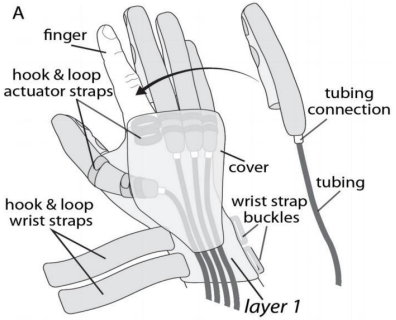
# 2022 Capstone

## Shape Estimation and Data-driven Intelligent Control of Soft Robotic Upper-limb Exoskeletons for In-home Telerehabilitation

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Client - MERIIT Lab, Dr.S.Farokh Atashzar
Dr.Jacqueline Libby

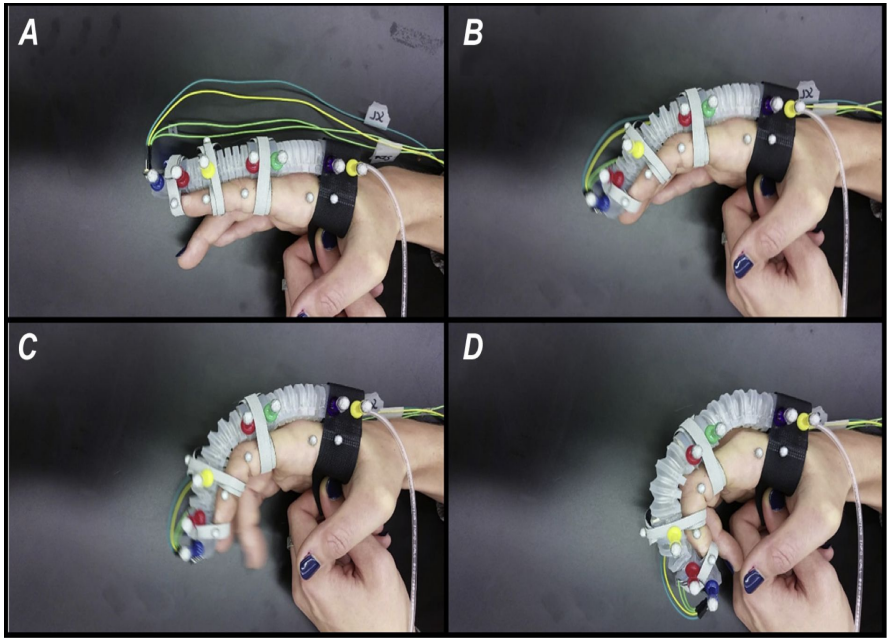
Center for Urban Science + Progress

**Progress Presentation**

NYU | TANDON

# Meet with the Team

# Why Soft Robotics ?




## Product Function

Helping patients with limited mobility to maximize their ability to regain self-care in daily life

## Advantage

- Light weight
- High wearing comfort
- High adaptability to target shape
- Low contact and collision force with human body

# Soft Robotics in Telerehabilitation


## Application Scenarios

- In-home Rehabilitation Physical Training
- Develop microtype to physical therapy

## Target People

- People with neuromuscular diseases such as Parkinson's disease and stroke
- People suffering from other conditions that limit their mobility

# Actionable Policy Insights

## Existing Policy

**2011 "National Robotics Plan"**

Building U.S. leadership in next-generation robotics and applications to **help bring manufacture industry back**

