Fraunhofer IOSB

# Implementation and evaluation of a real-time capable approach to sensorbased sorting using CNNs

**15.11.2024**

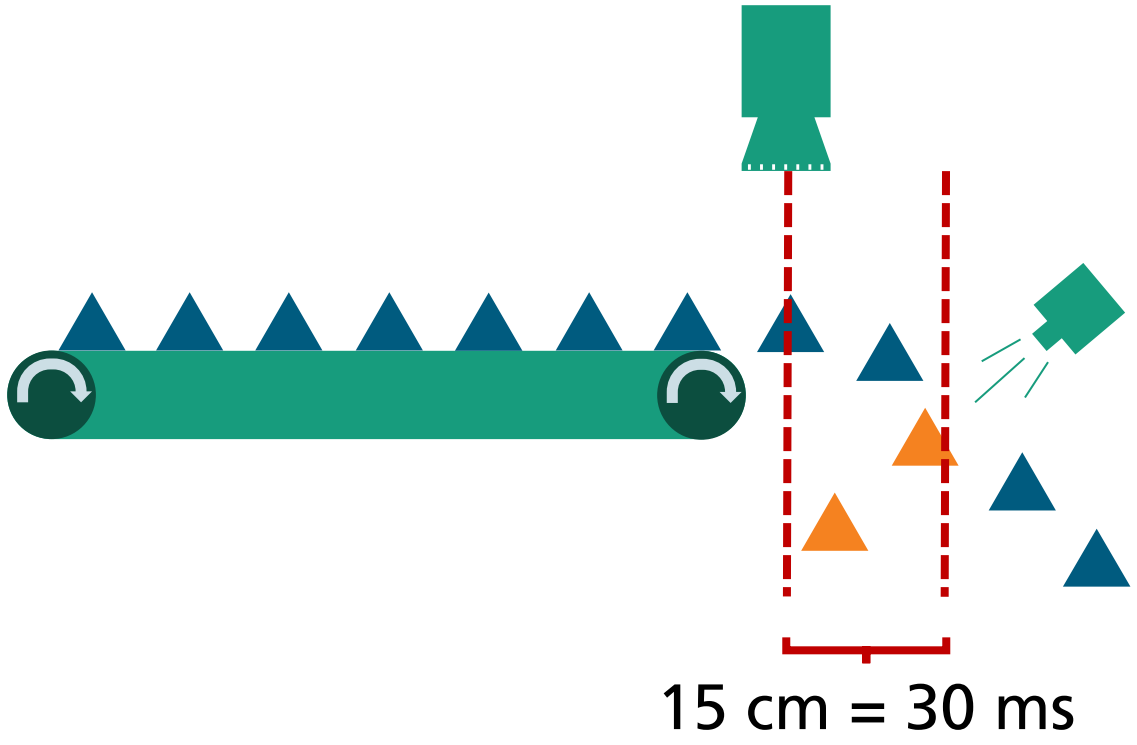
# Contents



# Problem

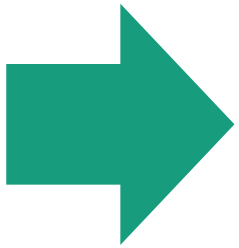
# Sorting system



# Problem

- conventional algorithms often are…
  - engineered to fit a specific sorting task
  - overgrown with configuration parameters
  - limited to primitive features
- Convolutional Neural Networks (CNNs) have proven their effectiveness in many computer vision tasks



- development of a CNN-based approach
- evaluation on a real sorting system and sorting results

