Karlsruhe Institute of Technology

How automation, machine learning, and DNA barcoding can accelerate species discovery in “dark taxa”: Robotics and AI

International Congress of Entomology

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Motivation and Goals

- Automation to speed up bio diversity exploring
- Insects are preserved in ethanol: three main problems

sorting

- handling
- size differences
- shape differences

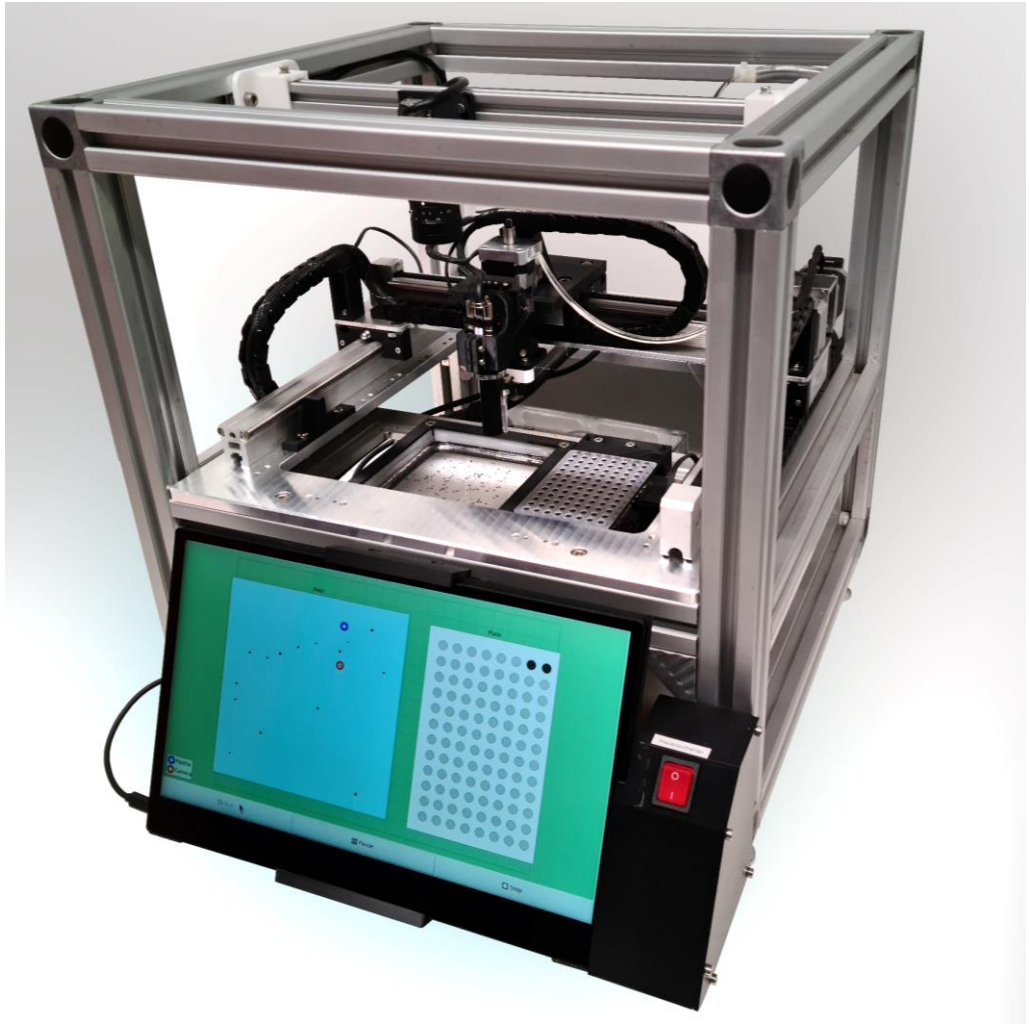
classification

- training data
- small characteristics
- position

biomass

- image-based
- exact
- segmentation

DiversityScanner
Setup



- Petri dish for specimens
- 96-well microplate for further processing (e.g. DNA-barcoding)
- Overview camera
- Detail camera
- Automated pipette
- Three linear axes
- Graphical User Interface (GUI)
  - Specimen position
  - Camera and pipette position
  - Filled wells