**2013 " US Robotics Technology Plan"**

Utilized robotics technology to **improve society's quality of life**

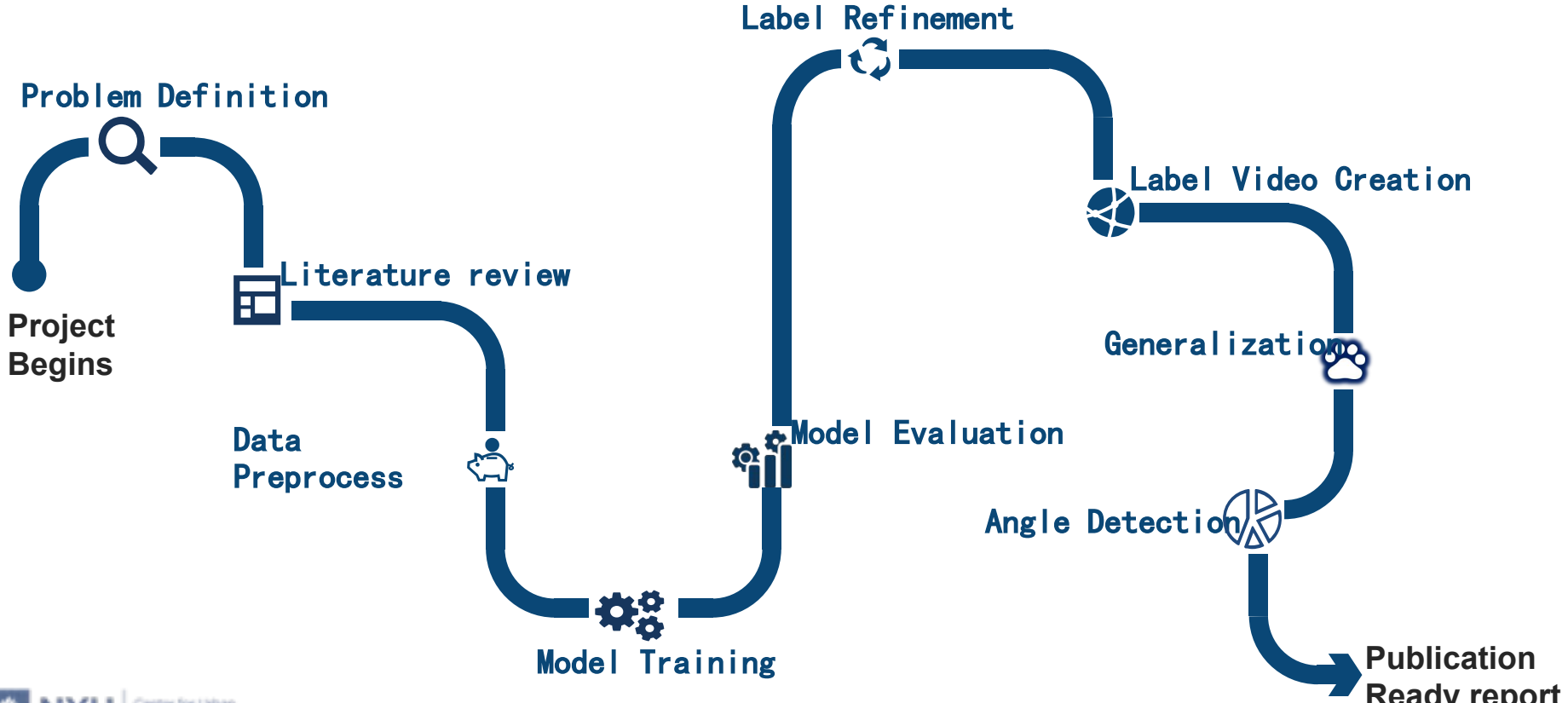
**2017 "National Robotics Plan 2.0"**

Support basic robotics research and accelerate the development and practical application of collaborative robots

## Potential Future Plan

- Address the self-care issues of an **aging society.**
- Let robotics be more **affordable & safe & accessible.**
- Allow **affordable rehabilitation** to everyone.
- Develop **microtype robotics** to physical therapy.
- Propose **Medicare reimbursement** for physical therapy products for post-war wounded service members.

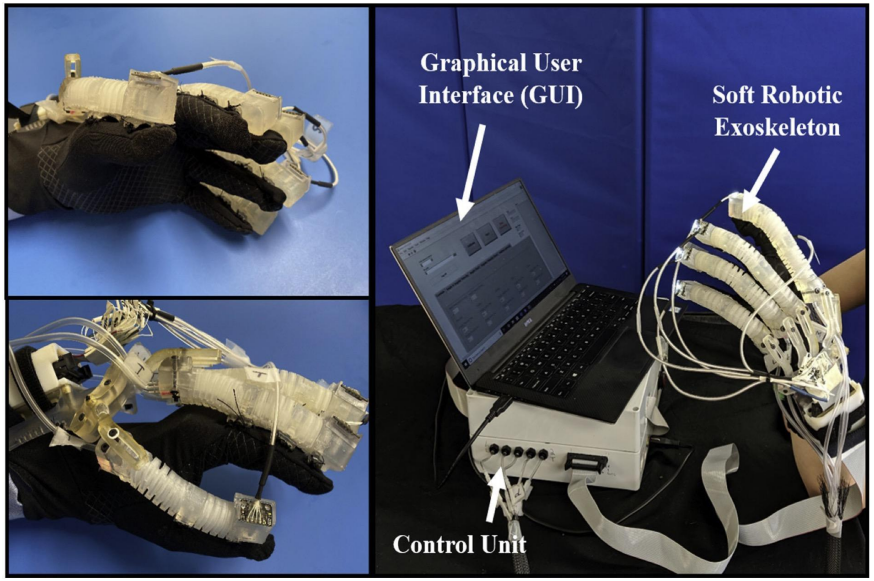
# Overall Workflow



# Overall Contribution

- **Process seven raw videos and creates relative datasets** for multi-segmentation shape estimation.
- Implement and modified **eleven models** for different Lab actuators.
- Classify **12-21 actuator features** and **track the skeleton movement** by detecting a set of features.
- Evaluate out **the optimal neural network** for the actuators.
- Produce **interactive likelihood graph** for frame refinement.
- Create **function** for angle detection based on model result.