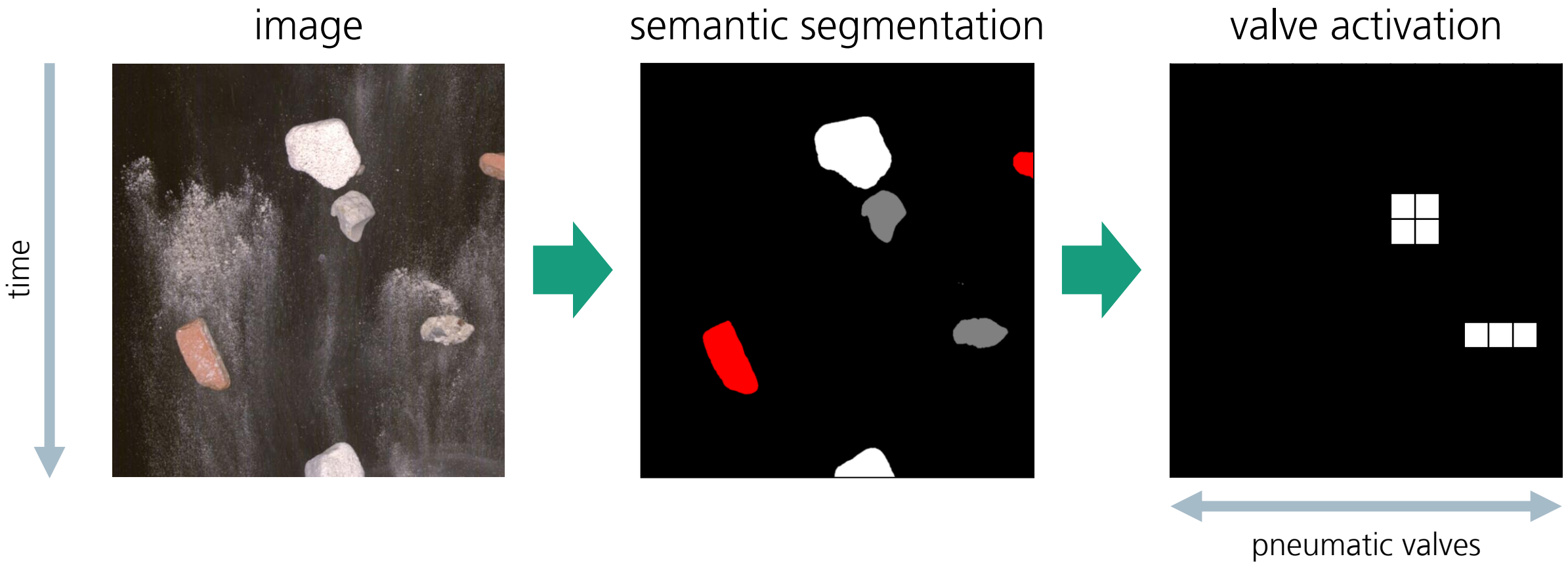
# Materials for evaluation

Peanuts & Hibiscus tea

Construction and Demolition Waste (CDW) with high amounts of dust

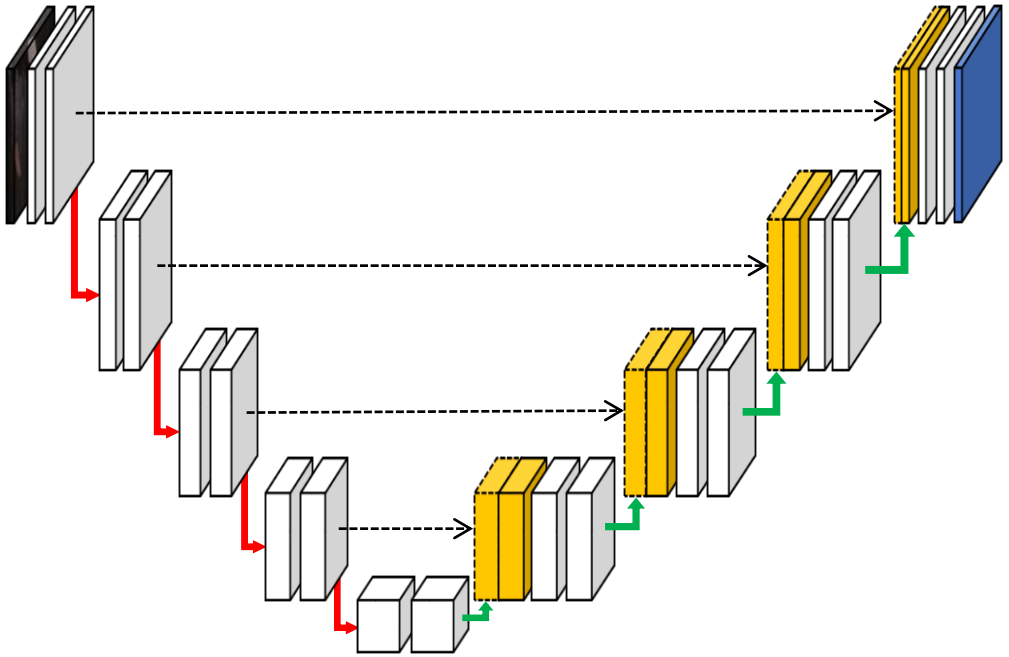
# Approach

# Approach



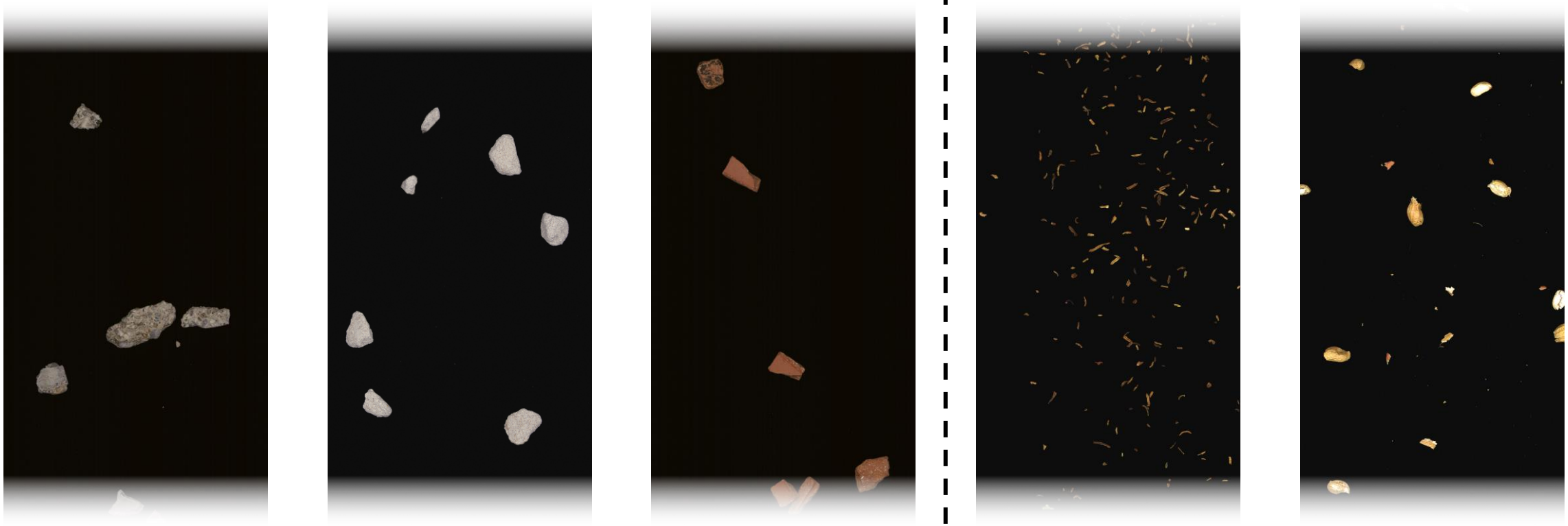
# Architecture



- based on U-Net architecture (Ronneberger et al., 2015)
- padded convolutions
- reduction of number of featuremaps by factor of 4
- for CDW: downsampling and upsampling layers on input / output

# Training

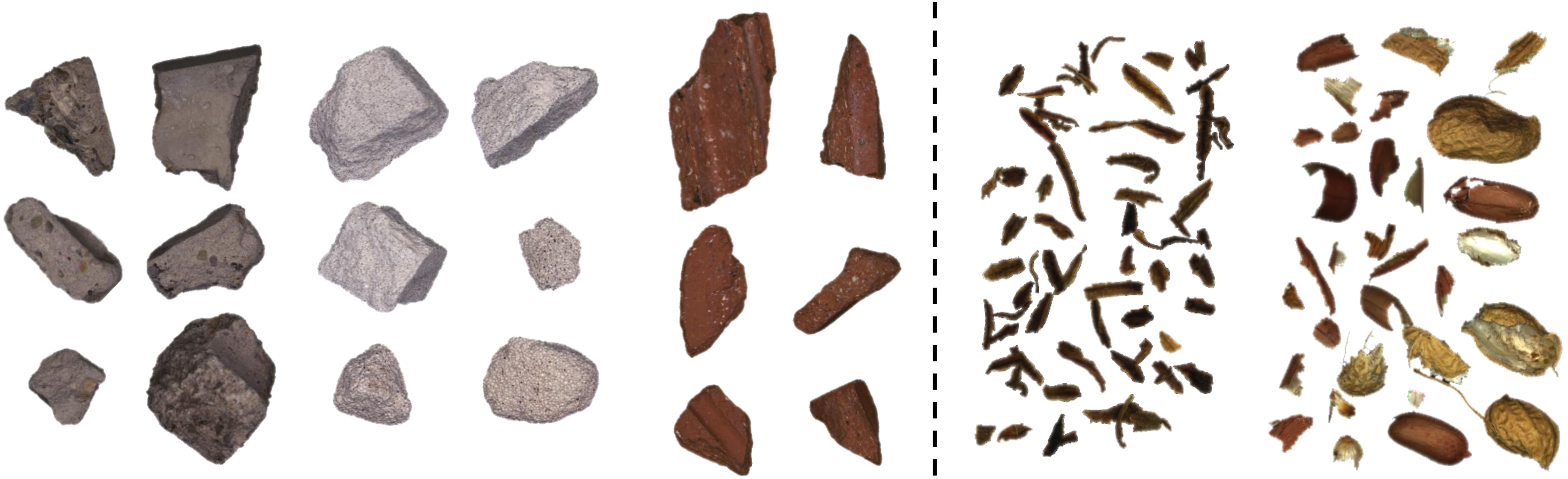
# Synthetic data generation
## Extraction of objects



