Material examination and classification using computer vision

construction robotics

international M.Sc.programme

Material examination and classification using computer vision

1. Task Description
2. Objectives & Workflow
3. Dataset
4. Particle Size Detection Approaches
5. Result
6. Implementation Plan
7. Schedule

Task Description

Material examination and classification using computer vision

Background

- Piles of materials are often delivered to the construction site.
- →Unmanned intelligent construction management
- Integration of robots with RGB-D cameras
- The biggest challenge of these studies is related to materials with similar shapes and textures.[1]→(Granular materials)

Goals:

Particle size and distribution prediction

[1] Maryam Soleymani, Construction Material Classification on Imbalanced Datasets Using Vision Transformer Architecture (Vit)

Objectives & Workflow

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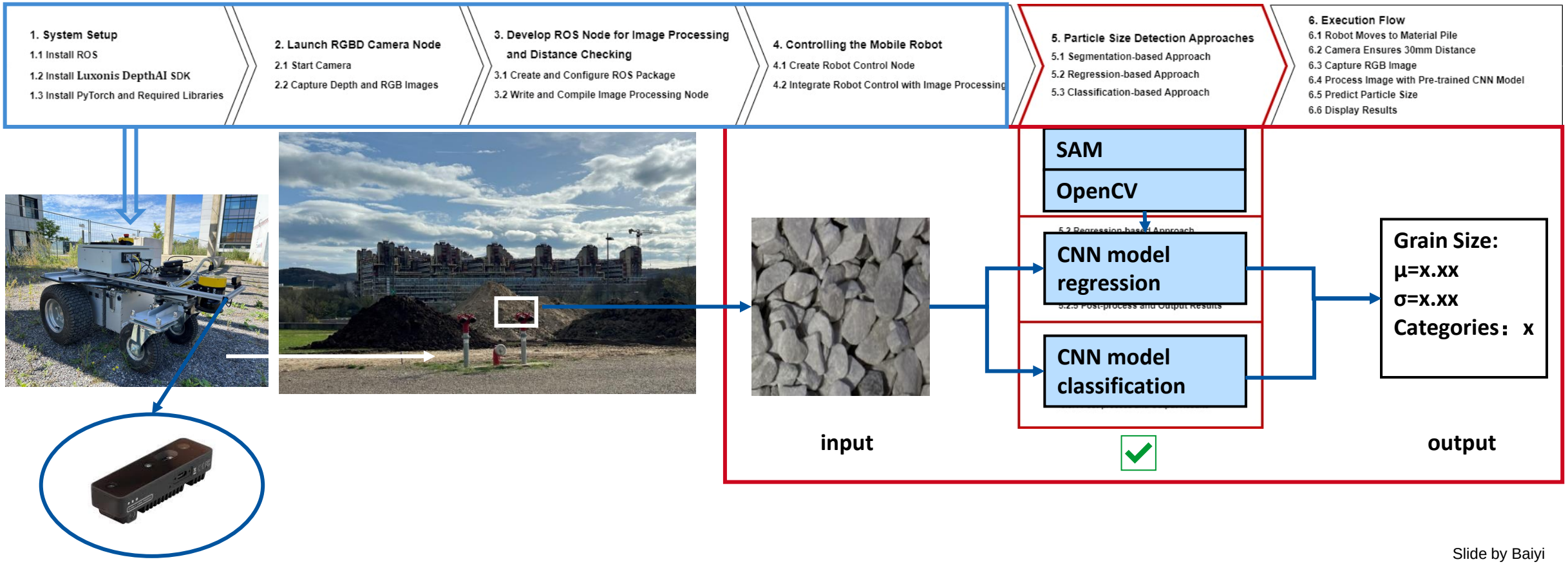
Automated Particle Size Detection Workflow



