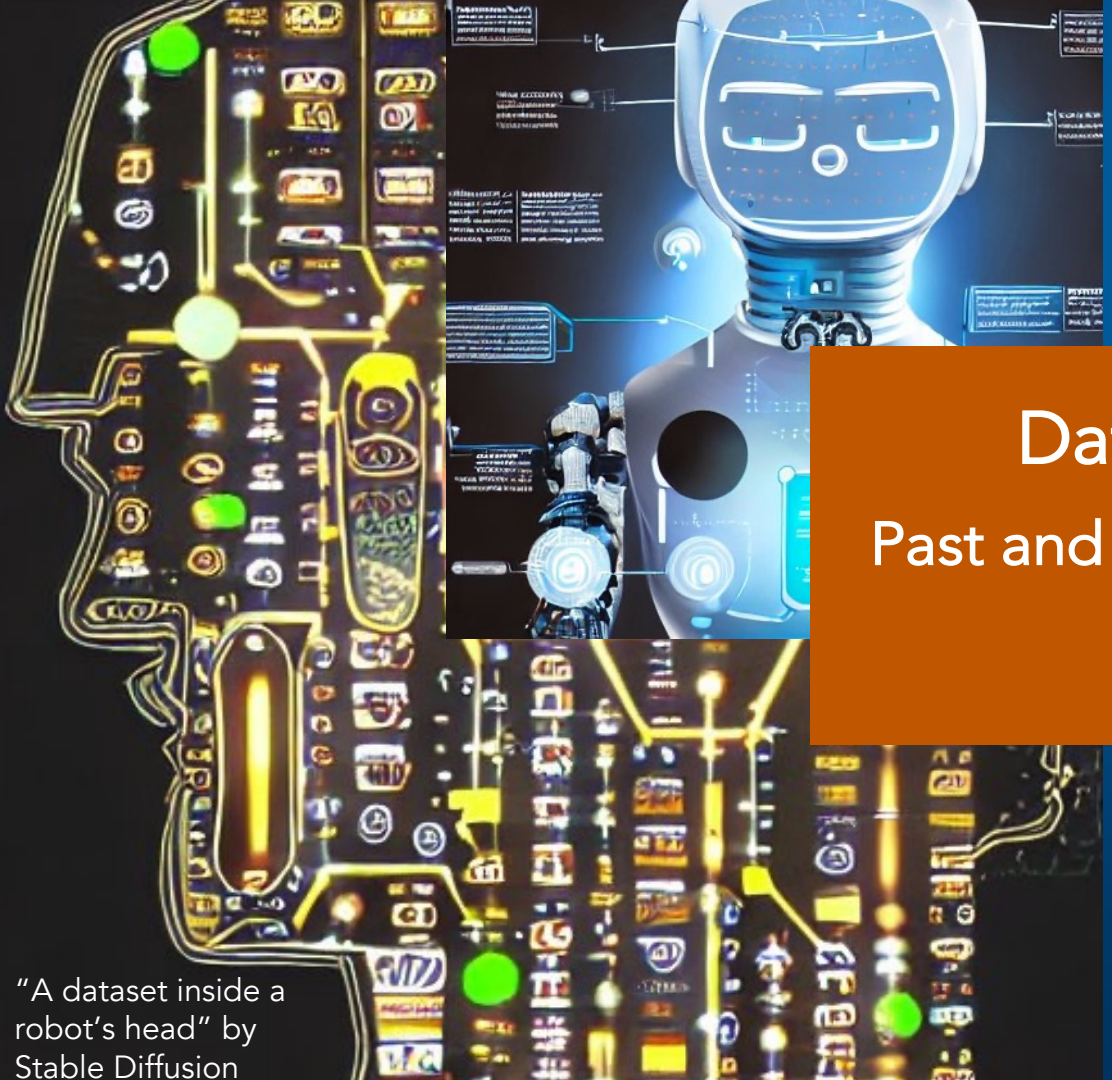


Datasets in Robotics:

Past and Future. An open discussion

Dr. Roberto Martín-Martín

RobIn
ROBOTIC INTERACTIVE INTELLIGENCE LAB

TEXAS Robotics

THE UNIVERSITY OF TEXAS AT AUSTIN

"A dataset inside a robot's head" by Stable Diffusion

Meta: Why this Presentation?