# Problem Definition




## Major Challenge

Perform smooth and correct shape estimation on banding angle

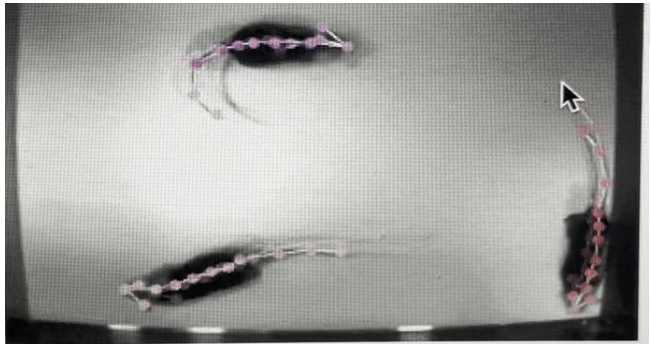
## Priority Mission

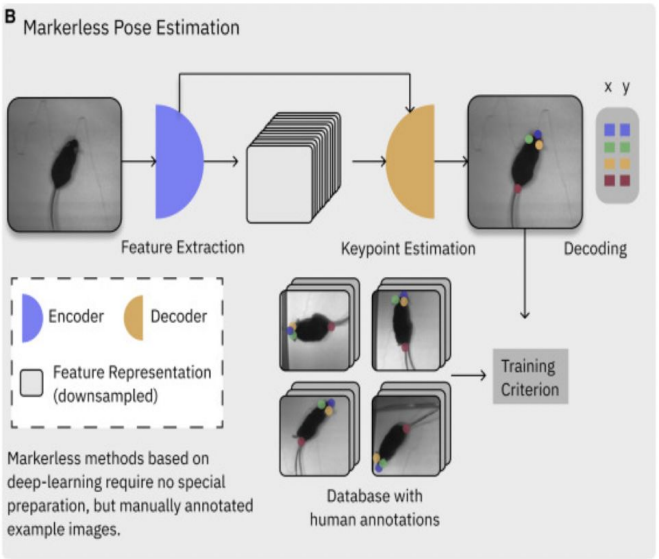
- Build and train ML model via DeepLabCut
- Find the optimal pre-trained model
- Improve shape estimation for soft robotic

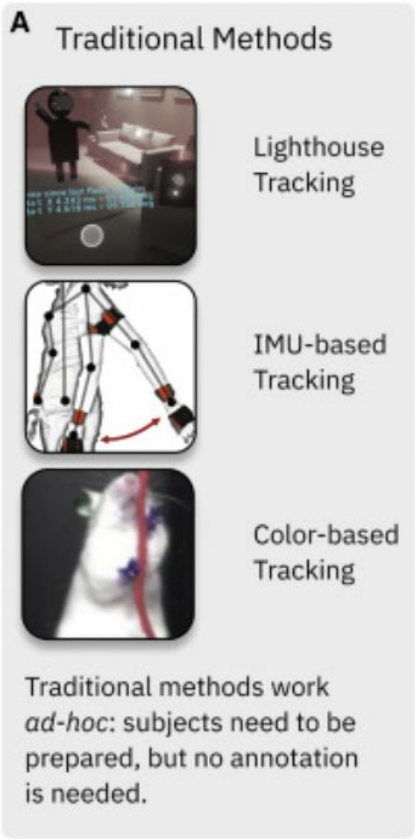
# Literature Discovery

## Shape estimation

- Tradition methods
- Markeless shape estimation
- Machine Learning (ML) methods
- ML methods:
  - Supervised learning
  - Semi-Supervised learning
  - Unsupervised learning
  - **Transfer learning**
  - reinforcement learning



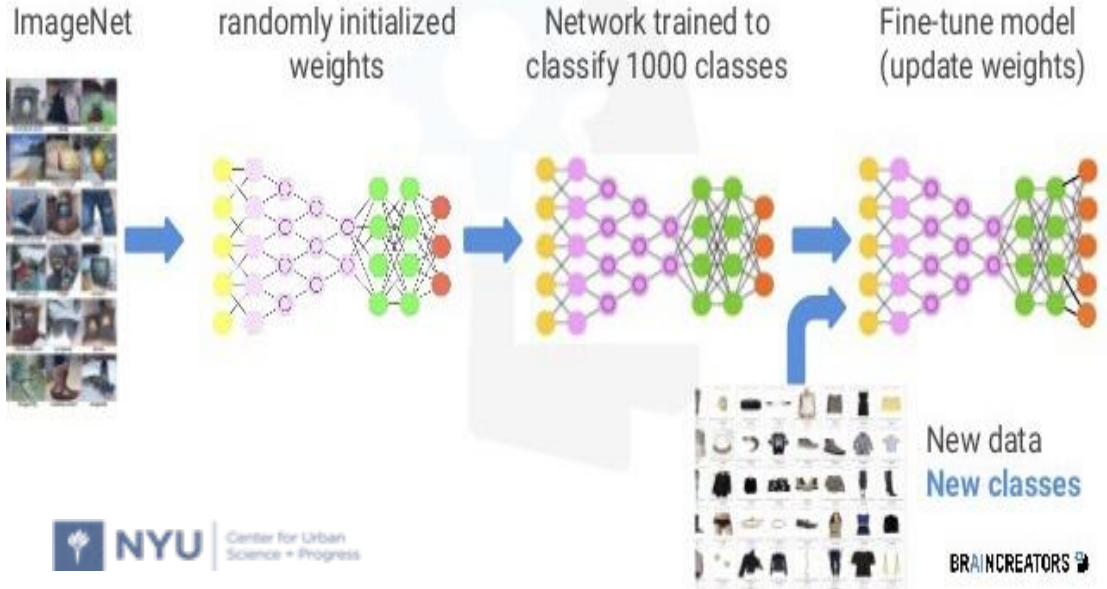


# Literature Discovery

## Transfer Learning: Pre-trained Model Approach

Transfer learning (TL) improve model performance and speed by **leveraging the already existing labeled data** of some related tasks.