Slide by Baiyi

Research methods

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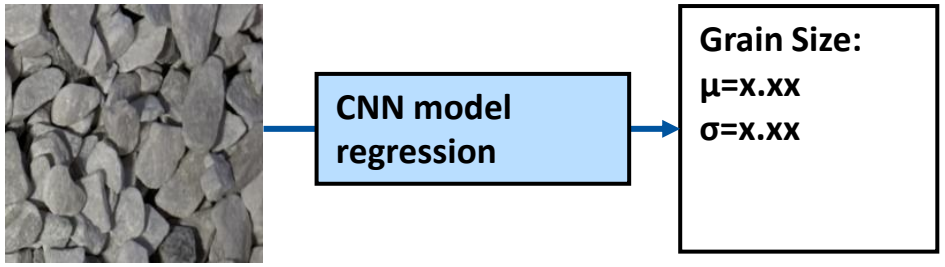
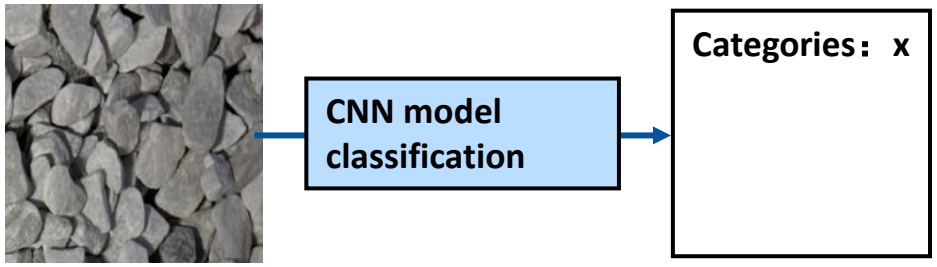
- **Regression-Based Method**
- Use a CNN model to extract features from each image.
- Map features to numerical values.
- Training set results correlate features with specific numerical outcomes.



- **Classification-Based Method**
- Train a CNN model to extract features from each image.
- Map features to corresponding labels.



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Dataset

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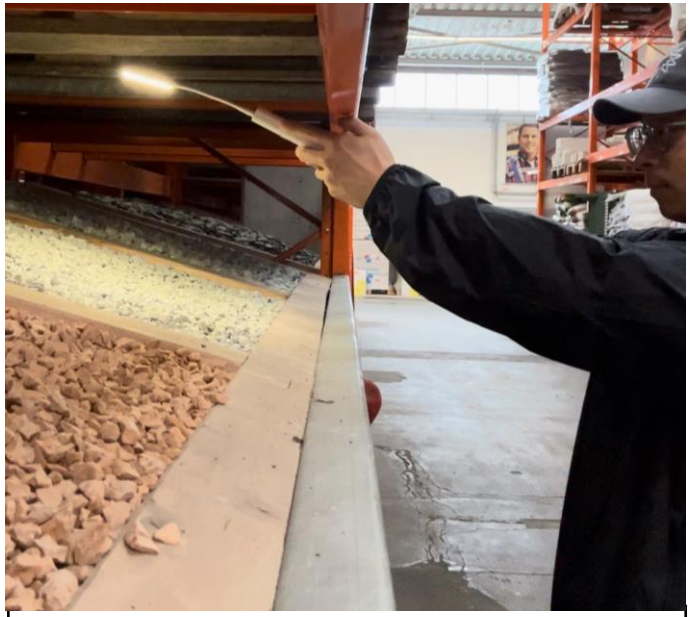
Dataset Preparation

- **Image Source:** Collected from Aachen Bauhaus and OBI, including 20 types of construction granular materials.
- **Product Diversity:** Ranges from 1-3mm gravel to 40-60mm marble.
- **Sampling and Labeling:** Products are representing the construction industry. (The most common construction particle size range is 0.075-80mm[1]). These products have small grain size variances and have been labeled. Easier for labeling, feature extraction, and machine learning.



- **Image Specifications:**
- Manual photography
- Consistent lighting conditions
- Fixed camera distance: 30mm
- Image resolution: 3024x4032 pixels

[1] K.V. Anusree, G.M. Latha, Characterization of sand particle morphology: state of the art, Bull. Eng. Geol. Environ. 82 (2023) 269.