- Collaboration in the "Good Systems" team between Roboticists and experts in Information Science and Data Management

- For Information Science and Data Management:
  Understanding the use of datasets in Robotics (and other fields) will help creating better information / dataset protocol

- For Robotics:
  Explicit discussion and introspective understanding of the reasons and the goals for dataset generation

What is a Dataset?

And some other definitions

Data are observations or measurements (unprocessed or processed) represented as text, numbers, or multimedia.

A **dataset** is a structured collection of data generally associated with a unique body of work.

A **database** is an organized collection of data stored as multiple datasets. Those datasets are generally stored and accessed electronically from a computer system that allows the data to be easily accessed, manipulated, and updated.

What is a Dataset?

"A Dataset if an opportunity for the research community to set a North Star"

Uses of Datasets in AI

Three main purposes

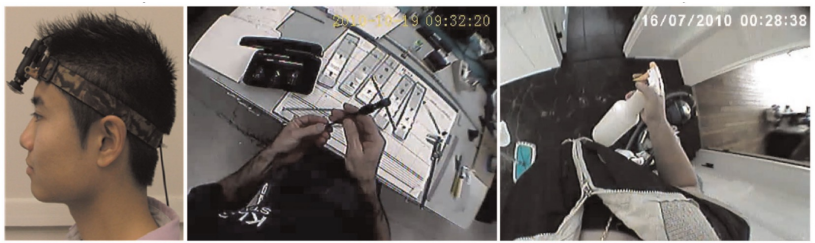
Record an event so that it can be analyzed later → extract regularities, understand events, gain knowledge

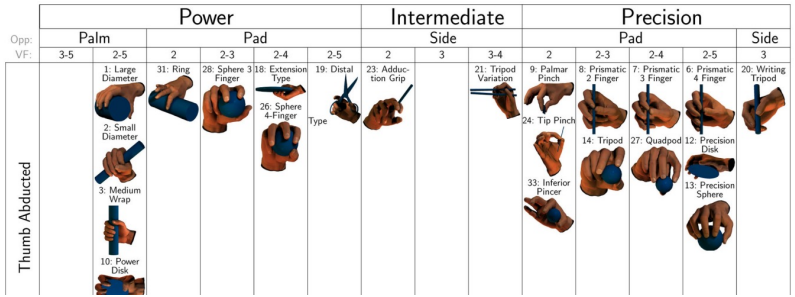
Serve as shared experimental evaluation for solutions to the same problem → Fair comparison

[RECENT!] Train solutions for a problem using data driven methods

Gaining Knowledge from a Dataset

The Yale human grasping dataset





- Dataset of humans performing common tasks
- Helps to create a comprehensive taxonomy of possible grasp types
- The taxonomy is used to analyze frequency and types of grasps in activities

Nr.	Name	Type	Opp. Type	Th. Pos	VF	Lit. Ref.	Prev. [54]	Mass [g] [57]	Size [cm] [57]	Rigidity [57]	Force [58]
1	Large Diameter	Pow.	Palm	Abd.	VF 2: 2-5 VF 3:	15	F: 1.7 % D: 1.5 %	0 500 1,000	0 5 10 15	ri sq	wt
2	Small Diameter	Pow.	Palm	Abd.	VF 2: 2-5 VF 3:	8	F: 0.7 % D: 0.3 %	0 500 1,000	0 5 10 15	ri sq	wt in
3	Medium Wrap	Pow.	Palm	Abd.	VF 2: 2-5 VF 3:	11	F: 12.7 % D: 23.8 %	0 500 1,000	0 5 10 15	ri sq	wt in
4	Adducted Thumb	Pow.	Palm	Add.	VF 2: 2-5 VF 3: 1	2	F: 1.0 % D: 0.9 %	0 500 1,000	0 5 10 15	ri	wt in
5	Light Tool	Pow.	Palm	Add.	VF 2: 2-5 VF 3: (1)	2	F: 4.8 % D: 3.6 %	0 500 1,000	0 5 10 15	ri	wt in
6	Prismatic 4 Finger	Pre.	Pad	Abd.	VF 2: 2-5 VF 3:	6	F: 4.0 % D: 2.0 %	0 500 1,000	0 5 10 15	ri sq	wt
7	Prismatic 3 Finger	Pre.	Pad	Abd.	VF 2: 2-4 VF 3:	4	F: 4.2 % D: 3.5 %	0 500 1,000	0 5 10 15	ri	wt
8	Prismatic 2 Finger	Pre.	Pad	Abd.	VF 2: 2-3 VF 3:	3	F: 6.4 % D: 4.3 %	0 500 1,000	0 5 10 15	ri	wt
9	Palmar Pinch	Pre.	Pad	Abd.	VF 2: 2 VF 3:	18	F: 3.9 % D: 2.3 %	0 500 1,000	0 5 10 15	ri fl	wt