- Pre-Trained Models
- All these model below are pre-trained on **ImageNet**
  - ResNet_50
  - MobileNetV2_1.0
  - MobileNetV2_0.75
  - EfficientNet_B6

# Literature Discovery

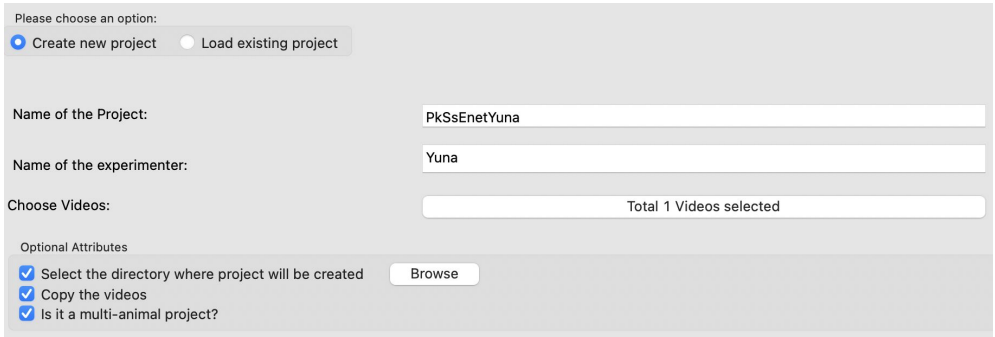
## DeepLabCut (DLC)

- DeepLabCut is a **toolbox** for markerless pose estimation of animals performing various tasks.
- it performs **frame-by-frame prediction** and therefore can also be used for intermittent occlusions.
- It also solve the problem of **detecting body parts in dynamic environments**.

# Data Preprocess Workflow

## Actuator Model Creation

I. Create project in client required naming conventions
II. Upload actuator videos and copy into target folder
III. Make sure select the multi-animal option




## Parameter Adjustment

I. Edit the config file
II. Set up label quantity
III. Set up individual skeleton

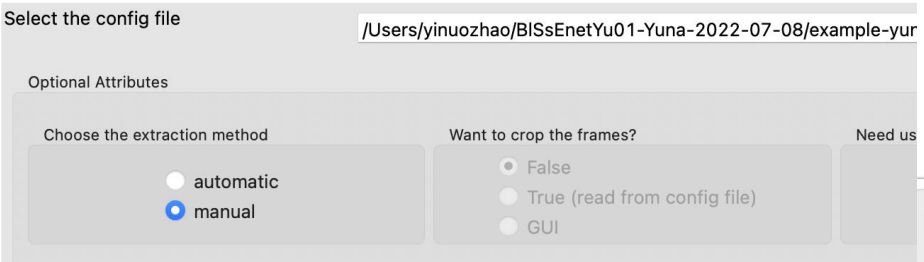

Time to get the frames！ ！

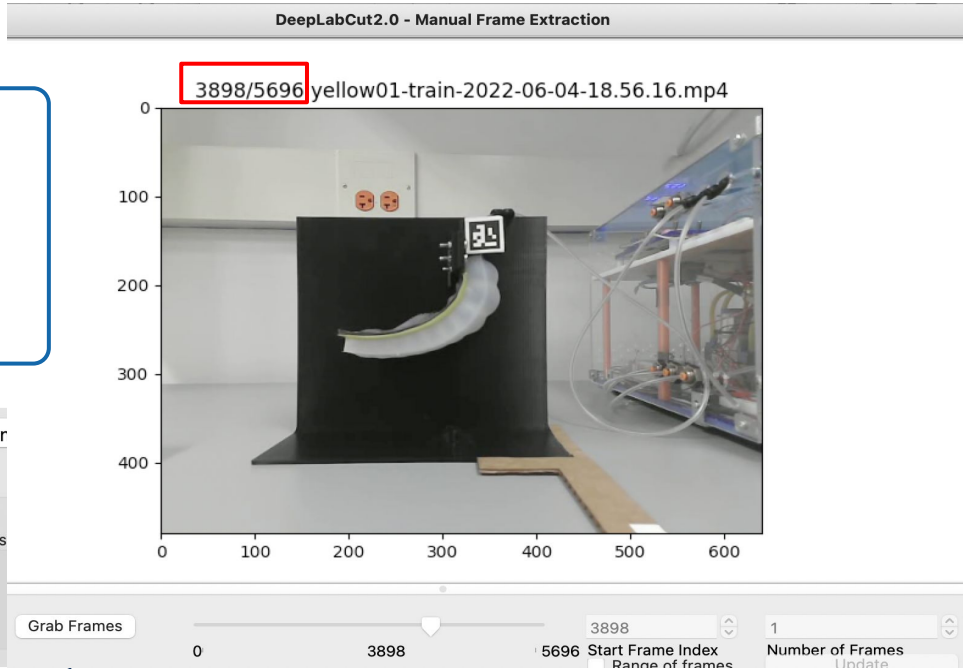
# Data Preprocess Workflow

## Data Extraction from videos

Based on Client's Requests:

I. Manually grab frames from videos
II. Normally grab 3% ~ 5% frames per video
III. Extract more bulging parts frames than straight ones



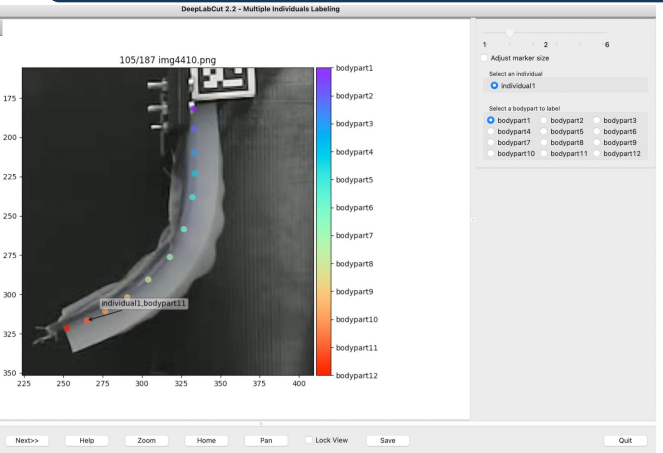




Time to make the dataset ! ! !

