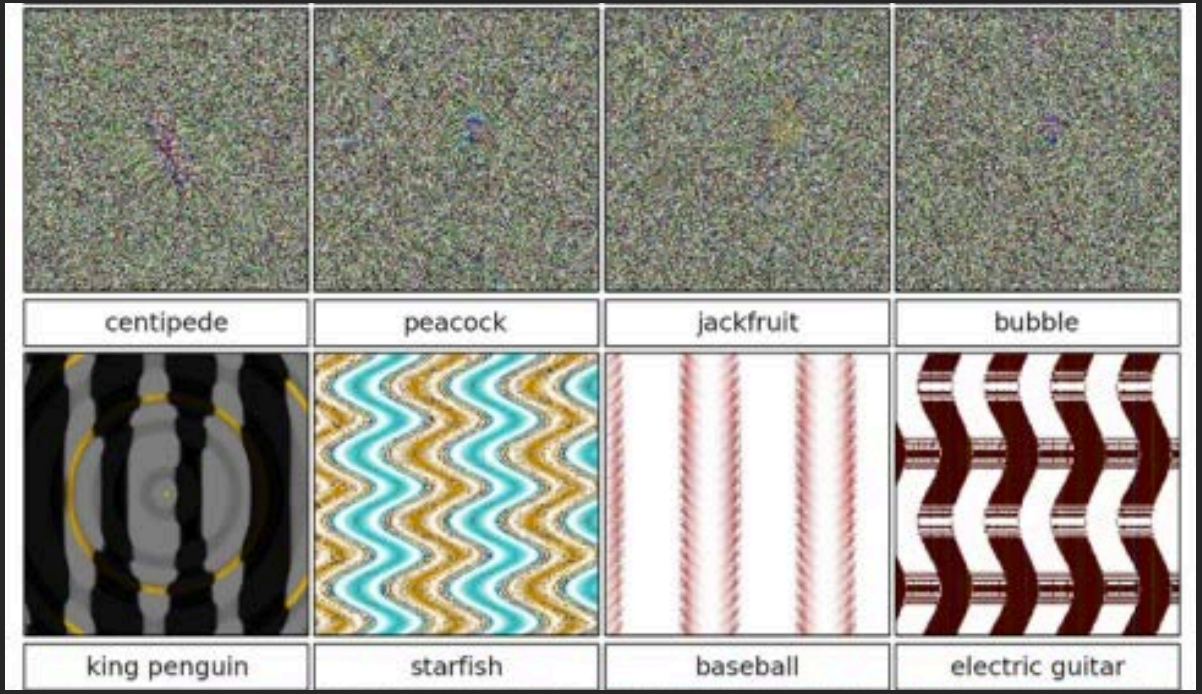
The Promise, Limits, and Future of Artificial Intelligence and Robotics





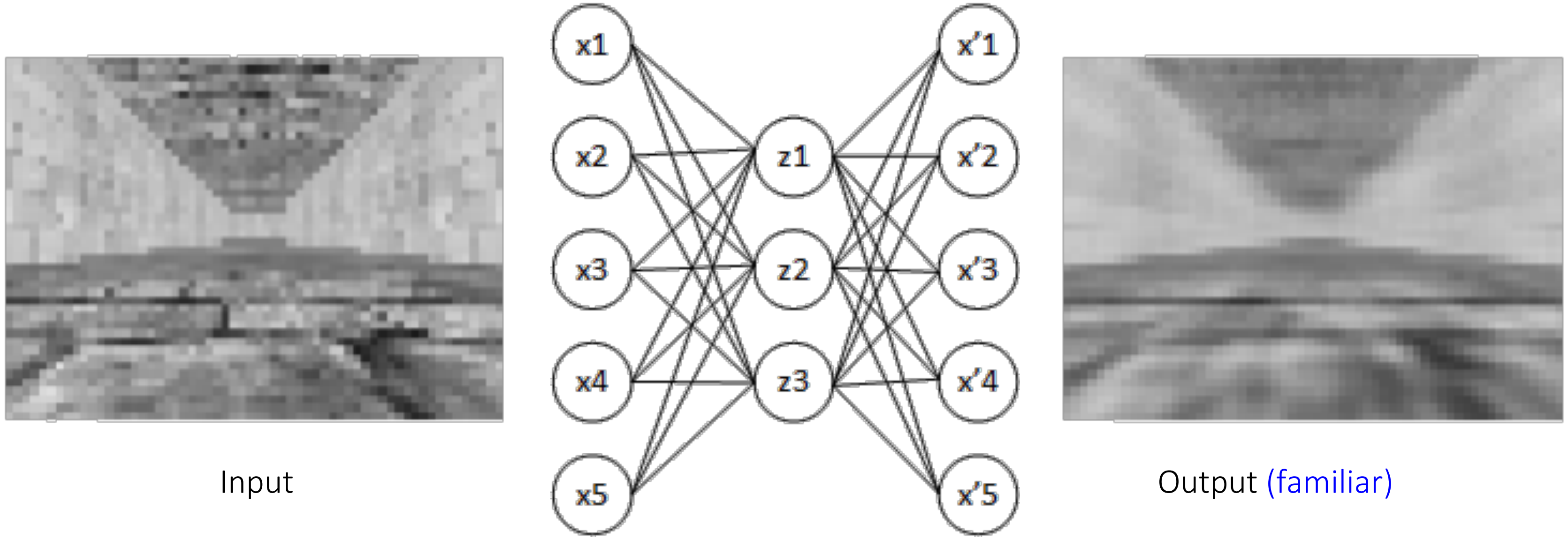
Data is Expensive!

Learning algorithms can be fooled, yet safety is critical



[Nguyen et al., 2015]

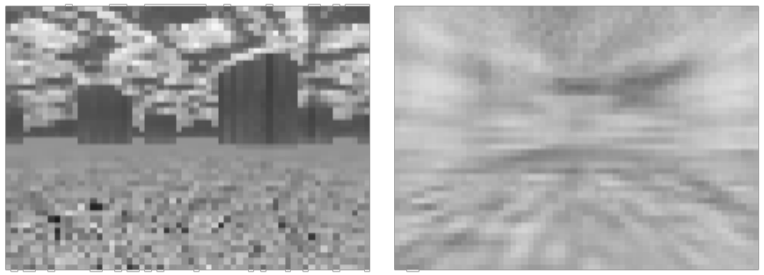
Measure how different the test environment is with an autoencoder



Input

Output (familiar)

