Datasets in Robotics: Past and Future. An open discussion

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“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
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

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

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

3. [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

[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

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

[Image of dataset]

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

dataset \rightarrow \text{trainable model} \rightarrow \text{task}
Background: Supervised Learning

How to consume datasets with machine learning

$$f(x) = \text{label}$$

$$(x, \text{label})$$
Supervised Learning + Datasets

Encode the information in the dataset into a model

\[ f(x) = \text{label} \]

\((x, \text{label})\)
The Dataset Revolution in Computer Vision

Data-driven methods win over classical (hardcoded) solutions

“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

Image Datasets

The fuel for the AI revolution

Image Classification

Image Segmentation

Scene Understanding

Static

Passive

ImageNet, 2009 [Deng et al.]

MS COCO, 2014 [Lin et al.]

OpenImage, 2016

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**

### MetaWorld, 2019 [Yu et al.]

<table>
<thead>
<tr>
<th>Train tasks</th>
<th>Test tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick and place</td>
<td>Peg insertion side</td>
</tr>
<tr>
<td>Pulling</td>
<td>Window opening</td>
</tr>
<tr>
<td>Reaching</td>
<td>Window closing</td>
</tr>
<tr>
<td>Door opening</td>
<td>Drawer opening</td>
</tr>
<tr>
<td>Button press</td>
<td>Drawer closing</td>
</tr>
</tbody>
</table>

### DoorGym, 2019 [Urakami et al.]

- Door opening
- Door closing

### RLBench, 2020 [James et al.]

- Door opening
- Door closing

### Ikea Assembly, 2019 [Lee et al.]

- Door opening
- Door closing
Some Examples of Robotics Datasets

Two types of Datasets

Datasets that are useful for Robots

- ImageNet
- ShapeNet
- EGO4D
- 20Bn-smth-smth
- RBO Dataset
- YCB Dataset

Datasets from Robots

- JRDB
- ScanD
- RoboTurk
- Real Robot Dataset
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](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](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](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] in Austin, Texas. It was founded in 1883 and is the oldest [in] in the University of [System].
The Future in Robotics

Learning to act from large datasets?

\[ f(x) = \text{label} \]

(x, label)

actions

policy

RoboTurk
Real Robot Dataset

111 hours of robot demonstrations
1 week of data collection
3 dexterous manipulation tasks
54 non-expert users
2,144 demonstrations
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?
• Grasping dataset: 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
• ImageNet: 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
References