# Data Preprocess Workflow

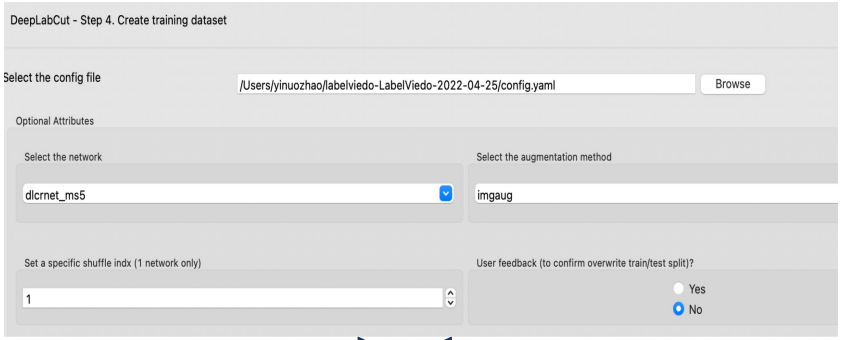
## Label Dataset Creation

I. Manually label the extracted frames
II. Create the key points dataset of labels
III. Check if the labels and skeleton correct




## Training Dataset Creation

I. Set training parameters
II. Choose pre-trained network
III. Create dataset for model training




Ready For Model Training !!!

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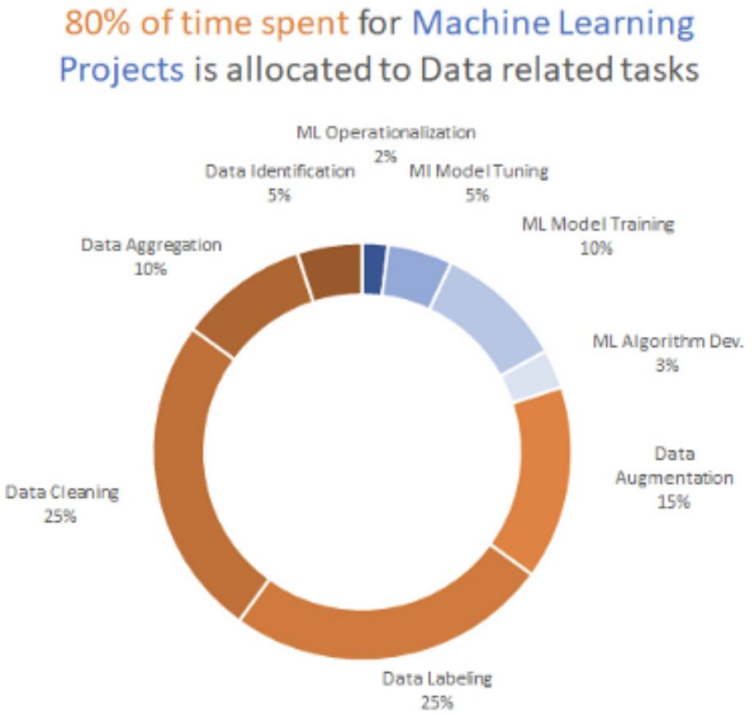
# Data Preprocess




**Business Value created**

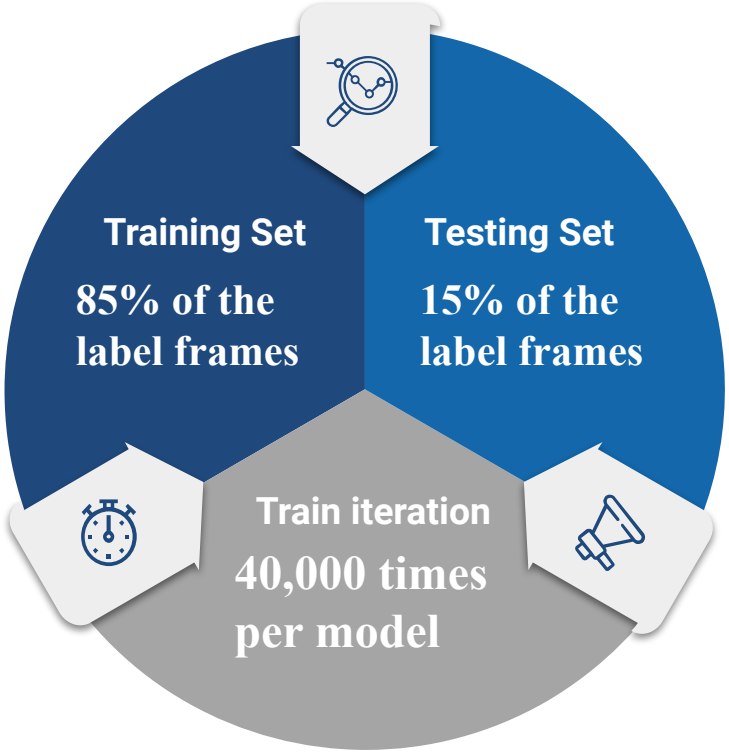
Based on 2022 On-Demand label price formula