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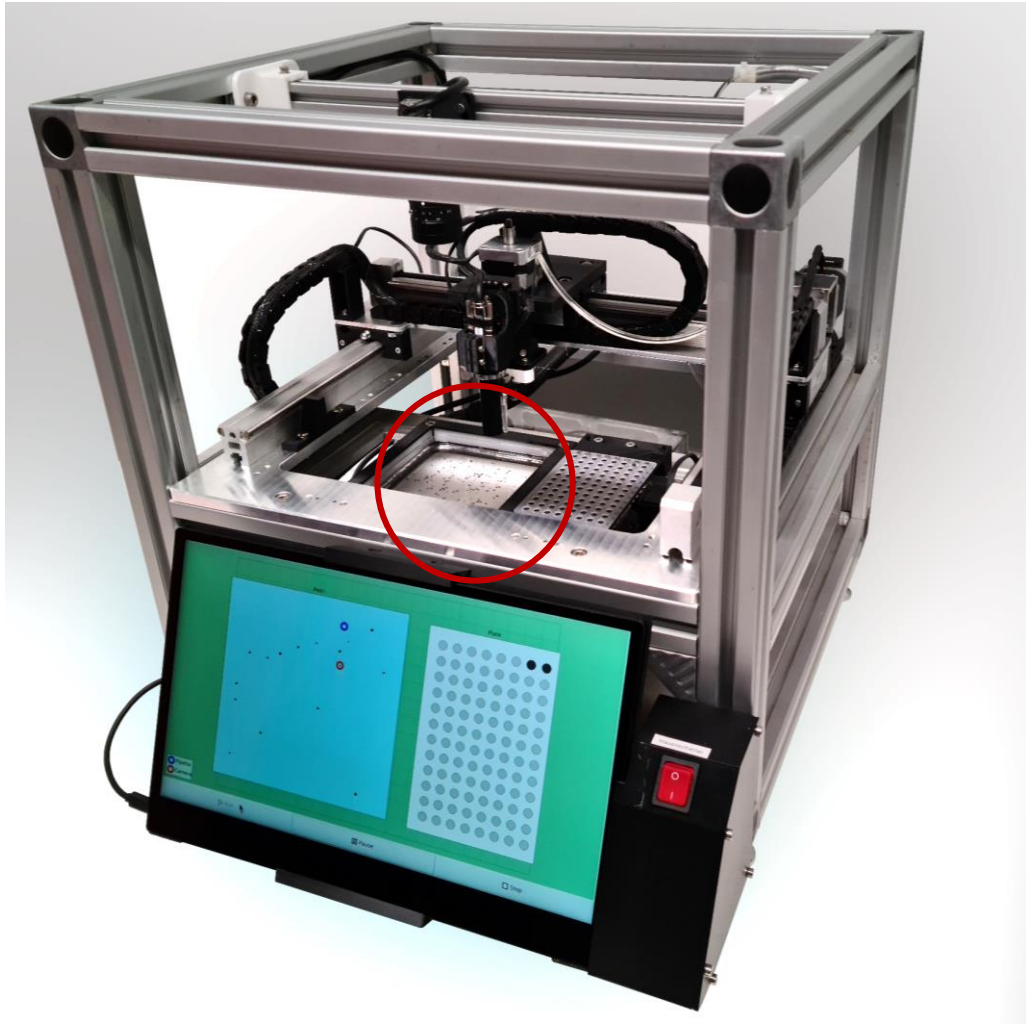