[The Yale human grasping dataset: Grasp, object, and task data in household and machine shop environments, IJRR 2015, Ian M. Bullock, Thomas Feix and Aaron M. Dollar]

Evaluating in Fair Conditions using a Dataset

Setting a common goal for the community

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- Dataset of images annotated with category labels
- Organized in a hierarchical taxonomy
- Used to benchmark image recognition solutions

Participation in 2011

96 registrations

15 submissions

Top Entries

Xerox Research Centre Europe
Univ. Amsterdam & Univ. Trento
ISI Lab Univ. Tokyo
NII Japan

[Deng, Jia, Wei Dong, Richard Socher, Li-Jia Li, Kai Li, and Li Fei-Fei. "Imagenet: A large-scale hierarchical image database." In 2009 IEEE conference on computer vision and pattern recognition, pp. 248-255. Ieee, 2009.]

Training Machine Learning Based Solutions

A recent(-ish) trend

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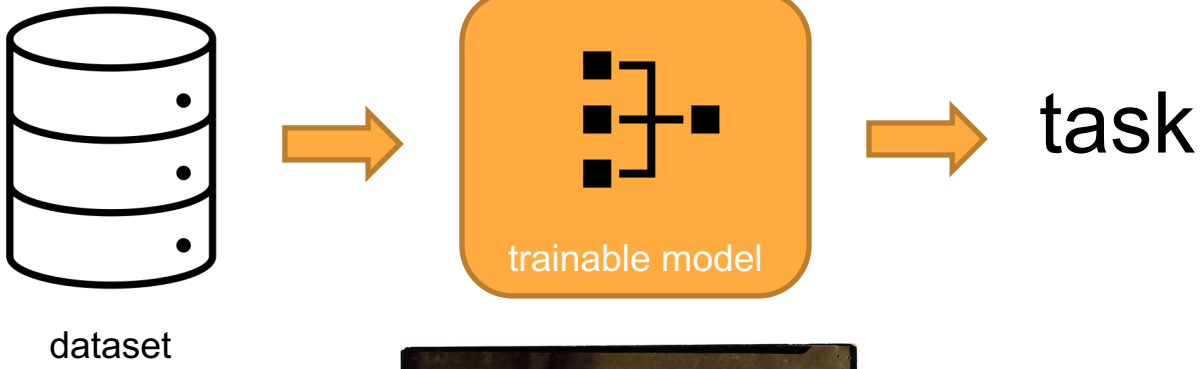
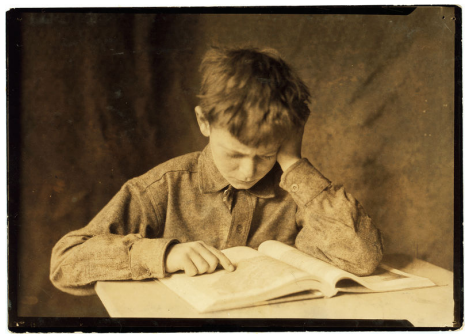