Concrete | Aerated concrete | Brick | Hibiscus | Peanut

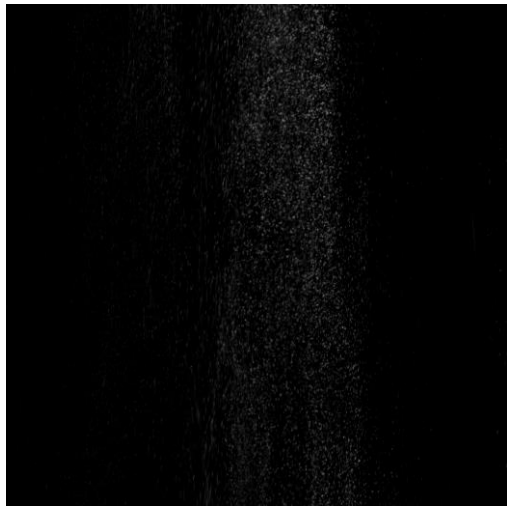
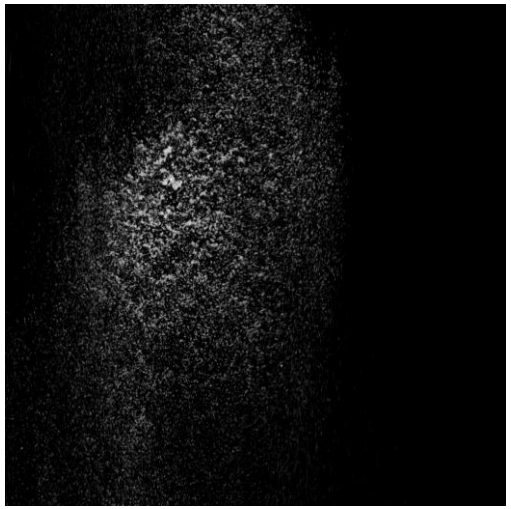
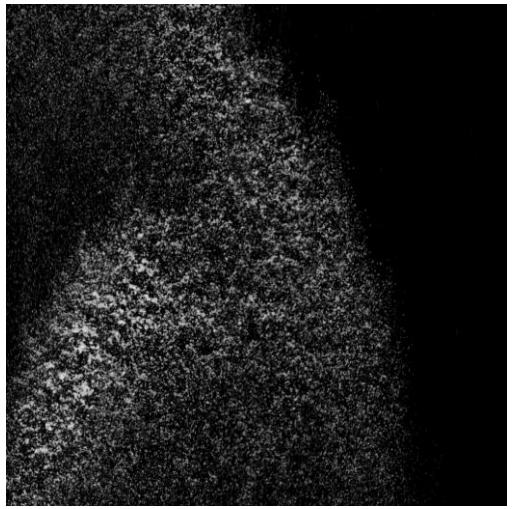
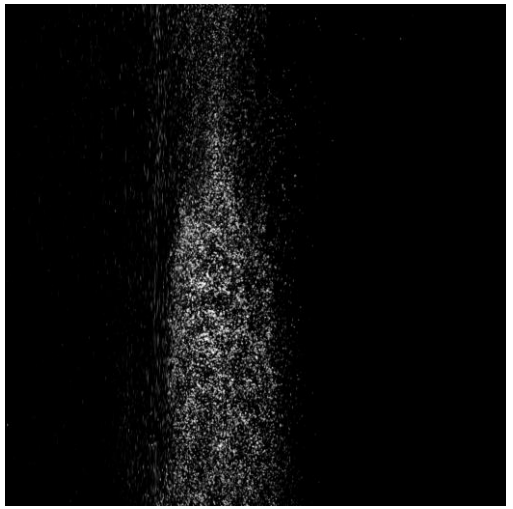
# Synthetic data generation
## Extraction of objects



Concrete | Aerated concrete | Brick | Hibiscus | Peanut

# Synthetic data generation
## Additional dust images

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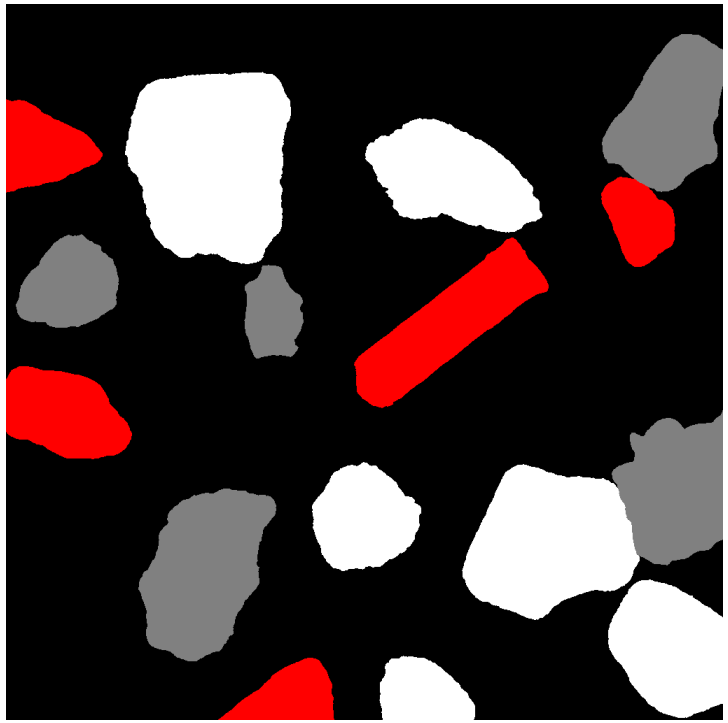