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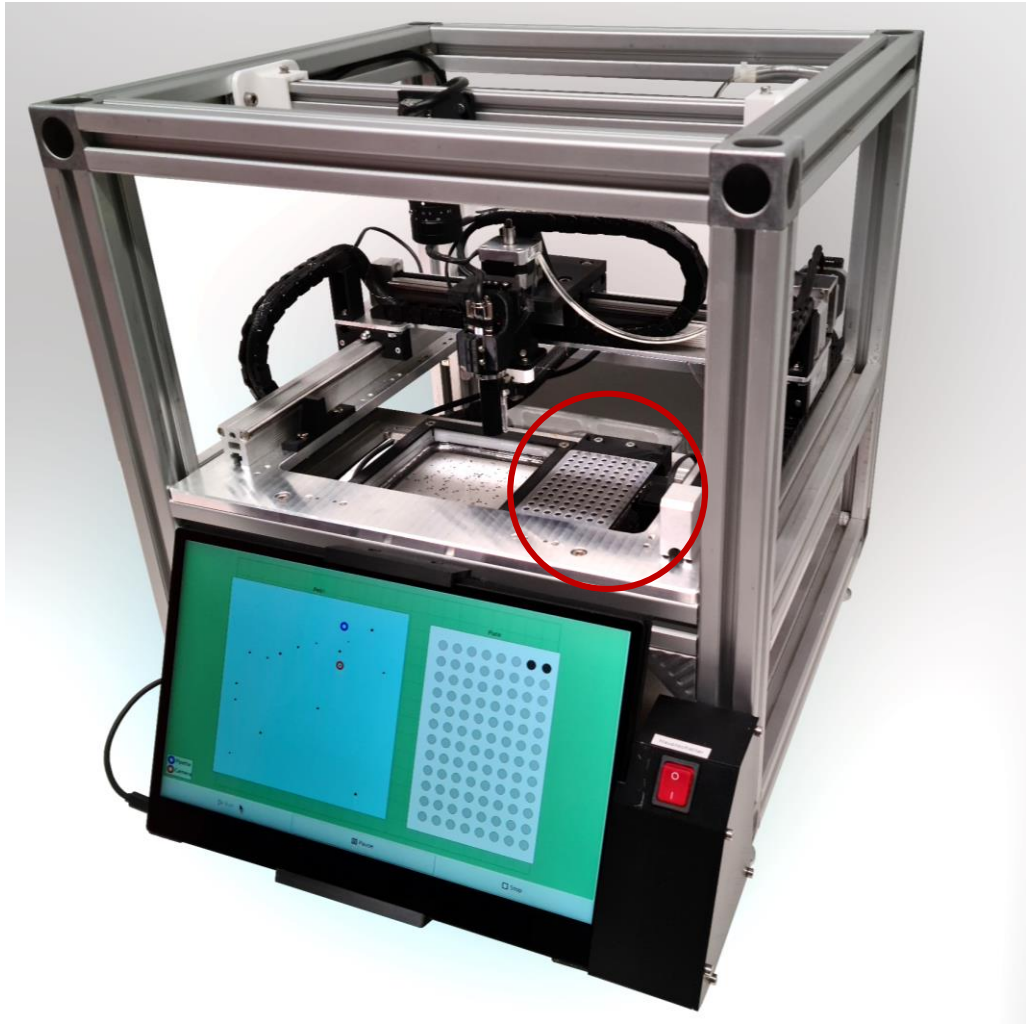