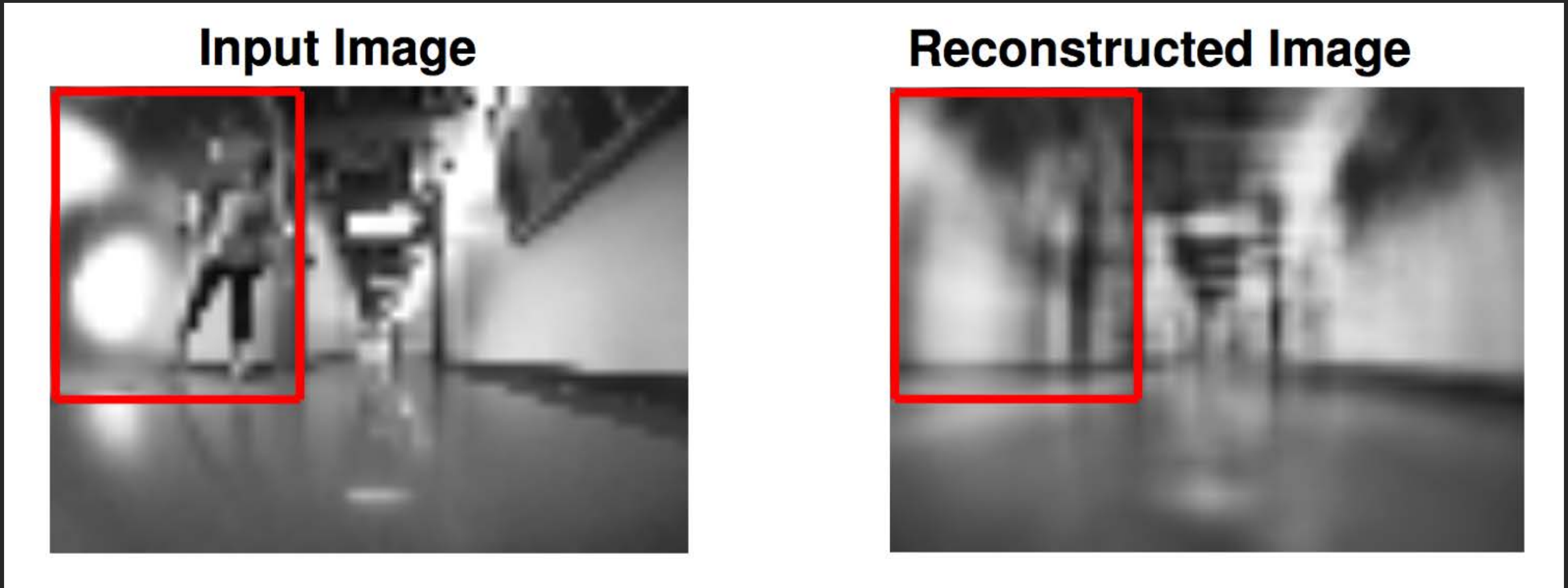
$$f_{\text{novel}}(i) \approx \begin{cases} 1 \text{ if } L_n(i) > T_{L_n} \\ 0 \text{ otherwise,} \end{cases}$$



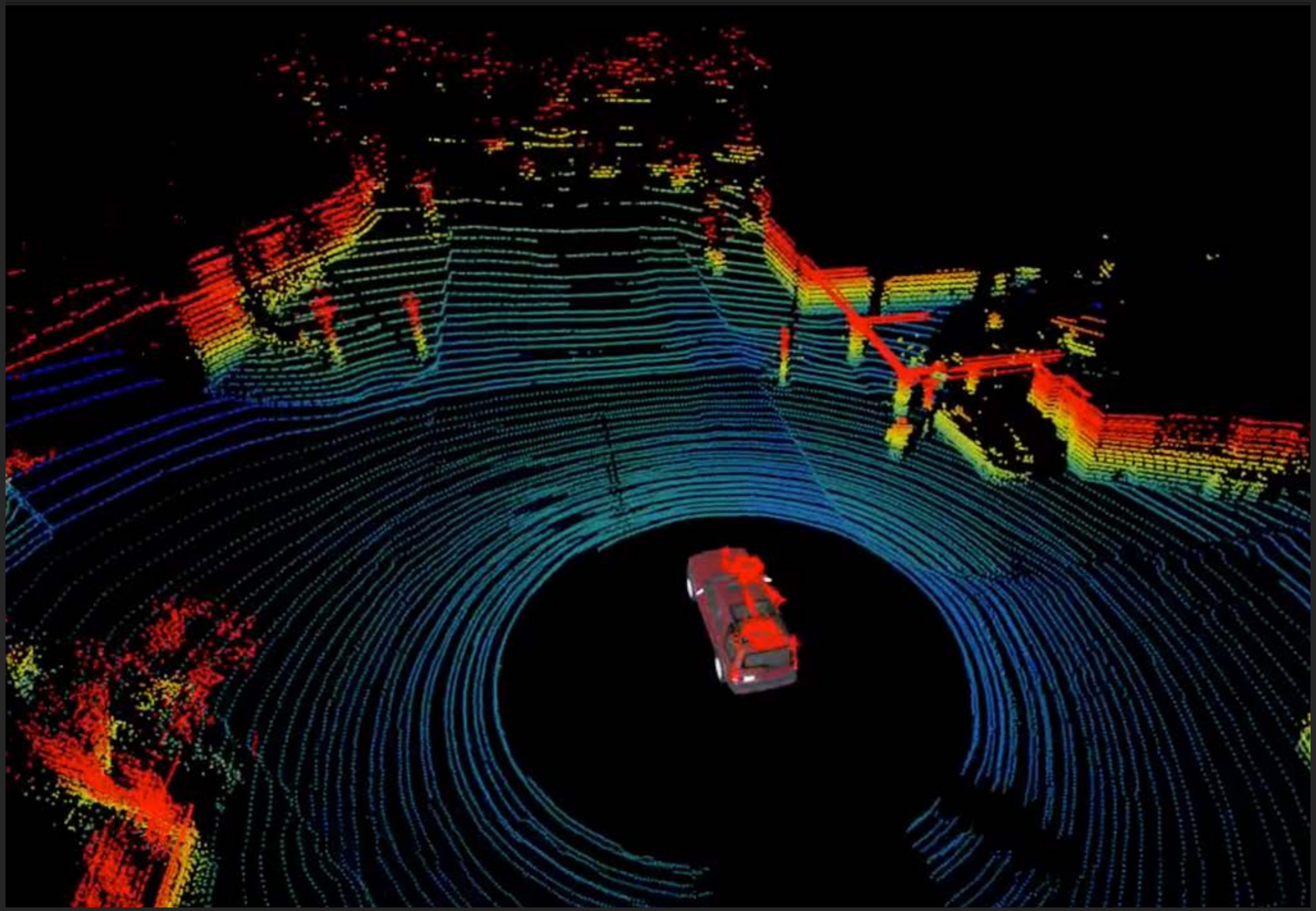
Testing Environment (novel)