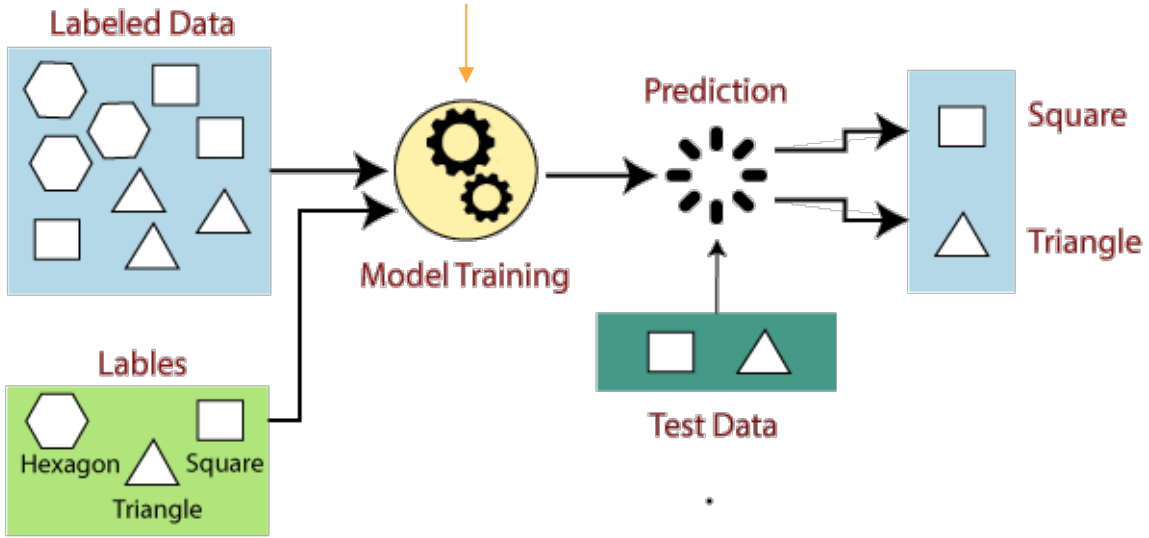


Background: Supervised Learning

How to consume datasets with machine learning

$$f(x) = label$$

$$(x, label)$$

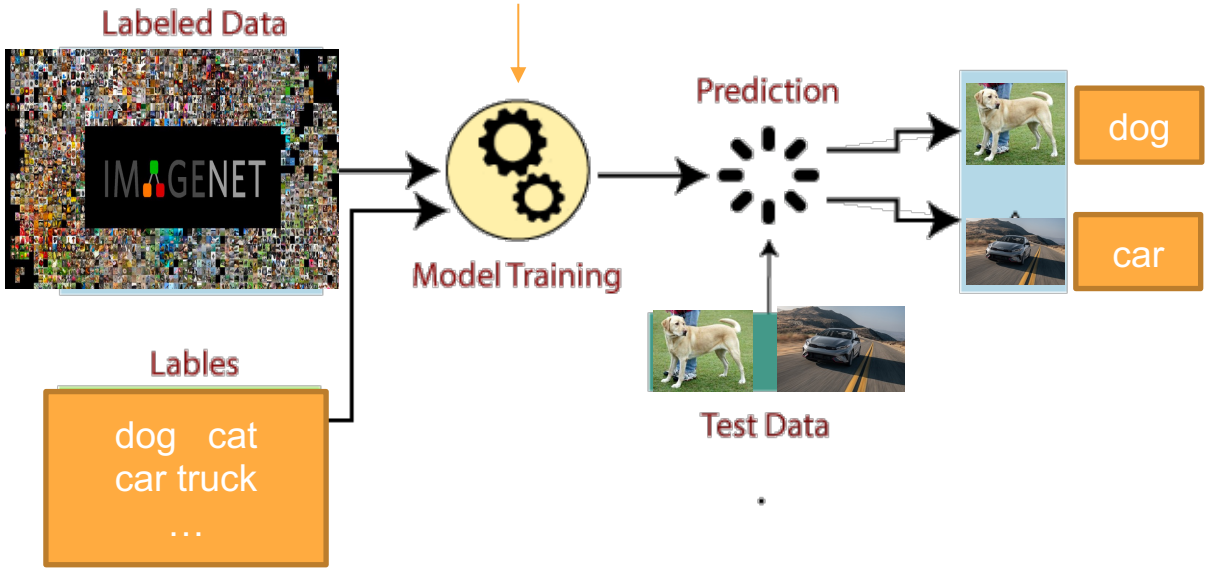


Supervised Learning + Datasets

Encode the information in the dataset into a model

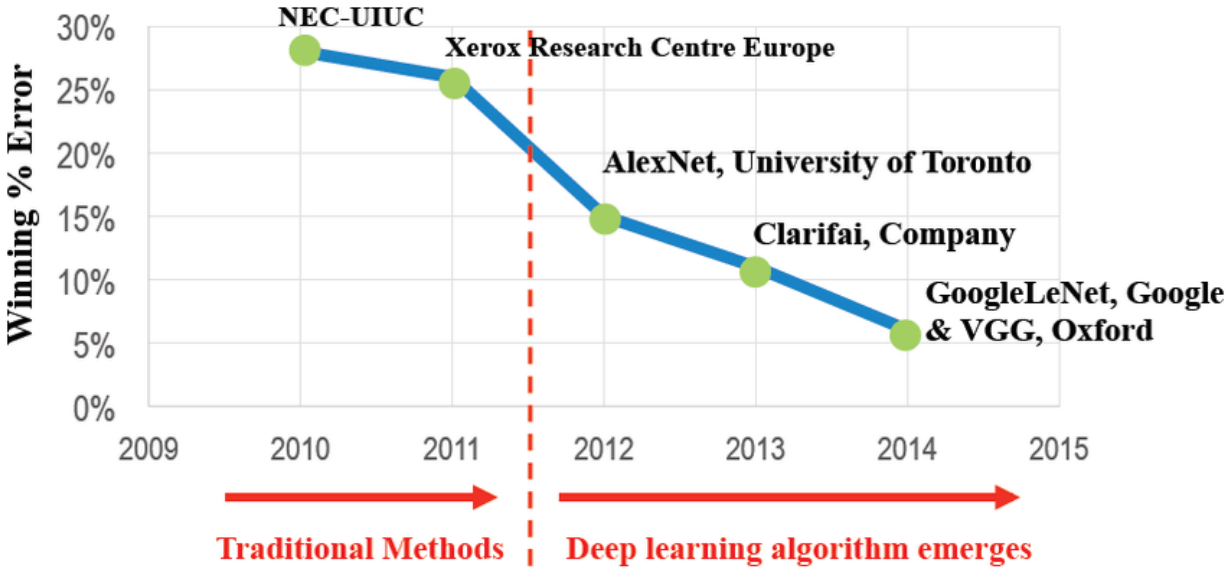
$$f(x) = label$$

$$(x, label)$$



The Dataset Revolution in Computer Vision

Data-driven methods win over classical (hardcoded) solutions



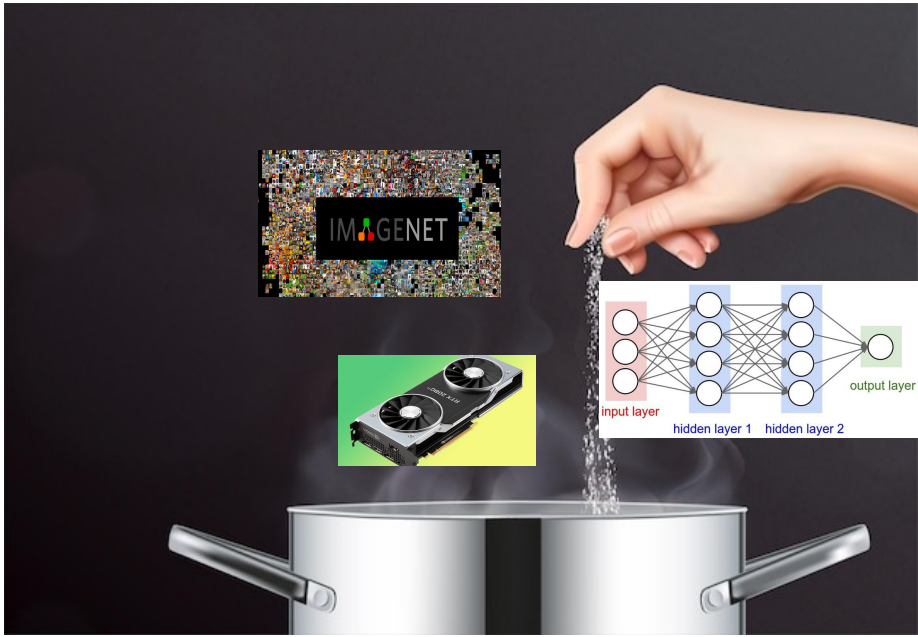
Results on ImageNet

"Image classification is solved"

The Ingredients of the Revolution

It is not (just) the algorithm; it is the data(set)!