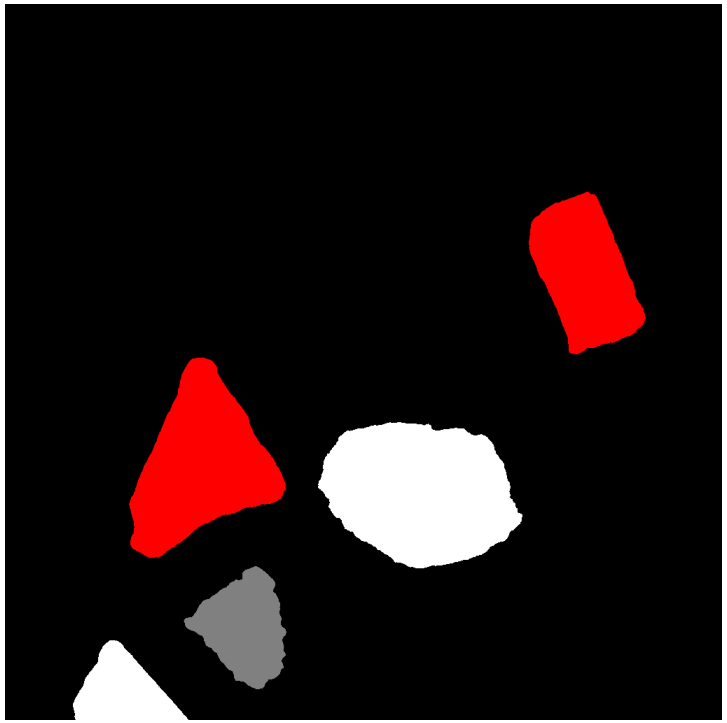

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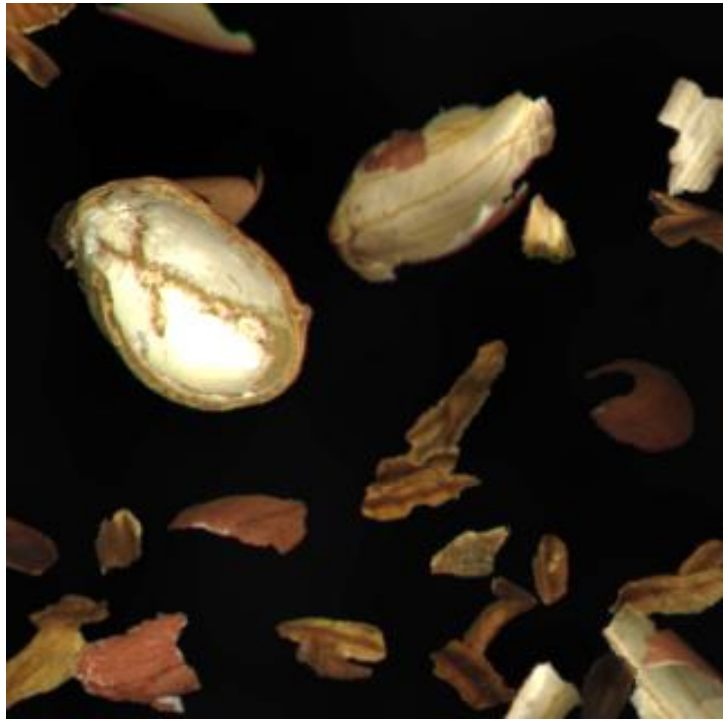

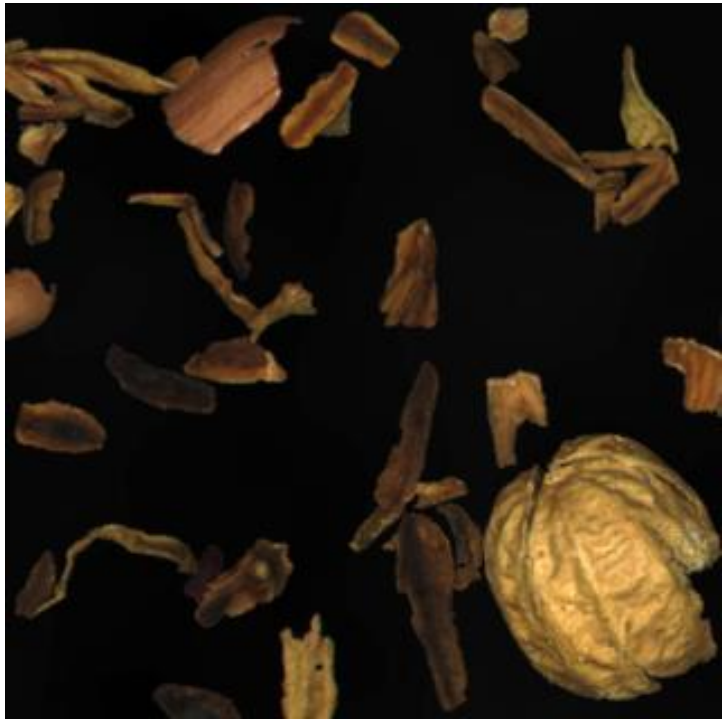

  

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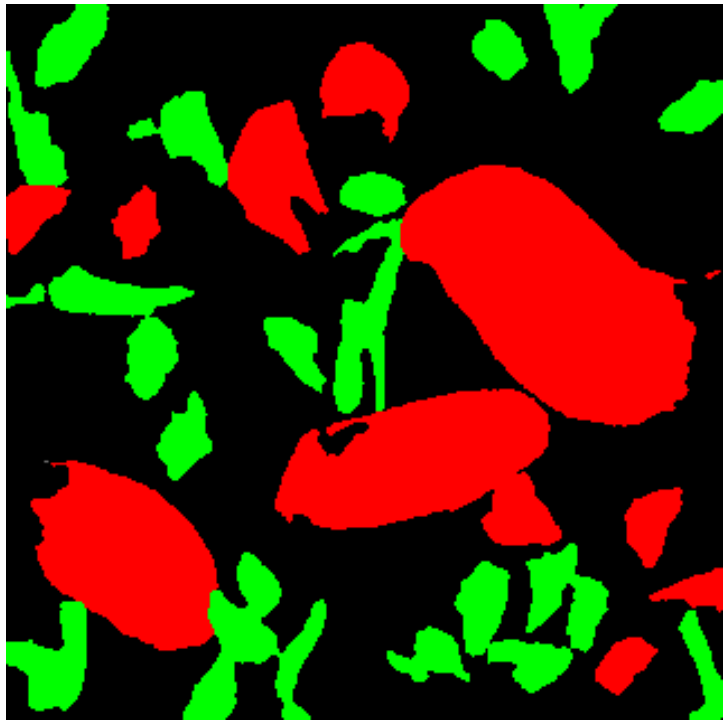