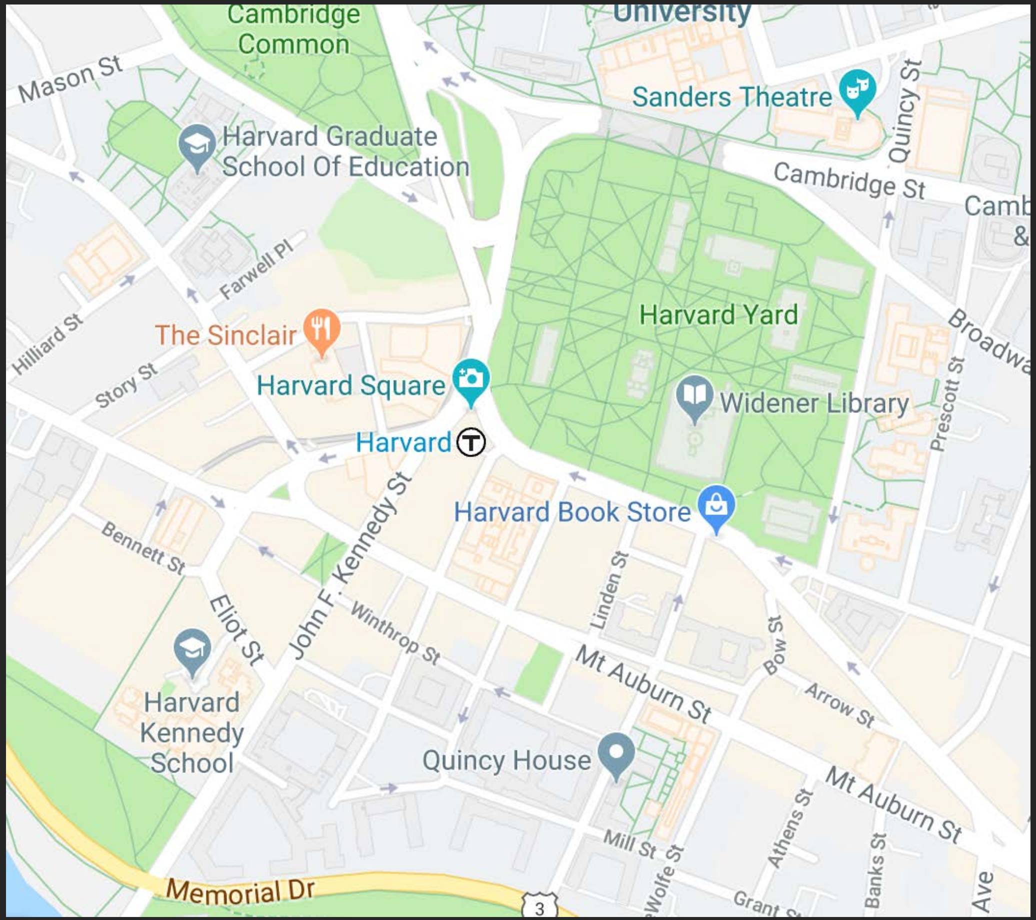
[Pomerleau 1993], [Japkowicz 1995]

What Makes an Image Novel?