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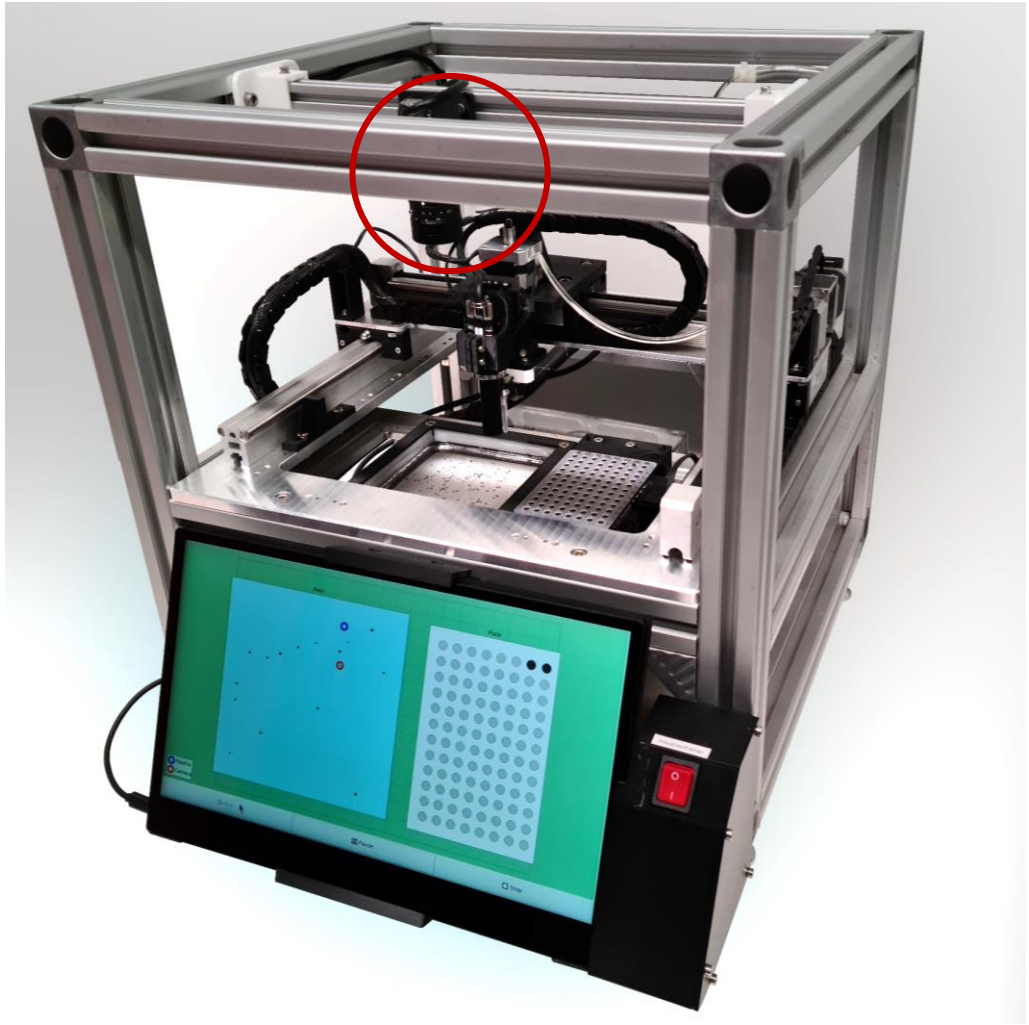

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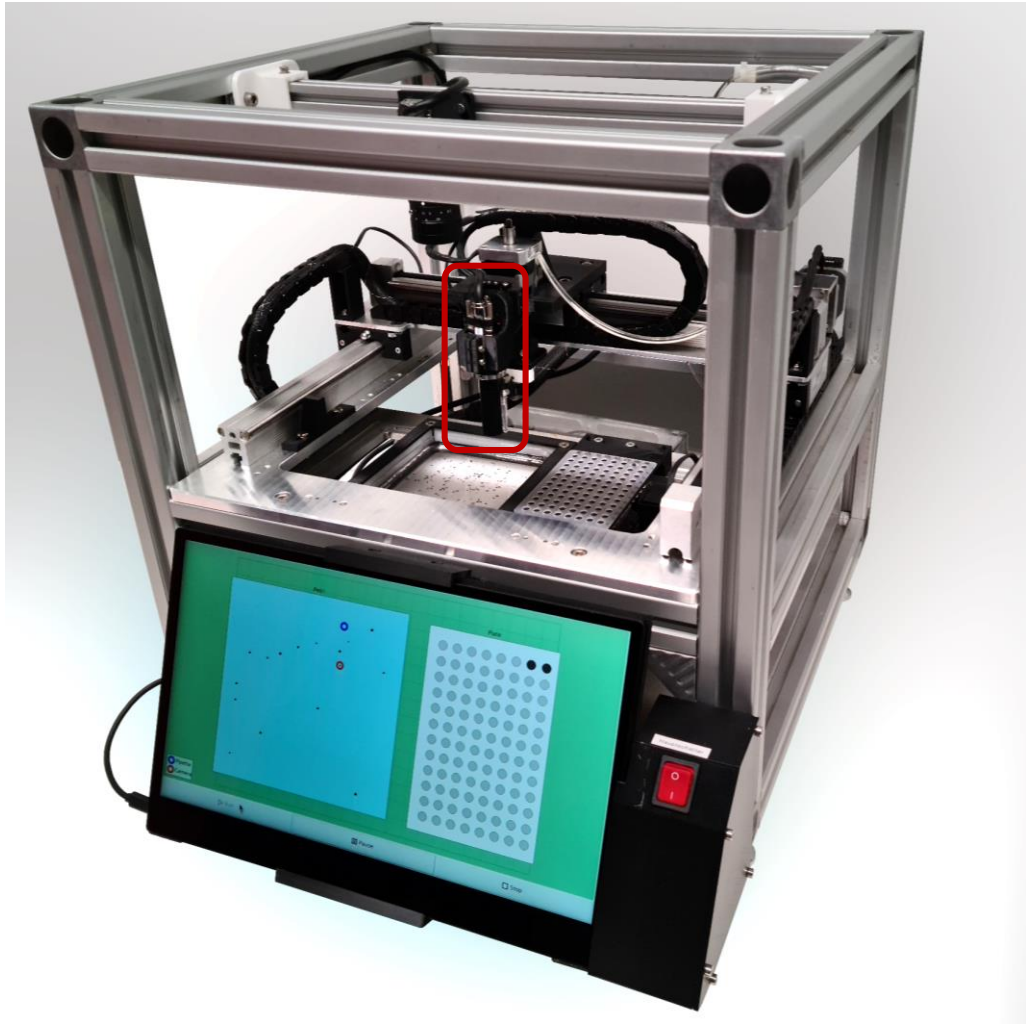