Particle size detection approachs

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- **Regression-Based Method**
- Use a CNN model to extract features from each image.
- Map features to numerical values.
- Training set results correlate features with specific numerical outcomes.

CNN model regression

input


```
C:\Users\guoba\anaconda3\python.exe "E:\granular materials classification and particle size identification\code\CNN_predict_ResNet50_regression_with_mu_and_std.py"
Prediction for transformed image 0: mu=10.72, std=7.36
Prediction for transformed image 1: mu=9.74, std=7.45
Prediction for transformed image 2: mu=9.17, std=6.91
Prediction for transformed image 3: mu=10.39, std=6.93
Prediction for transformed image 4: mu=8.03, std=6.38
Prediction for transformed image 5: mu=9.89, std=7.76
Prediction for transformed image 6: mu=10.57, std=7.8
Prediction for transformed image 7: mu=10.43, std=7.86
Prediction for transformed image 8: mu=9.42, std=7.32
Prediction for transformed image 9: mu=9.65, std=7.04
Average Predicted Grain Size for E:\granular materials classification and particle size identification\old\input\marmorkiesel_weiss_7-15mm.jpg: mu=9.8, std=7.28

Process finished with exit code 0
```

```
C:\Users\guoba\anaconda3\python.exe "E:\granular materials classification and particle size identification\code\CNN_predict_ResNet50_regression.py"
Prediction for transformed image 0: 9.02
Prediction for transformed image 1: 8.86
Prediction for transformed image 2: 8.84
Prediction for transformed image 3: 9.42
Prediction for transformed image 4: 9.64
Prediction for transformed image 5: 9.15
Prediction for transformed image 6: 9.71
Prediction for transformed image 7: 9.32
Prediction for transformed image 8: 9.15
Prediction for transformed image 9: 13.24
Average Predicted Grain Size for E:\granular materials classification and particle size identification\old\input\marmorkiesel_weiss_7-15mm.jpg: 9.64

Process finished with exit code 0
```