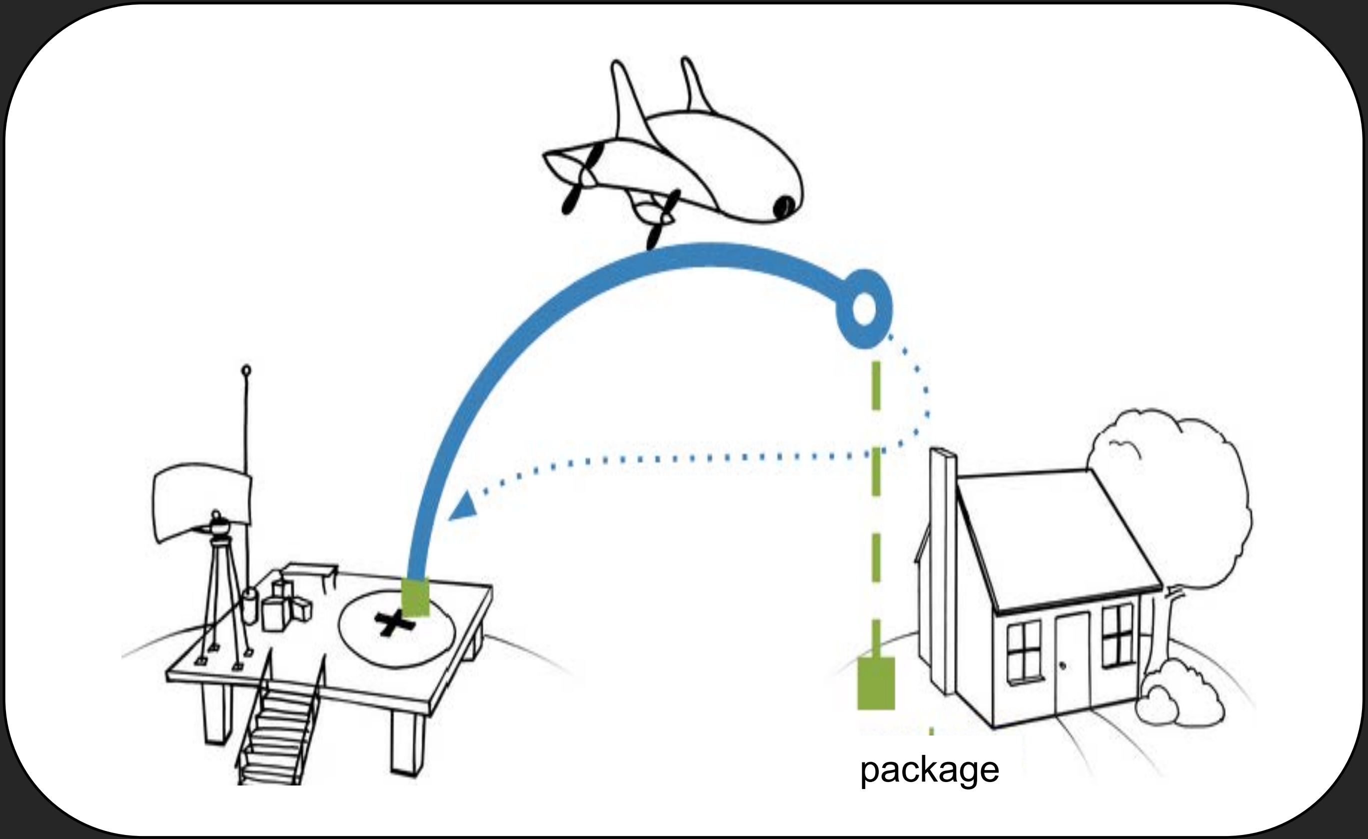


Human vs Machine Cognition

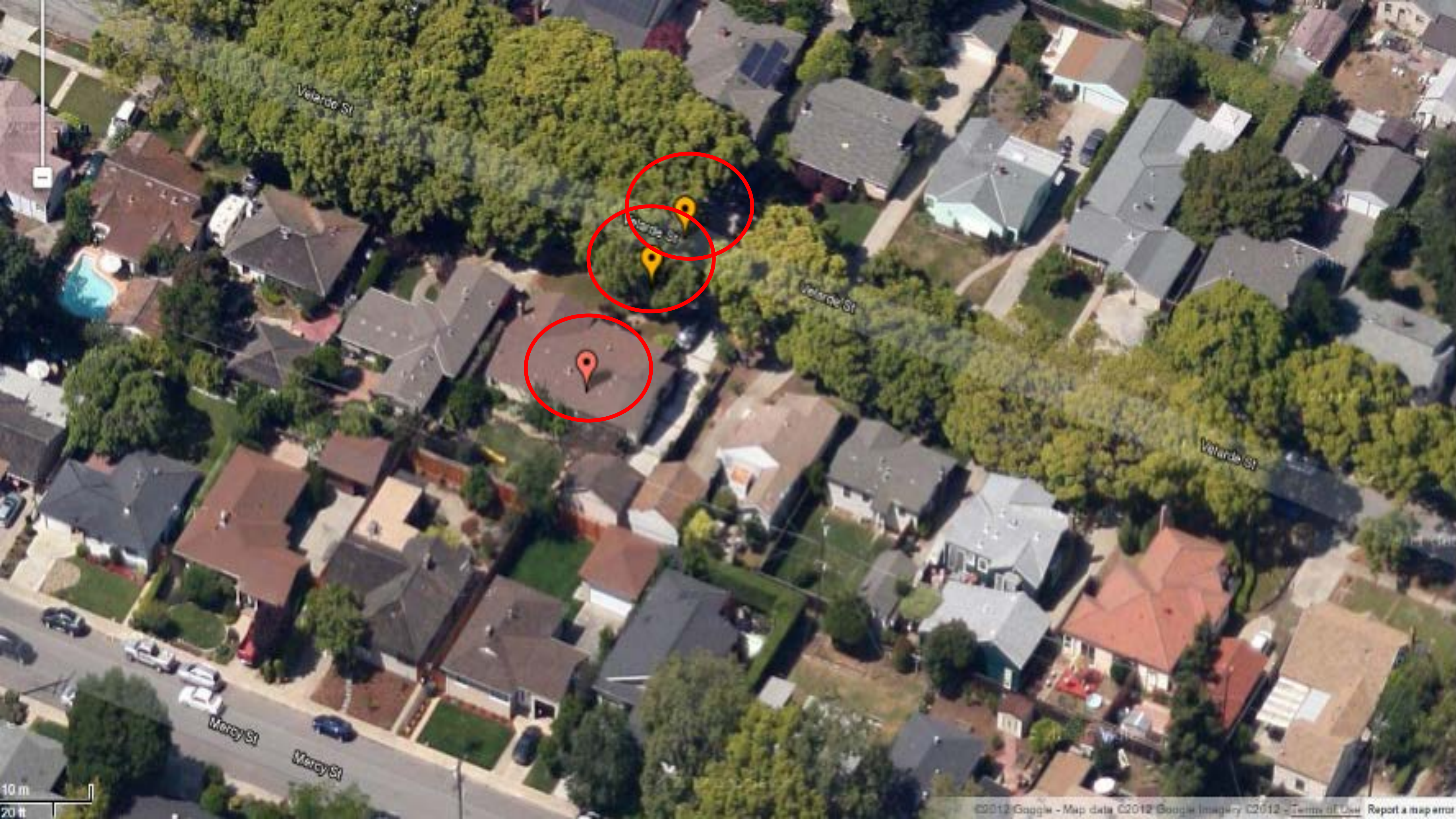




Robot and AI Do Not Have Understanding



Delivery sequence:
1. Take off
2. Fly to destination address
3. Enter hover
4. Lower winch
5. Release package
6. Raise winch
7. Fly home
8. Land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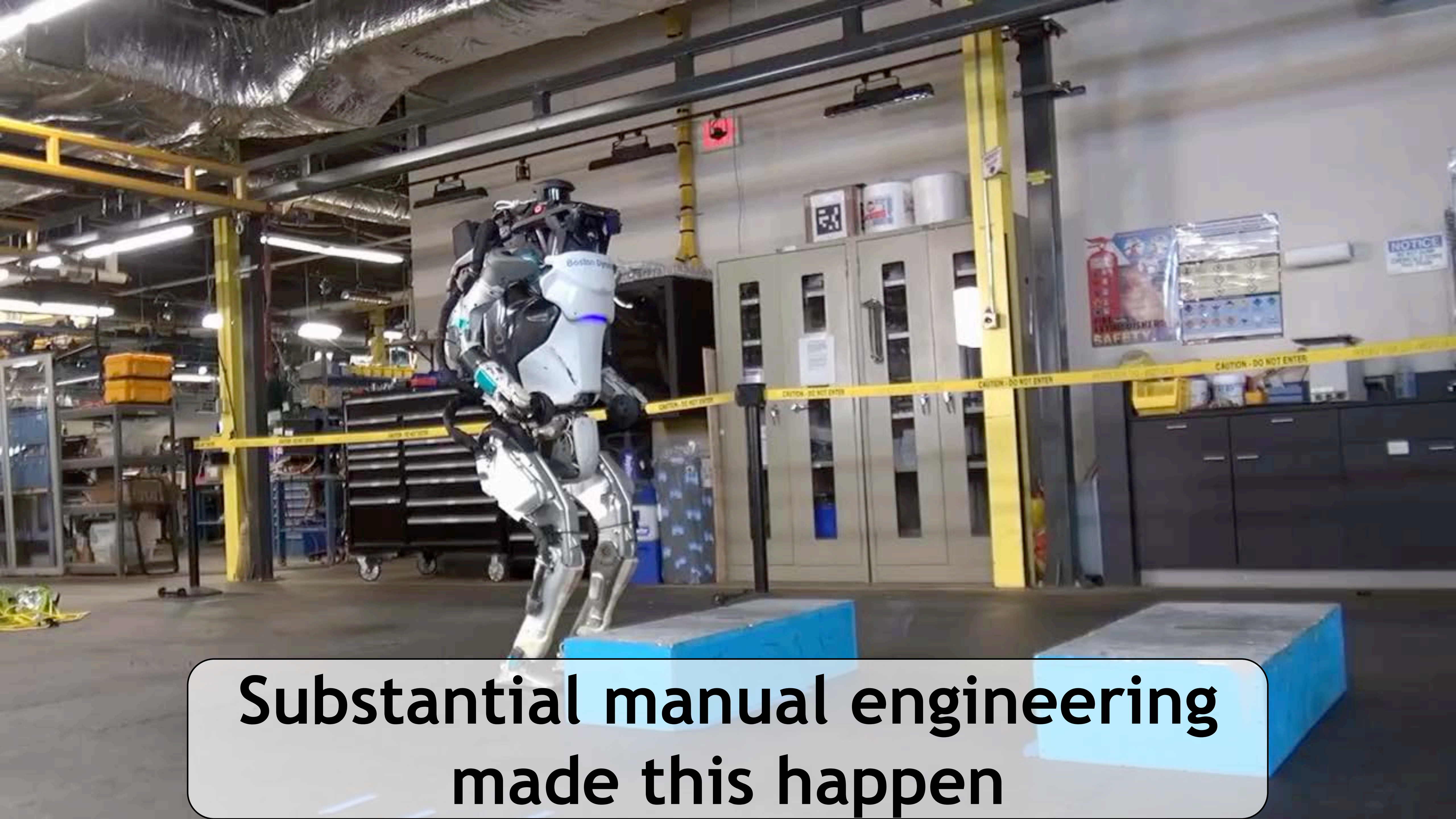
©2012 Google - Map data ©2012 Google Imagery ©2012 - Terms of Use
Report a map error