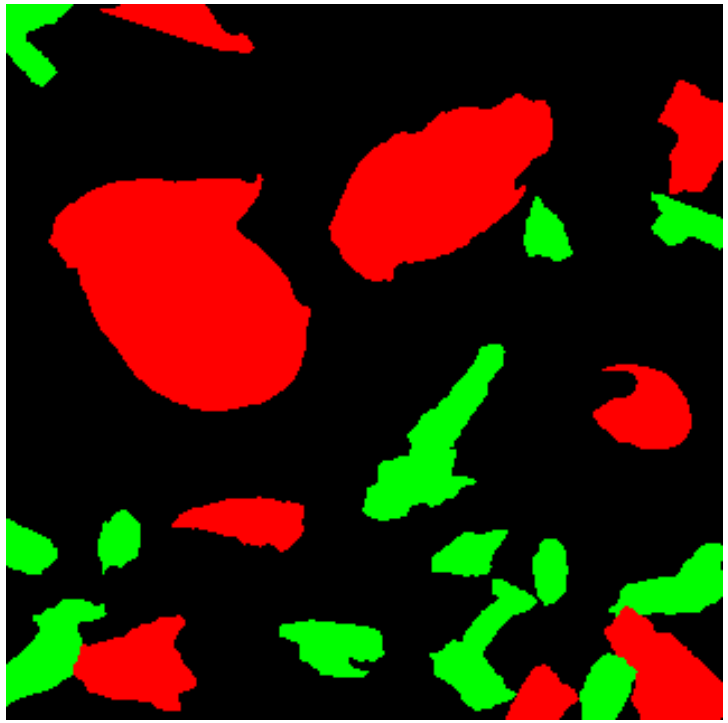

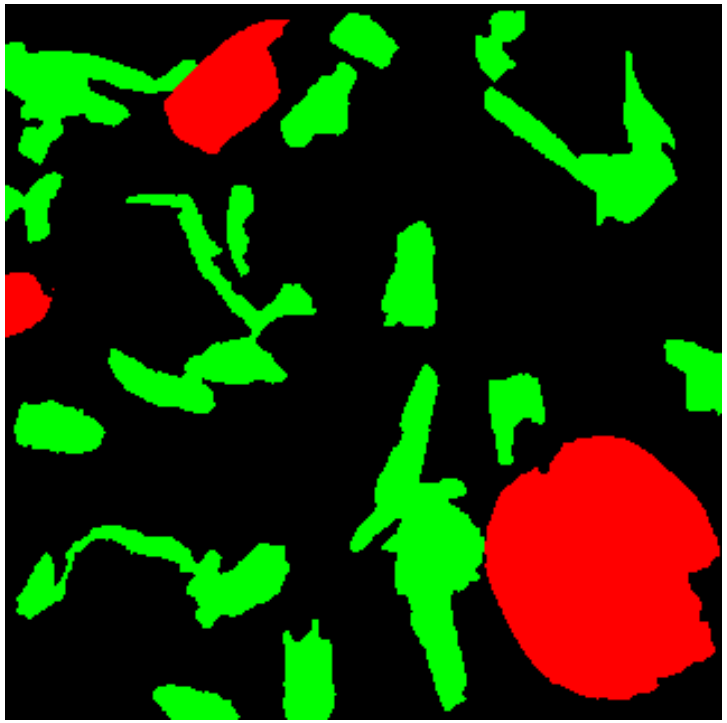

  

# Inference

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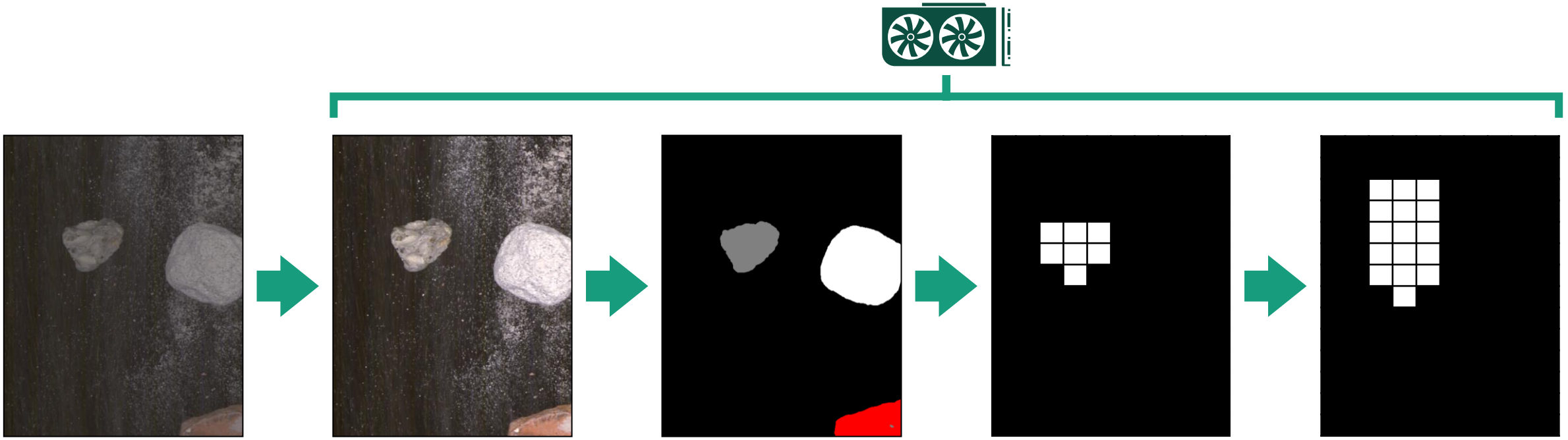
## Overview