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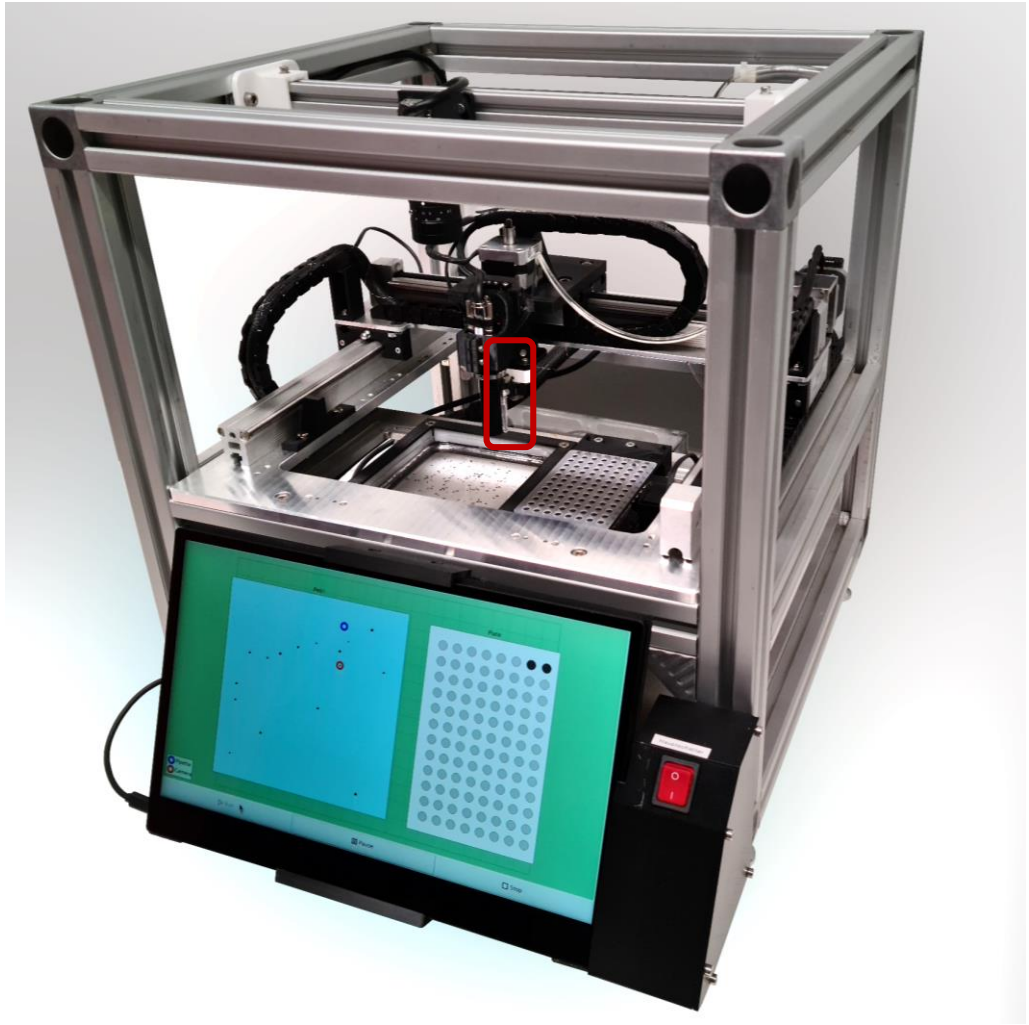