Substantial manual engineering made this happen

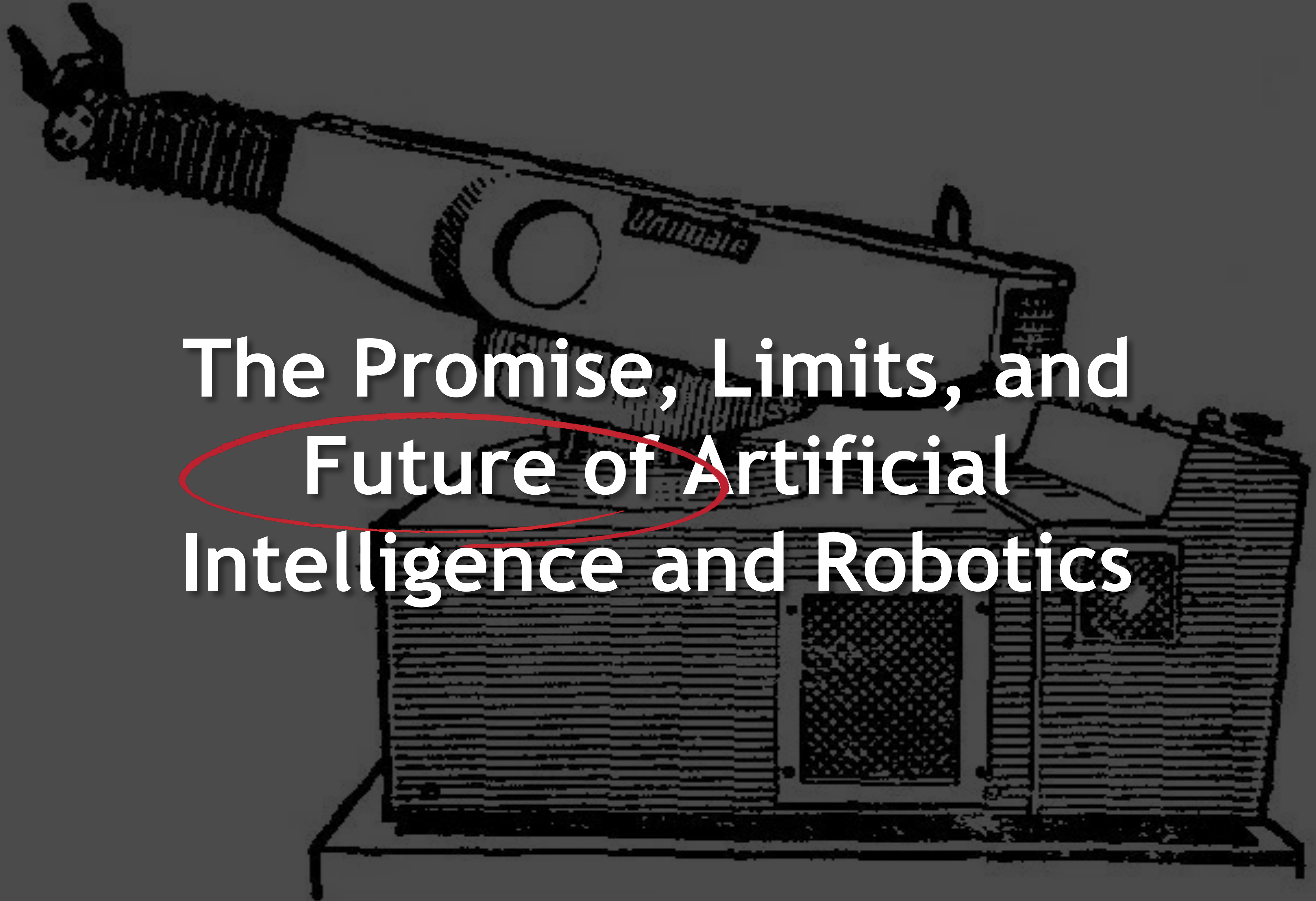
Operator Cost

Total Cost of Ownership

Vehicle cost: relatively low

3 big TCO problems:
- Supervisor costs
- Energy costs
- Back-end infrastructure


Construction has:
• Expensive Data
• High cost of failure
• Complex operational constraints
• High need for human oversight



The Promise, Limits, and Future of Artificial Intelligence and Robotics

MIT
Quest for
Intelligence

What is the MIT Quest for Intelligence?

- The Quest aims to advance two fundamental intelligence challenges:
  - Can we reverse engineer intelligence?
  - How can we deploy our current and expanding understanding of intelligence to the benefit of society?

- The goal is to make true progress in our understanding of intelligence, and use that knowledge to create a better world

MIT Quest for Intelligence

Who is involved in The Quest?