➢ Point-annotation :

$0.08/image frame + 0.04/point

| Actuator label type | Total Image frame | Labeled Frame | Frame Refine | Point per frame | Label times | Cost |
|---|---|---|---|---|---|---|
| Pink Sealing 02 | 697 | 80 | 30 | 12 | 9 | 530.96 |
| Pink Vally 01 | 1162 | 40 | 56 | 11 | 4 | 261.92 |
| Pink Vally 02 | 697 | 35 | 36 | 11 | 6 | 243.2 |
| Pink Peak 01 | 1162 | 30 | 60 | 12 | 6 | 352.16 |
| Pink Peak 02 | 697 | 20 | 52 | 12 | 6 | 263.12 |
| Pink Peak&Vally 01 | 1162 | 40 | 57 | 21 | 2 | 255.92 |
| Pink Peak&Vally 02 | 672 | 24 | 50 | 21 | 6 | 426.72 |
| Blue Seling | 5134 | 60 | 45 | 12 | 7 | 763.52 |
| Yellow Seling | 5696 | 75 | 30 | 12 | 2 | 556.48 |
| Orange Seling | 5211 | 67 | 50 | 12 | 4 | 641.52 |
| Green Seling | 4466 | 65 | 80 | 12 | 2 | 496.48 |
| | | | | | Total cost | 4792 |

# Training Parameters

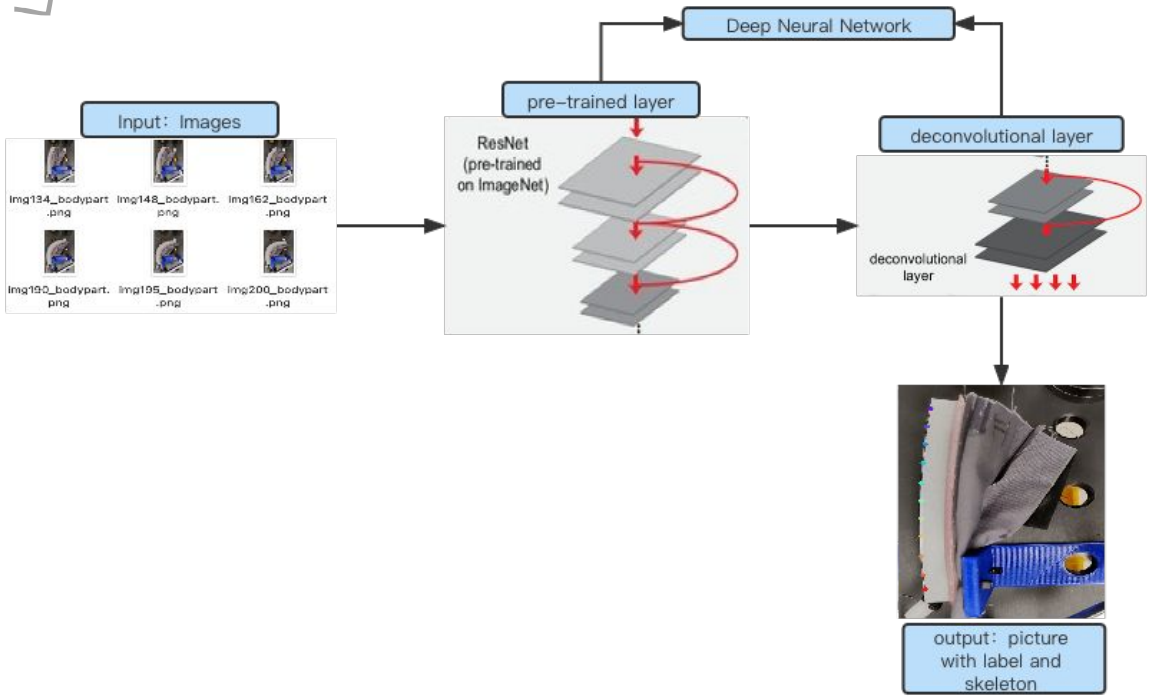



- The part of the model that is **learned from historical training data.**
- **Iterations** is the number of batches needed to complete one epoch
- **Data Augmentation** : Use imgaug for our image augmentation
- Crop frame into suitable size could improve model performance

# Methodology

**Feature Extraction**

- Deep Neural Network
- Input: images
- Output: images with label and skeleton



# Methodology

## HPC Training

- **High-performance computing (HPC)**
- Use **supercomputers** and **computer clusters** to solve advanced computation problems
- Improve **Training Speed**

## Angle Detection

- **Clockwise Angle** Calculation with coordinate
- Help to prove model accuracy
-