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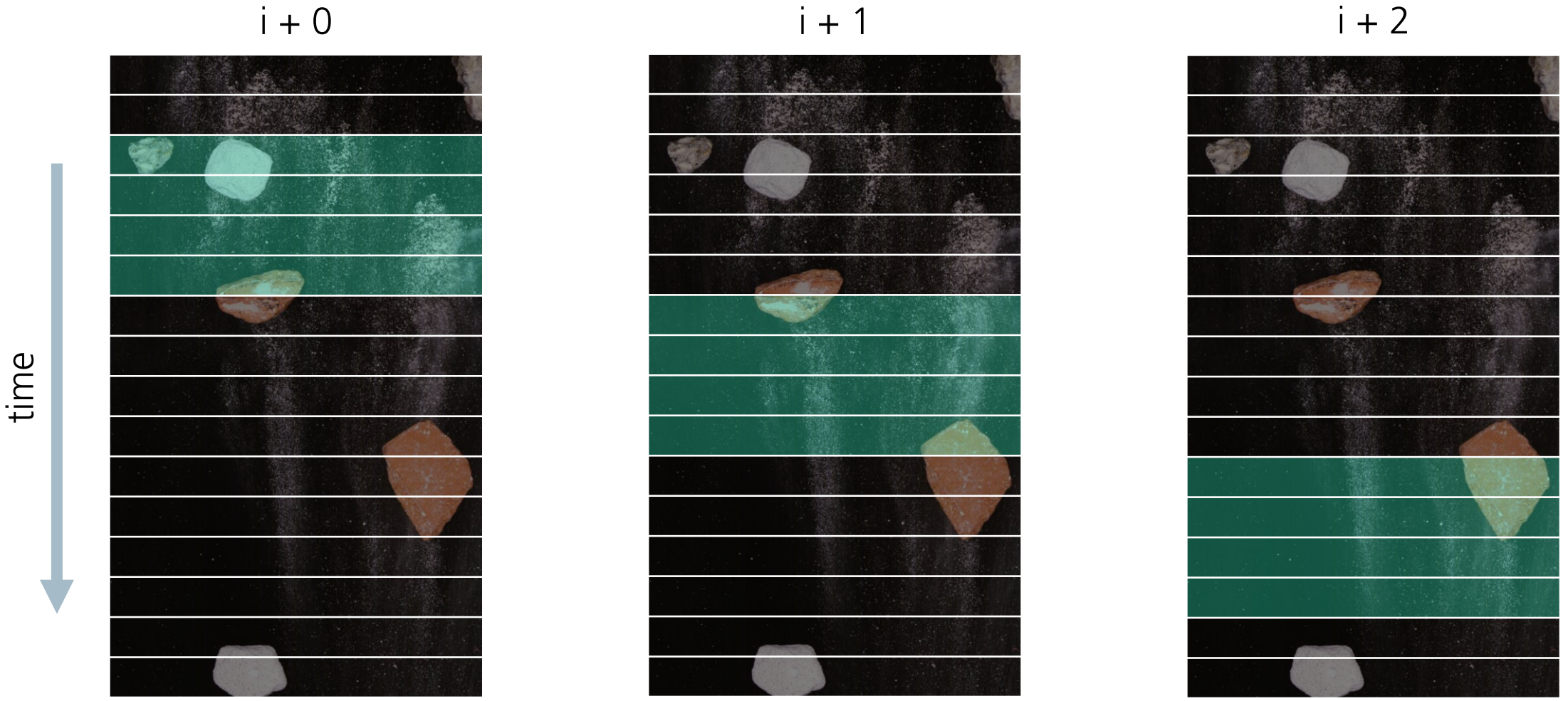


 

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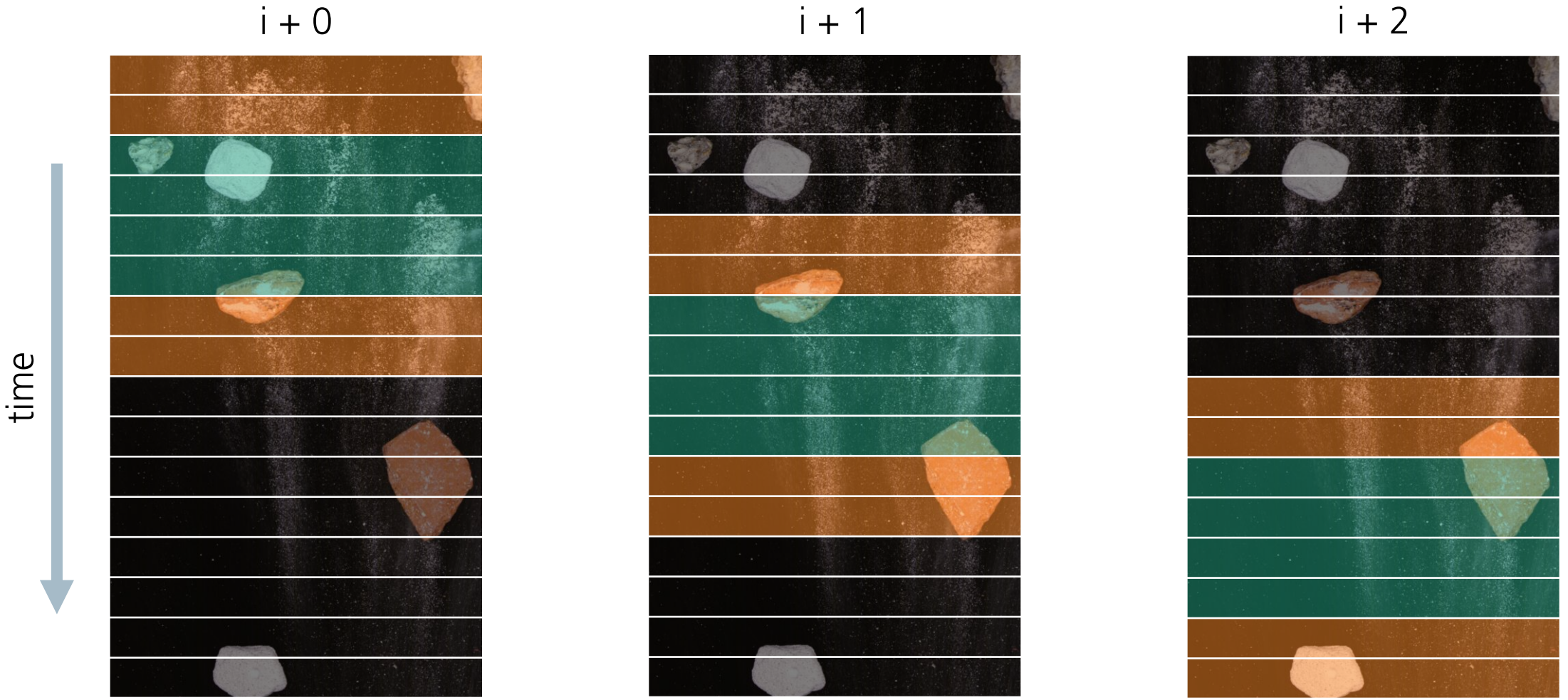