Architecture & Planning

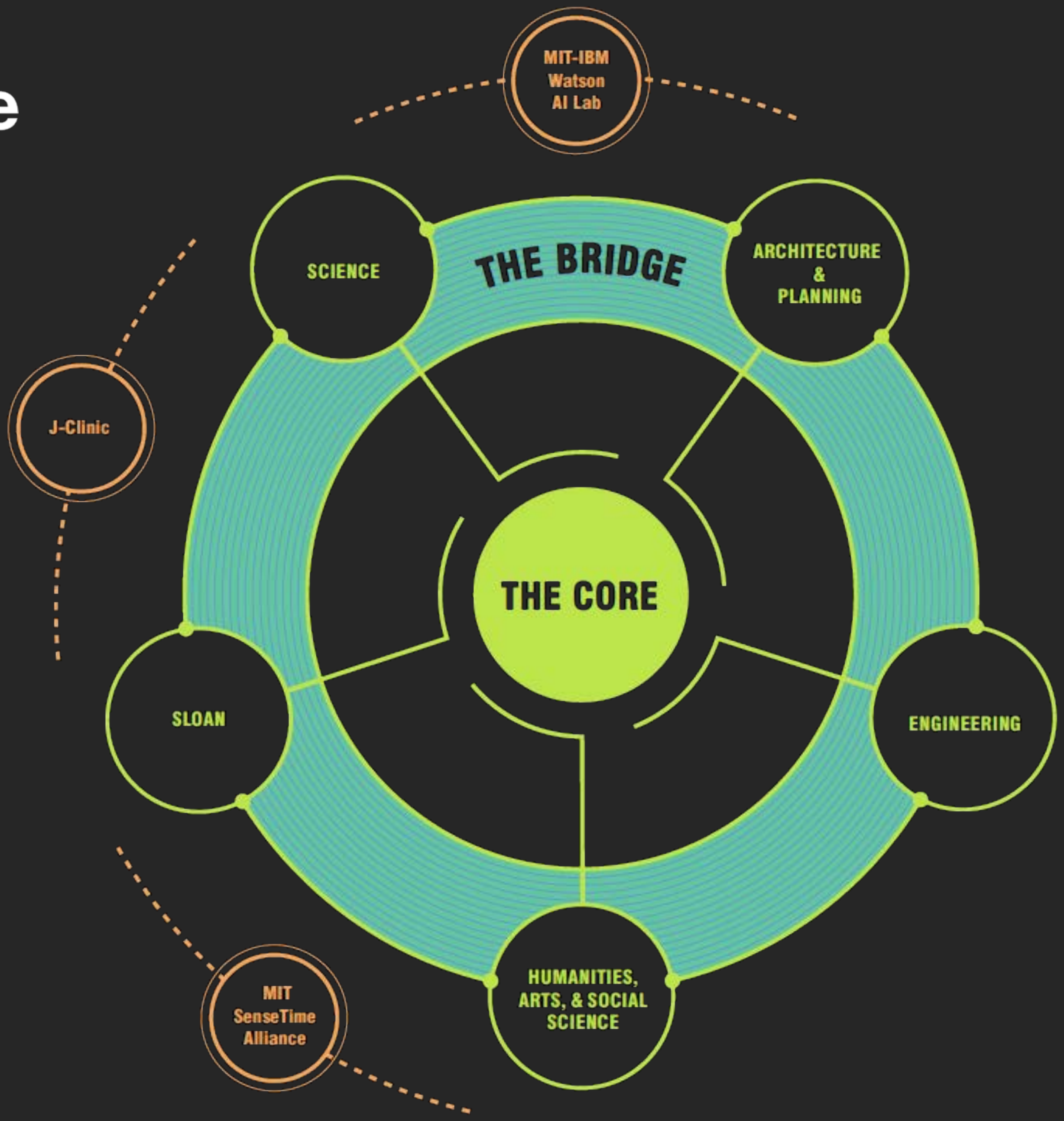
Humanities, Arts, & Social Sciences

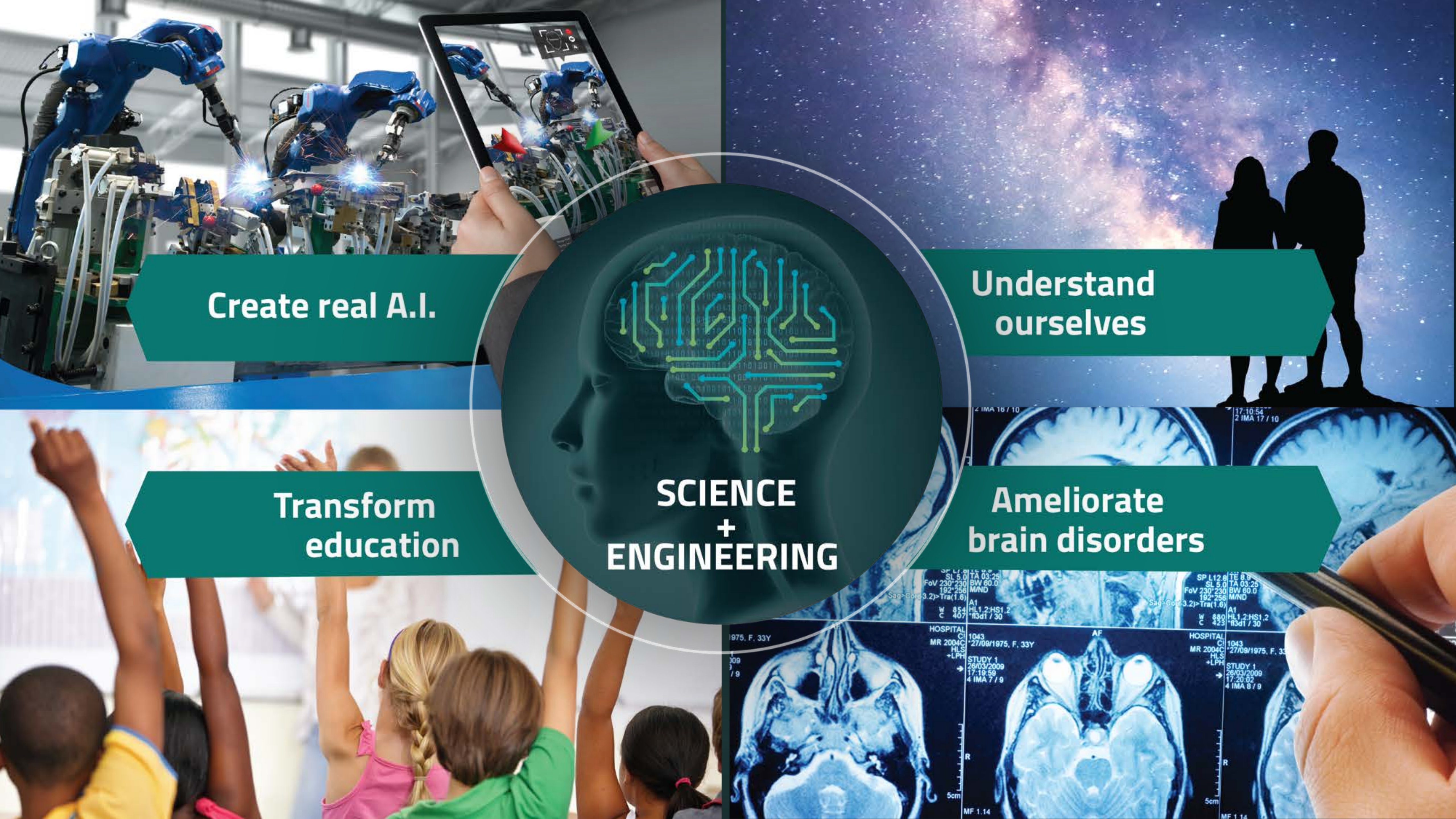
Engineering

Science

Sloan School of Management

MIT Quest for Intelligence




Create real A.I.
Understand ourselves
Transform education
Ameliorate brain disorders
SCIENCE
+
ENGINEERING

https://youtu.be/aS-QLB8ELyk?t=95

MIT Quest for Intelligence

Current Issues and Challenges

- Lack of accessibility
- Lack of resources
- Lack of expertise in tools
- Lack of reproducibility

Project Athena at MIT

Photo credit: MIT Infinite History

AI Platforms - Tools - Services

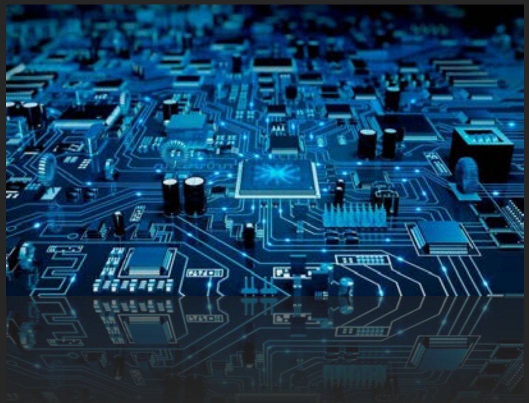
Data

Curation
Hosting
Archiving
- Benchmarks
- Research datasets

Software

Open repository
Standardized
Reproducible
Deployable
- AI workflows
- AI pipelines