# Risk Identification

**1st**
Manual label result in bad labels

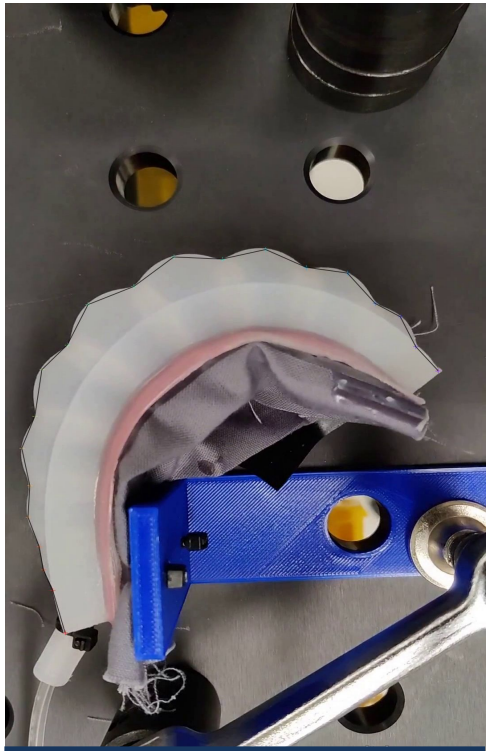
**2nd**
Model is too easy to re-write

**3rd**
Can’t decide which frame to refine

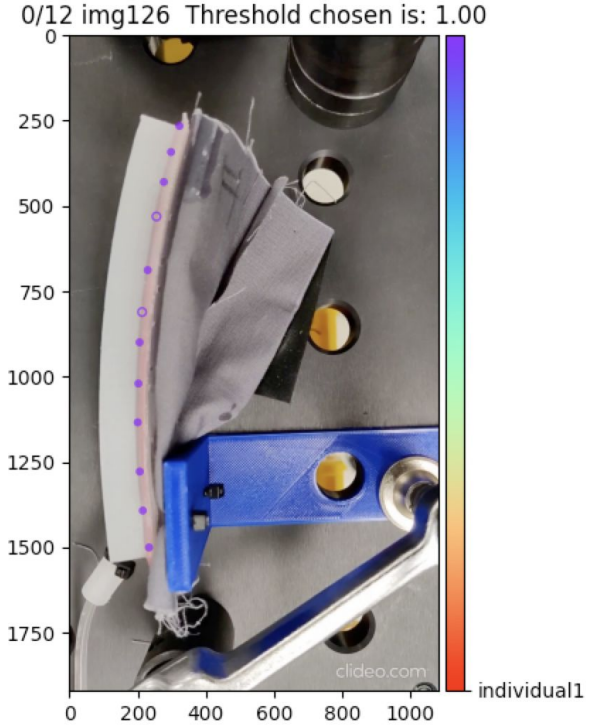
# Alternative Approach

**Label Problem** → check label skeleton

**Label Problem** → label refinement



**Overall checking**




**Individual point checking based on likelihood**

# Alternative Approach

**Model rewrite** — Set Github Organization

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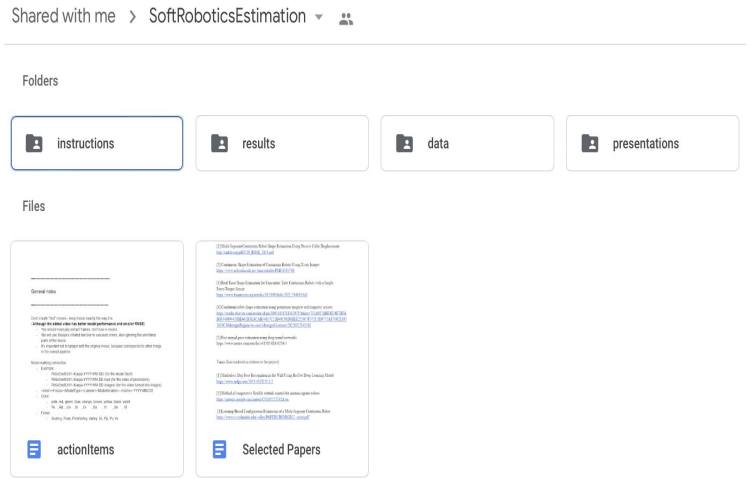
Overview | Repositories 40 | Projects | Packages | Teams | People 5