 

# Results

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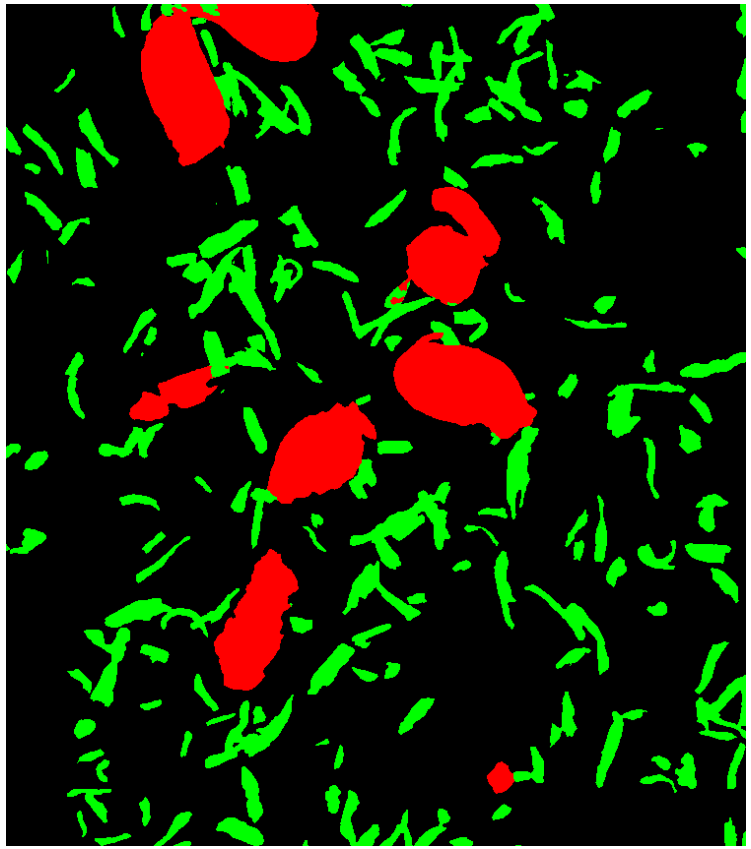
## Classification result peanuts & hibiscus tea

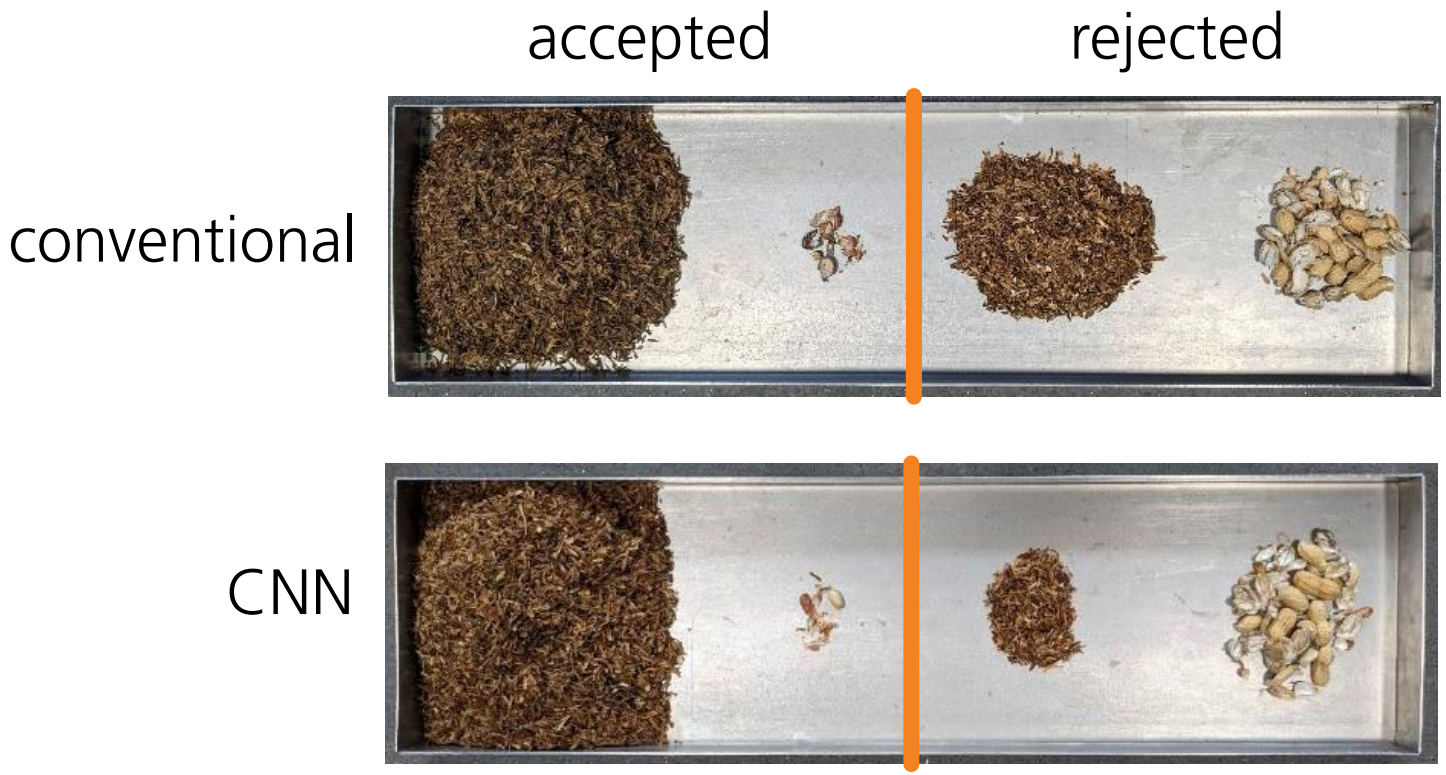
image



result (semantic segmentation)

- background
- peanut
- hibiscus

# Results
## Sorting quality: peanuts & hibiscus tea



# Results
## Sorting quality: peanuts & hibiscus tea

| | False Positive Rate | False Negative Rate |
|---|---|---|
| **Conventional** | **19 %** | **4 %** |
| **CNN** | **2 %** | **5 %** |