Hardware



Seamless AI development
- Industry clouds
- Local clusters

New Hardware

People

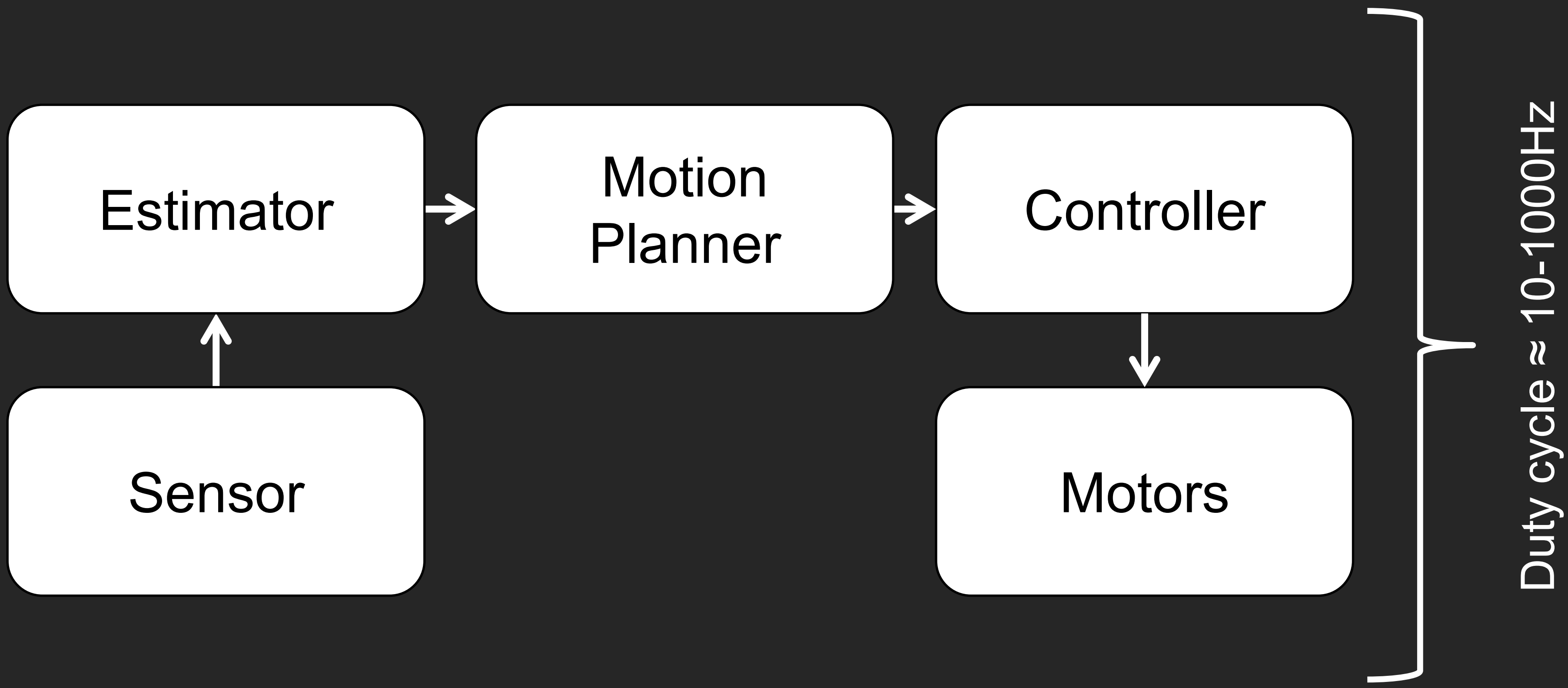
Consulting Team & Ethical Team
- Academic
- Industry
- Developers
- Users

What is next?

The next generation of AI theories and systems that are safe around people, learn by themselves and understand how the world works.

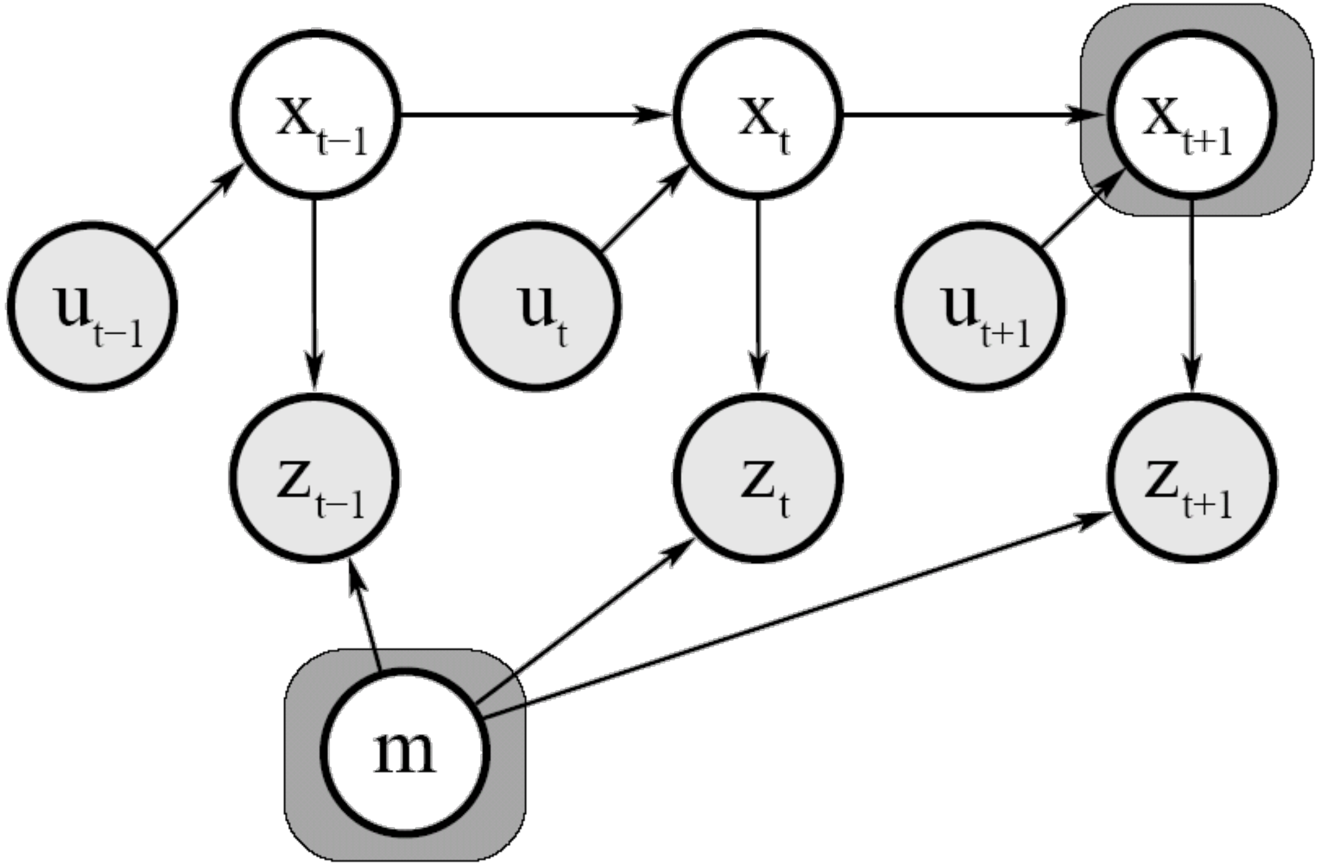
AI In the Physical World

- Where am I and what is around me?
- What should I do?
- How to learn from experience?