**Model rewrite** — Google drive back-up



# Alternative Approach

**Frame Specification**

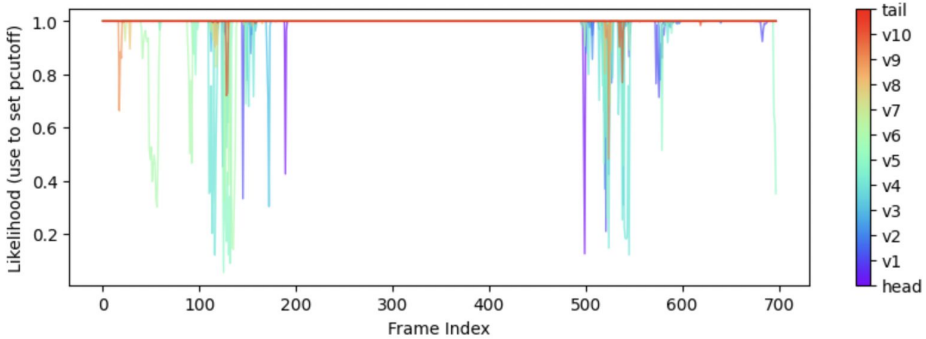
Extract outliers in command line

**Frame Specification**

Likelihood Graph

## Command method

```
"""
>>> config = '/Users/yinuozhao/Downloads/PkSsEnetYu03-main/config.yaml'
>>> video = '/Users/yinuozhao/Downloads/PkSsEnetYu03-main/videos/pink02-train-20
22-02-21-20.05.09.mp4'
>>> deeplabcut.extract_outlier_frames(config, video,outlieralgorithm='uncertain'
,p_bound=0.95, shuffle=0)
Method  uncertain  found  15  putative outlier frames.
Do you want to proceed with extracting  50  of those?
If this list is very large, perhaps consider changing the parameters (start, sto
p, p_bound, comparisonbodyparts) or use a different method.
yes/noyes
Frames from video pink02-train-2022-02-21-20.05.09  already extracted (more will
 be added)!
Loading video...
Duration of video [s]:  23.266666666666666 , recorded @  30.0 fps!
Overall # of frames:  406 with (cropped) frame dimensions:
Kmeans-quantization based extracting of frames from 4.19  seconds to 17.68  seco
nds.
Let's select frames indices: [139, 155, 156, 157, 158, 159, 214, 488, 490, 496,
499, 501, 502, 507, 513]
```

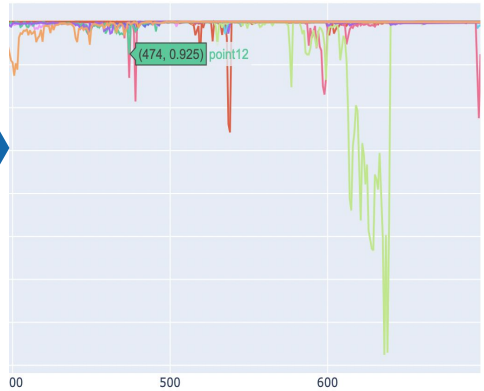


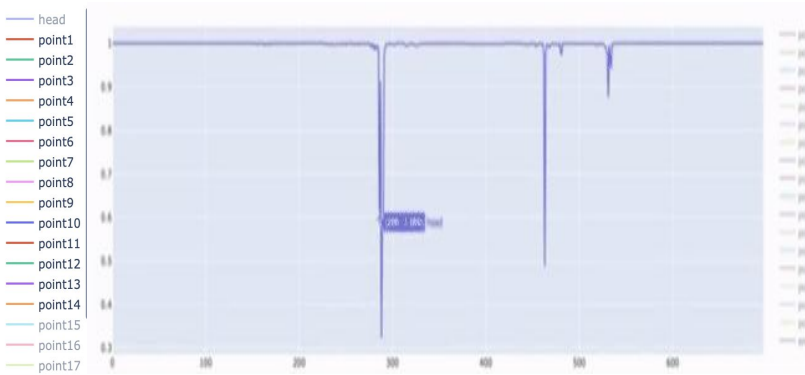

## Original DLC Graph

# Alternative Approach

**Frame Specification**

Interactive Likelihood Graph



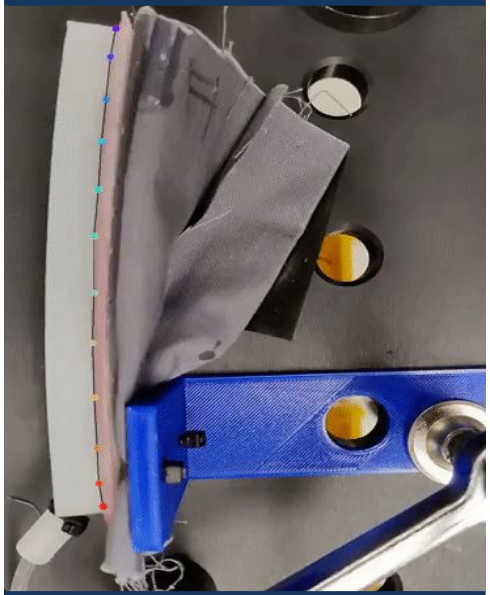




**New Interactive Graph**

# Evaluation Metrics

# Result: Model Comparison

**Pink Sealing**



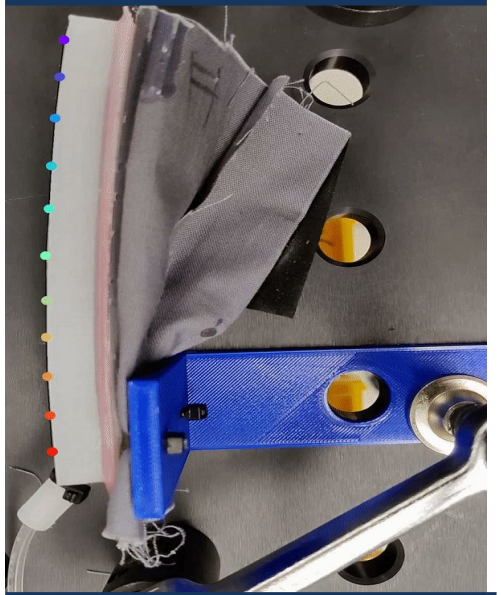
**MobileNetV2_0.75**

**ResNet_50**

**EfficientNet_B6**

# Result: Label Comparison

**Bulging Peak**



**PinkPeak_ResNet_50**

**Bulging Valley**

**PinkValley_ResNet_5**

**PinkPeakVally_ResNet_50**

# Result: Other Color Actuators

Blue Model

Yellow Model

Orange Model

Green Model

# Result: Angle Detection

# Reference for the project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# Question Time

## Any Questions ?

## Contact Information


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