- Large Dataset
- Model with enough capacity → Deep Neural Network
- Hardware to train the large model using the large dataset



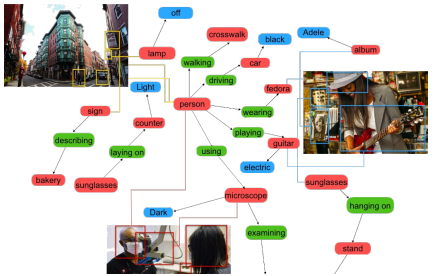
[Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "Imagenet classification with deep convolutional neural networks." Communications of the ACM 60, no. 6 (2017): 84-90.]

Image Datasets

The fuel for the AI revolution

- Image Classification
- Image Segmentation
- Scene Understanding
- Static
- Passive

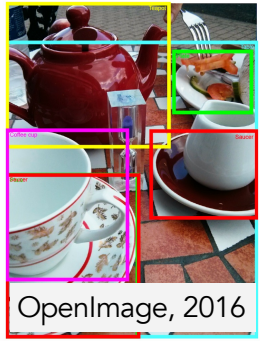
ImageNet, 2009 [Deng et al.]



VisualGenome, 2016 [Krishna et al.]

Pascal VOC, 2010 [Everingham et al.]

MS COCO, 2014 [Lin et al.]



OpenImage, 2016

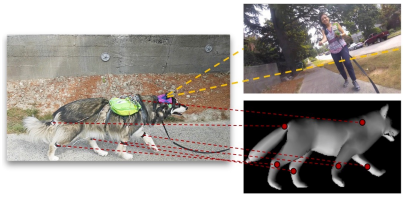
Extending the First Successes to other CV Tasks

Bringing in the temporal dimension

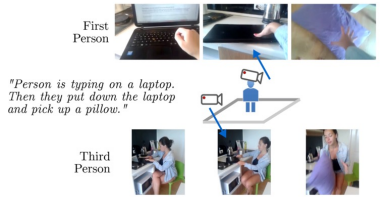
- Activity Recognition
- **Motion Understanding**
- **Human-Object Interaction**
- **Dynamic**
- **Passive**

Something-Something, 2017 [Goyal et al.]

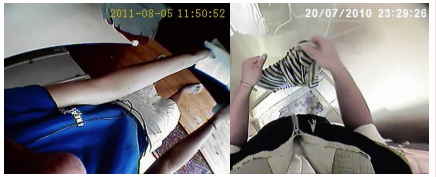
Epic Kitchens, 2018 [Damen et al.]



Decade-Dog, 2018 [Ehsani et al.]



Charades-Ego, 2018 [Sigurdsson et al.]

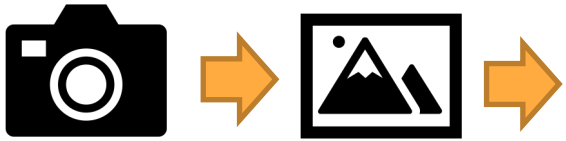


Grasping Dataset, 2014 [Bullock et al.]