Grain Size:
μ=x.xx
σ=x.xx

output

Segmentation and Feature extaction

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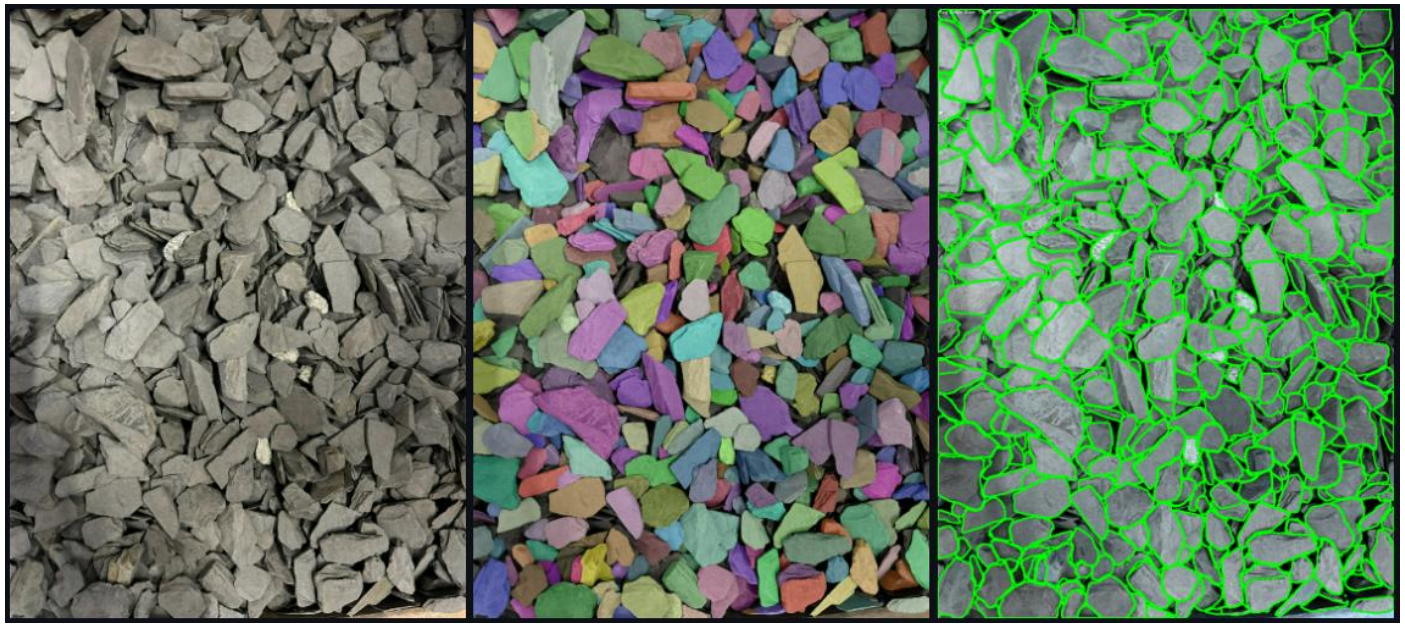
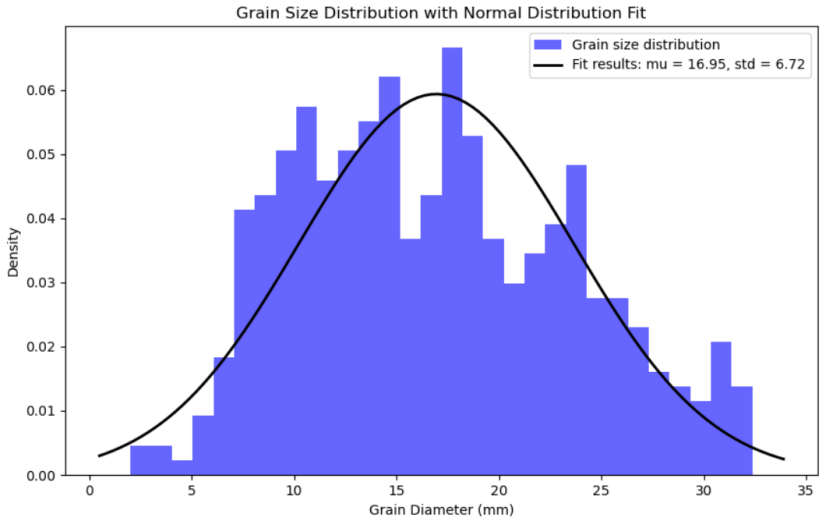
- Segment materials into individual particles using a segmentation model (e.g., SAM).
- Extract features from each particle using OpenCV .
- Estimate particle size distribution.



Input picture → Segment materials into individual particles → Extract features



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Particle size detection approachs

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- **Classification-Based Method**
- Train a CNN model to extract features from each image.
- Map features to corresponding labels.

CNN model classification

Categories： x

Category	Characteristics	Product Names
Fine Pebbles and Gravel	Small size, rounded to semi-rounded, smooth to medium roughness	Marmorkiesel_Weiss_7-15mm, Marmorkiesel_Weiss_15-25mm, Marmorkiesel_Gruen_15-25mm, Quarzkies_Rund_Hell_8-16mm, Kies_2-8mm, Kies_8-16mm, Kies_1-3mm
Medium Pebbles and Gravel	Medium size, rounded to semi-rounded, smooth to medium roughness	Marmorkiesel_Weiss_25-40mm, Marmorkiesel_Weiss_40-60mm, Marmorkiesel_Schwarz_40-60mm, Quarzkies_Rund_Hell_16-32mm, Kies_16-32mm, Marmorsplitt_7-12mm, Splitt_2-5mm
Large Pebbles and Broken Stones	Large size, irregular shape, rough texture	Bruchsteine_Veronarot_30-60mm, Schieferplaettchen_22-40mm, Marmorsplitt_Veronarot_9-12mm, Marmorsplitt_Donaublau_8-12mm, Basaltsplitt_8-12mm, Granitsplitt_8-12mm, Marmorkiesel_Weiss_15-25mm