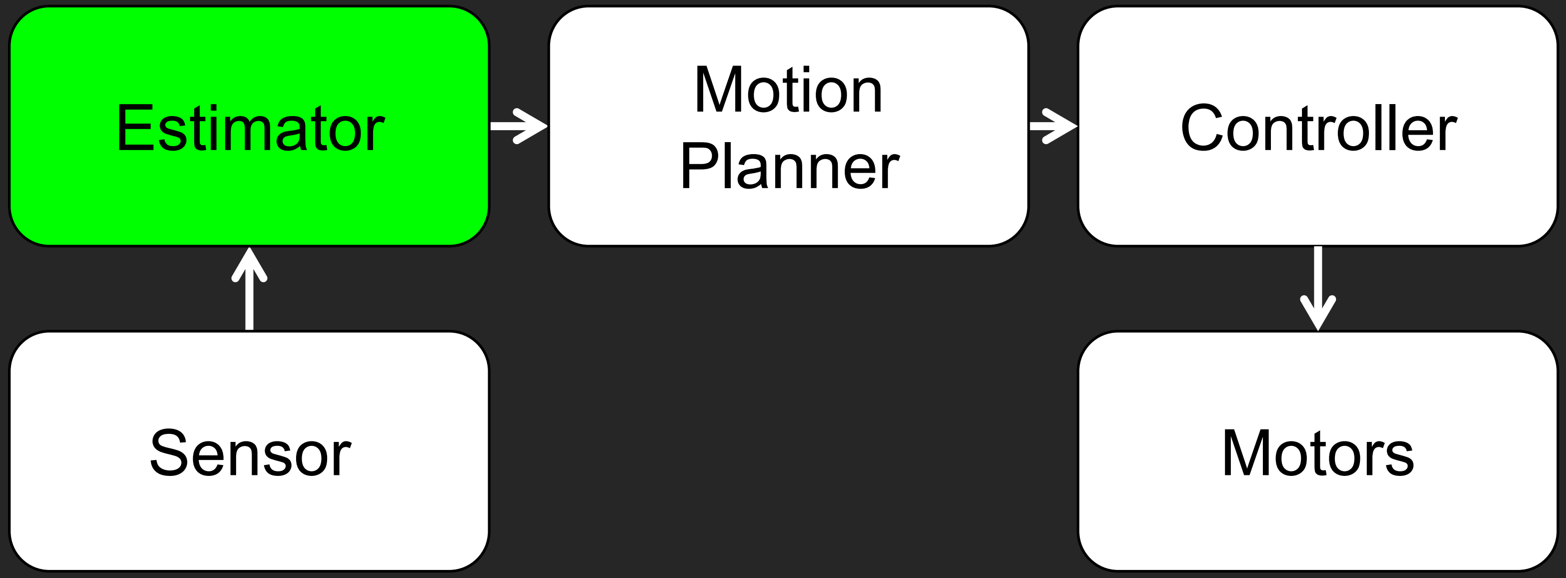
Statistical Models

$$p(x_t, m \mid z_{1:t}, u_{1:t})$$



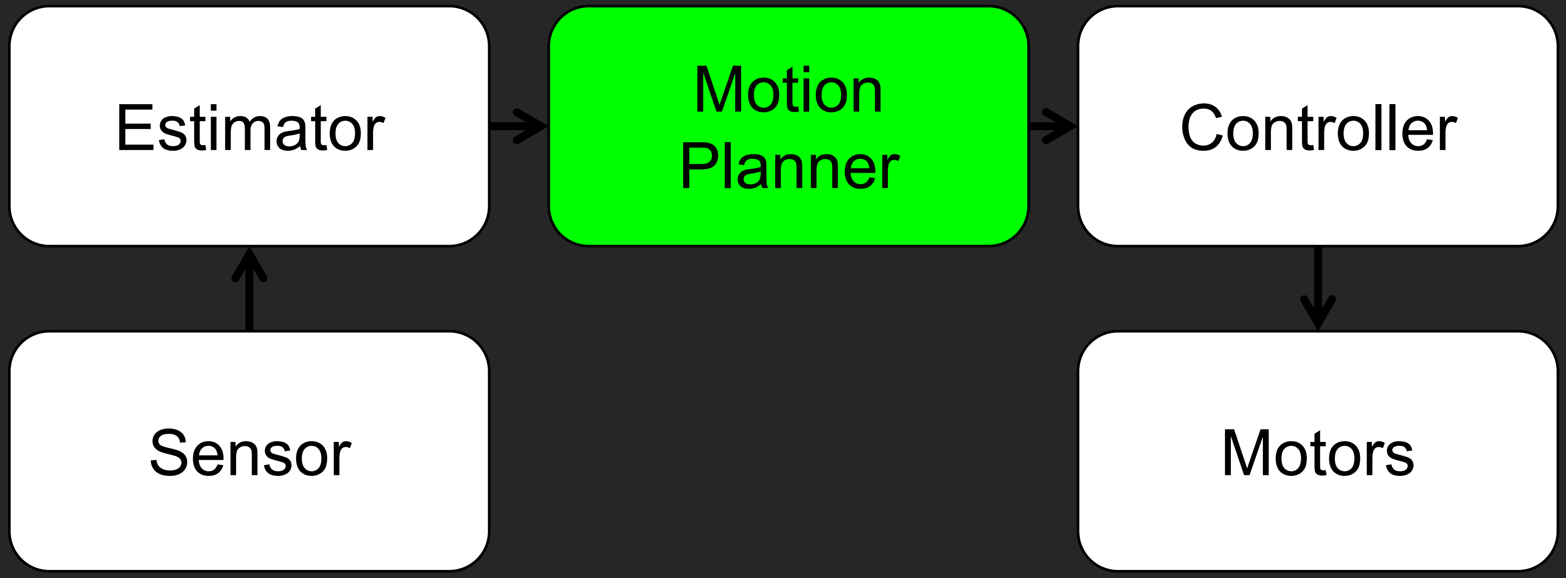
AI In the Physical World

- **Where am I and what is around me?**
- What should I do?
- How to learn from experience?



Autonomy for Robotics

- Where am I and what is around me?
- **What should I do?**
- How to learn from experience?



A common assumption: models are known

- YCB Dataset : models of household objects fabricated from specified model files