Meanwhile, in Robotics…

Difficulties to find common ground

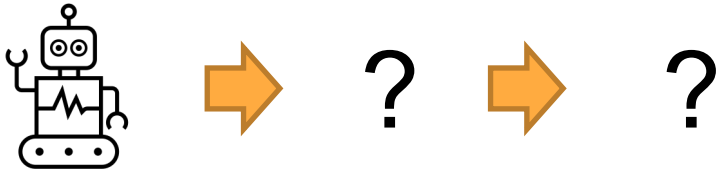
In Computer Vision:



- Image Classification
- Object Detection
- Segmentation
- Action Recognition
- Optical Flow Estimation

...

In Robotics:



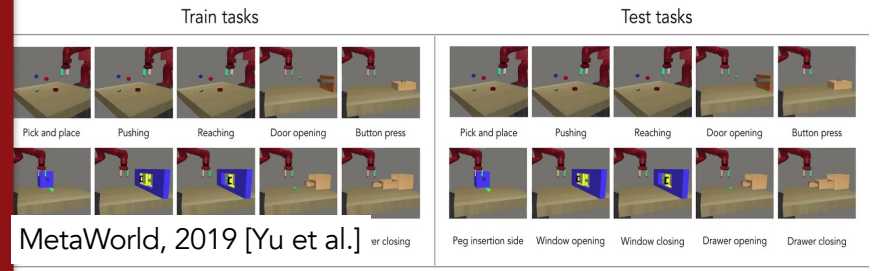
Robotics: Active Datasets?

From datasets to simulation environments?

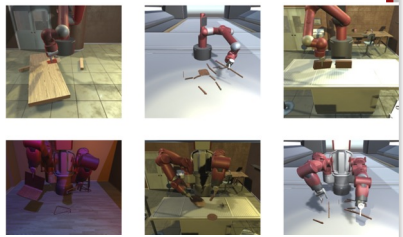
- Robot Task Learning
- **Benchmark for Solutions**
- **Task-Specific**
- **Dynamic**
- **Active**

RLBench, 2020 [James et al.]

DoorGym, 2019 [Urakami et al.]



MetaWorld, 2019 [Yu et al.]

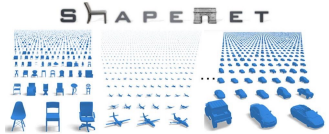


Ikea Assembly, 2019 [Lee et al.]

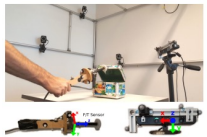
Some Examples of Robotics Datasets

Two types of Datasets

Datasets that are useful for Robots



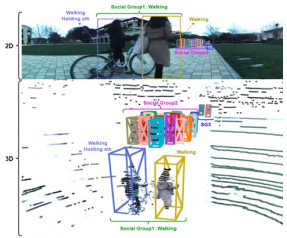
20Bn-smth-smth



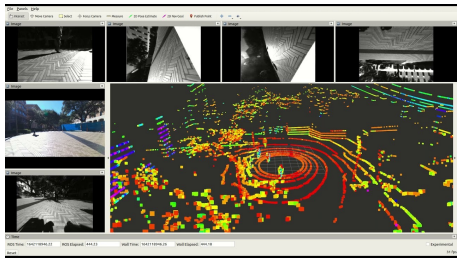
RBO Dataset

YCB Dataset

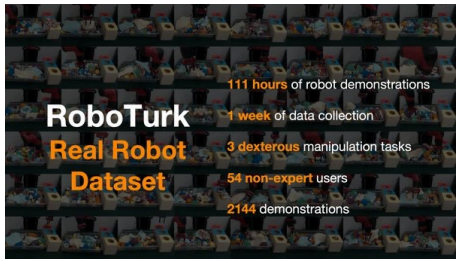
Datasets from Robots



JRDB



ScanD

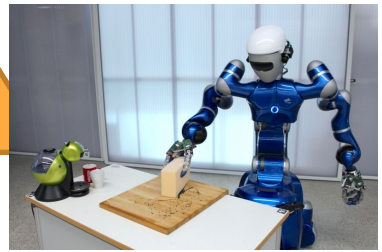


What does a Good Dataset in Robotics need?