Classification Criteria:
Combines particle size, shape, and smoothness.
Three categories:
1 Small particles (0-15mm)
2 Medium-sized particles (aesthetic, suitable for decoration and outdoor paving)
3 Large and rough particles (suitable for construction, providing higher friction)
Challenges: Overfitting during training, further optimization needed

Implementation plan

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Step 1:

Deploy the robot to navigate to the material pile.

Step 2

Ensure the camera is positioned at the optimal 30mm distance.

Step 3

Capture RGB images under controlled lighting conditions.

Step 4

Utilize a pre-trained CNN model to process the images.

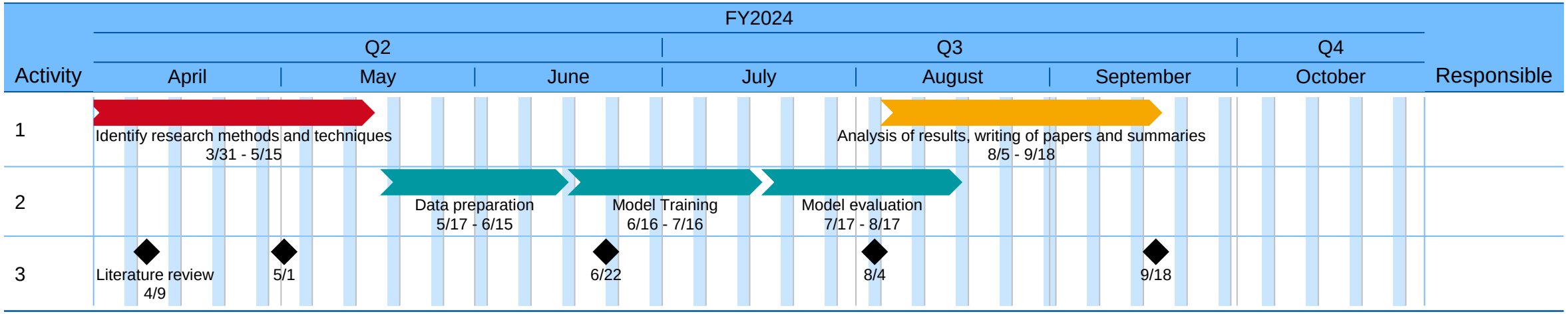
Step 5

Predict the particle size using the model.

Step 6

Display and analyze the results for construction site management.

Schedule


FY2024
Q2
Q3
Q4
Activity
April
May
June
July
August
September
October
Responsible
1
Identify research methods and techniques
3/31 - 5/15
Analysis of results, writing of papers and summaries
8/5 - 9/18
2
Data preparation
5/17 - 6/15
Model Training
6/16 - 7/16
Model evaluation
7/17 - 8/17
3
Literature review
4/9
5/1
6/22
8/4
9/18

Sources

https://paperswithcode.com/task/material-recognition/codeless
https://www.cs.columbia.edu/CAVE/software/curet/ https://www.csc.kth.se/cvap/databases/kth-tips/index.html
https://www.fmdsa.org/research-network/ http://opensurfaces.cs.cornell.edu/
https://en.wikipedia.org/wiki/Convolutional_neural_network https://image-net.org/challenges/LSVRC/
https://towardsdatascience.com/r-cnn-fast-r-cnn-faster-r-cnn-yolo-object-detection-algorithms-36d53571365e
https://arxiv.org/abs/1312.6229 https://viso.ai/deep-learning/vgg-very-deep-convolutional-networks/
http://yann.lecun.com/exdb/publis/pdf/farabet-pami-13.pdf https://arxiv.org/abs/2304.07193

Thanks for listening.
Any Question?

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