**Materials:**

- 400 g hibiscus tea
- 20 g peanut

# Results
## Sorting quality: peanuts & hibiscus tea

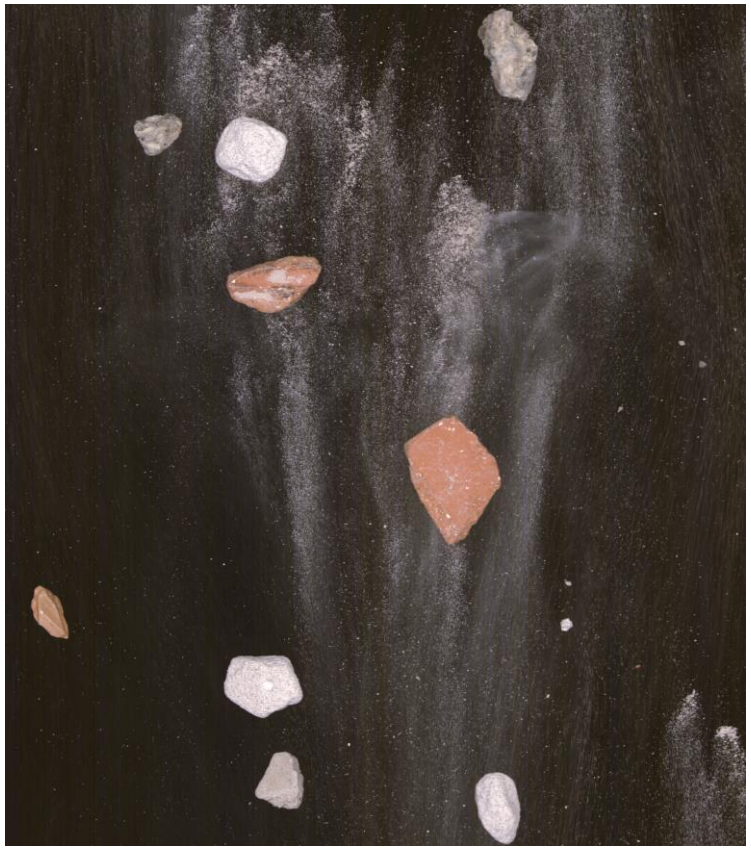
| | conventional | | CNN | |
|---|---|---|---|---|
| | hibiscus | peanut | hibiscus | peanut |
| accepted | 81.3% | 3.5% | 97.8% | 5.0% |
| rejected | 18.8% | 96.5% | 2.3% | 95.0% |

**Sorting quality in % of true material class.**

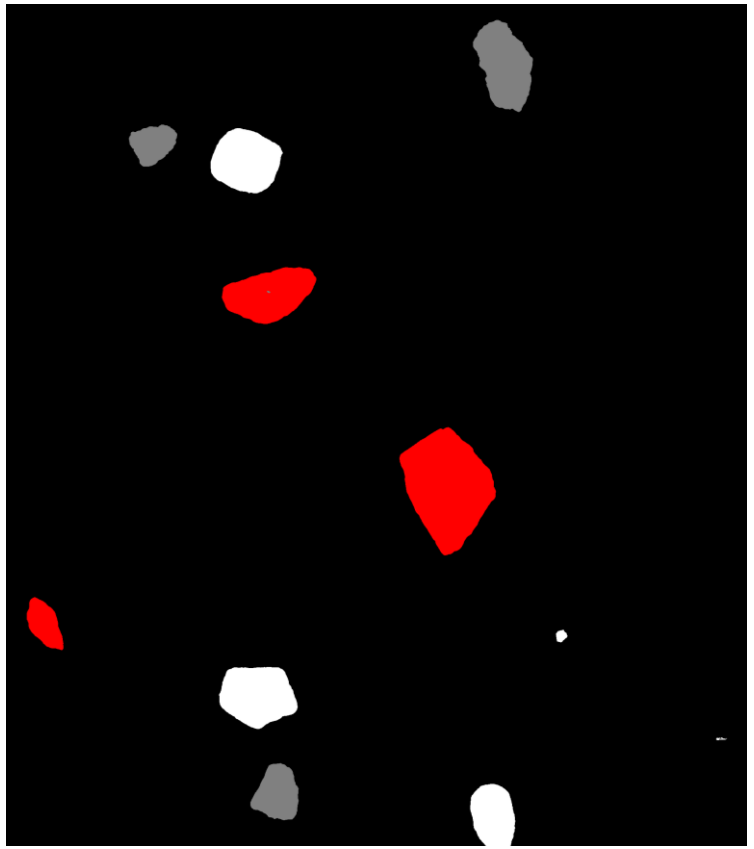
- 400 g hibiscus tea
- 20 g peanut

# Results

## Classification result construction and demolition waste



image




result (semantic segmentation)

# Results
## Sorting quality: construction and demolition waste

| | False Positive Rate | False Negative Rate |
|---|---|---|
| **Conventional** | **14 %** | **47 %** |
| **CNN** | **4 %** | **10 %** |

**Materials:**

- 2 kg concrete
- 3 kg other (brick and aerated concrete)
- 100 g dust

# Results
## Sorting quality: construction and demolition waste

| | conventional | | CNN | |
|---|---|---|---|---|
| | other | concrete | other | concrete |
| accepted | 86.2% | 42.4% | 96.3% | 9.5% |
| rejected | 13.9% | 52.9% | 2.1% | 90.0% |
| lost | 0.0% | 4.8% | 1.5% | 0.5% |

**Sorting quality in % of true material class.**

- 2 kg concrete
- 3 kg other (brick and aerated concrete)
- 100 g dust

# Realtime capability
## Example: construction and demolition waste

- 30 ms max. allowed latency
- 10 ms for line buffering (64 + 2x32 lines)
- 4 ms for all GPU calculations (NVIDIA RTX 4070 GPU)
- throughput > 13,333 lines (4096 pixels) per second
  - limited by camera

# Conclusion

# Conclusion

- conventional algorithms are limited in quality
- direct mapping of semantic segmentation result to valves
- training with synthetically generated training data
- CNN achieves increased sorting quality
- real-time capable

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OCM 2025

# OPTICAL CHARACTERIZATION OF MATERIALS

International Conference

MARCH 26th – 27th, 2025

Karlsruhe, Germany

KIT Karlsruhe Institute of Technology

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