Meta information

Robot Embodiment:
- Actuation
- Sensing
- Morphology

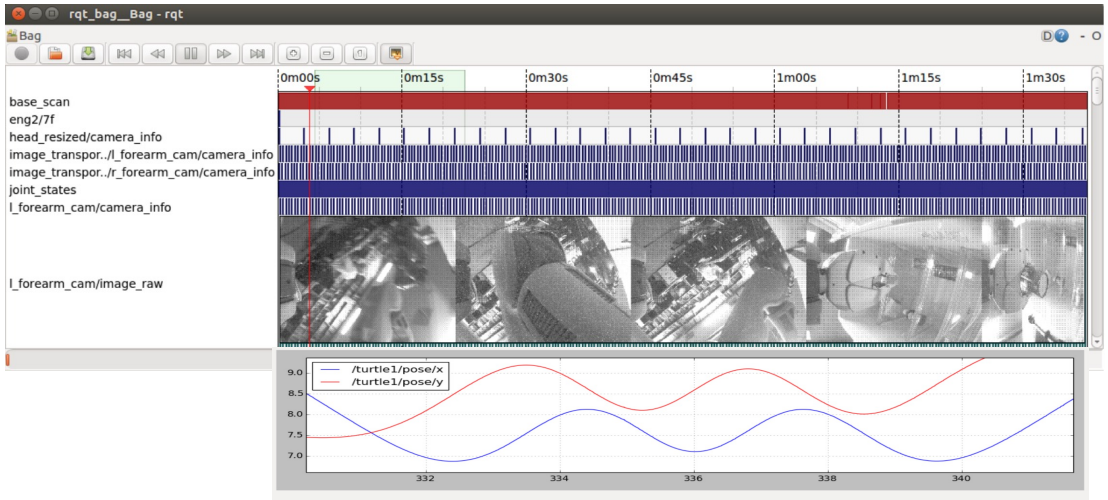
Environment:
- Layout
- Type
- Other agents
- Context



Event:
- Task/Goal
- Objectives
- Conditions

What does a Good Dataset in Robotics need?

Temporal information



- Timestamps of each signal
  - ideally synced
- Values in a protocoled format
  - Careful with compression!
  - Better raw
- Annotations

Resources

Where to find datasets that are relevant for Robotics

- IJRR Data Papers: https://journals.sagepub.com/topic/collections-ijr/ijr-3-datapapers/ijr
  - ”Dry” description of the datasets with focus on reproducibility

- NeurIPS Dataset track: https://neurips.cc/Conferences/2022/CallForDatasetsBenchmarks
  - New track focused on Datasets and Benchmarks for Robotics and AI in general

- Awesome Datasets for Robotics: https://github.com/mint-lab/awesome-robotics-datasets
  - Collection of links collected by a lab in Korea

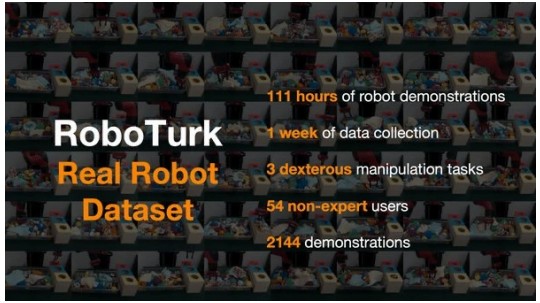
The Future in Other Fields

Removing the need for (costly) annotations

"The University of Texas at [ ] (UT Austin, UT, or Texas) is a public research [ ] in Austin, Texas. It was founded in 1883 and is the oldest [ ] in the University of [ ] System.

The Future in Robotics

Learning to act from large datasets?



$(x, label)$

actions

$f(x) = label$

policy

YouTube

Summary

- Datasets have three usages in AI/Robotics
  - Analyze/understand events
  - Benchmark solutions
  - Train solutions with ML
- This last usage is becoming more and more important in robotics
- Robotics datasets are harder than in CV due to the unclear/variable interface
- Datasets will still play an important role in AI/robotics but researchers want to avoid manual annotations

Open Questions:

- What type of datasets did/do you use for robotics?
  - What data
  - What annotations
  - What size

- What do you think are the main current and future uses of datasets in robotics?

- What information do our non-robotics colleagues need from us when helping us creating datasets?

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