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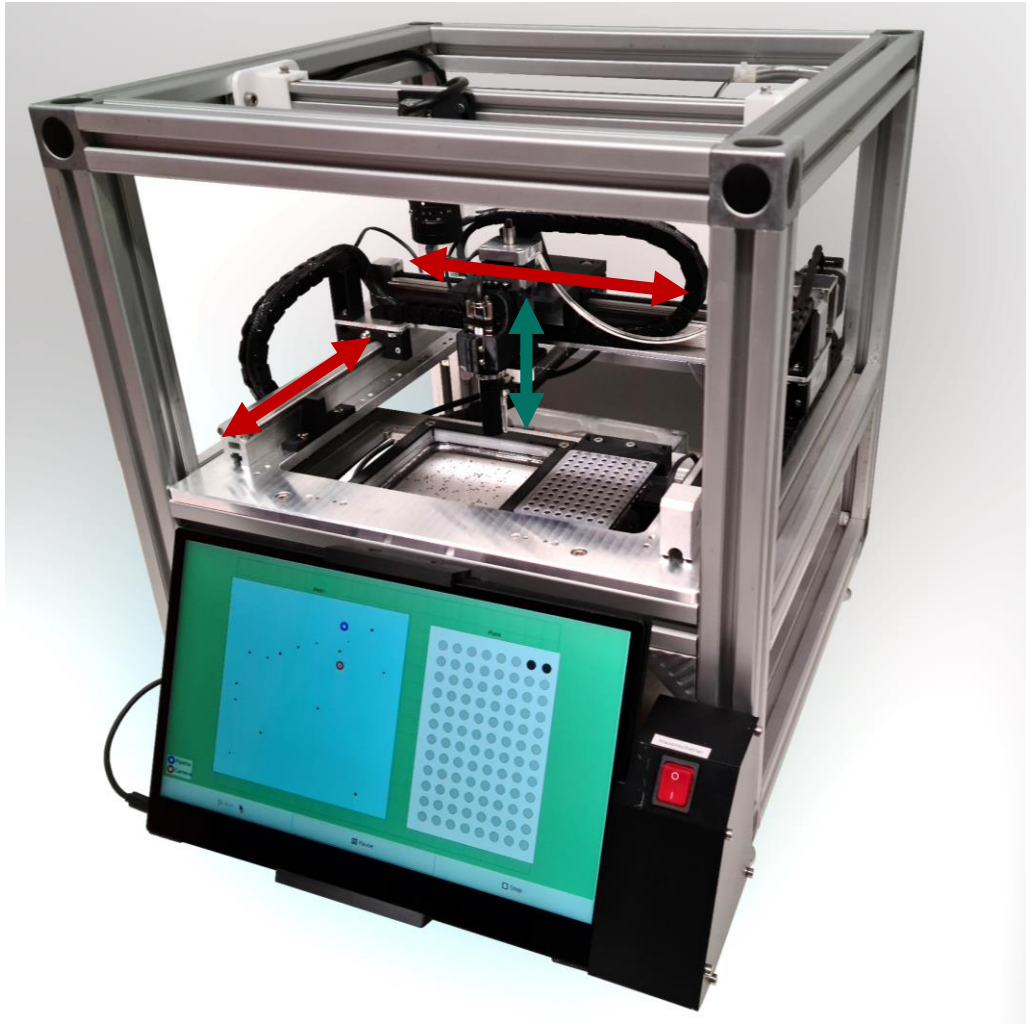

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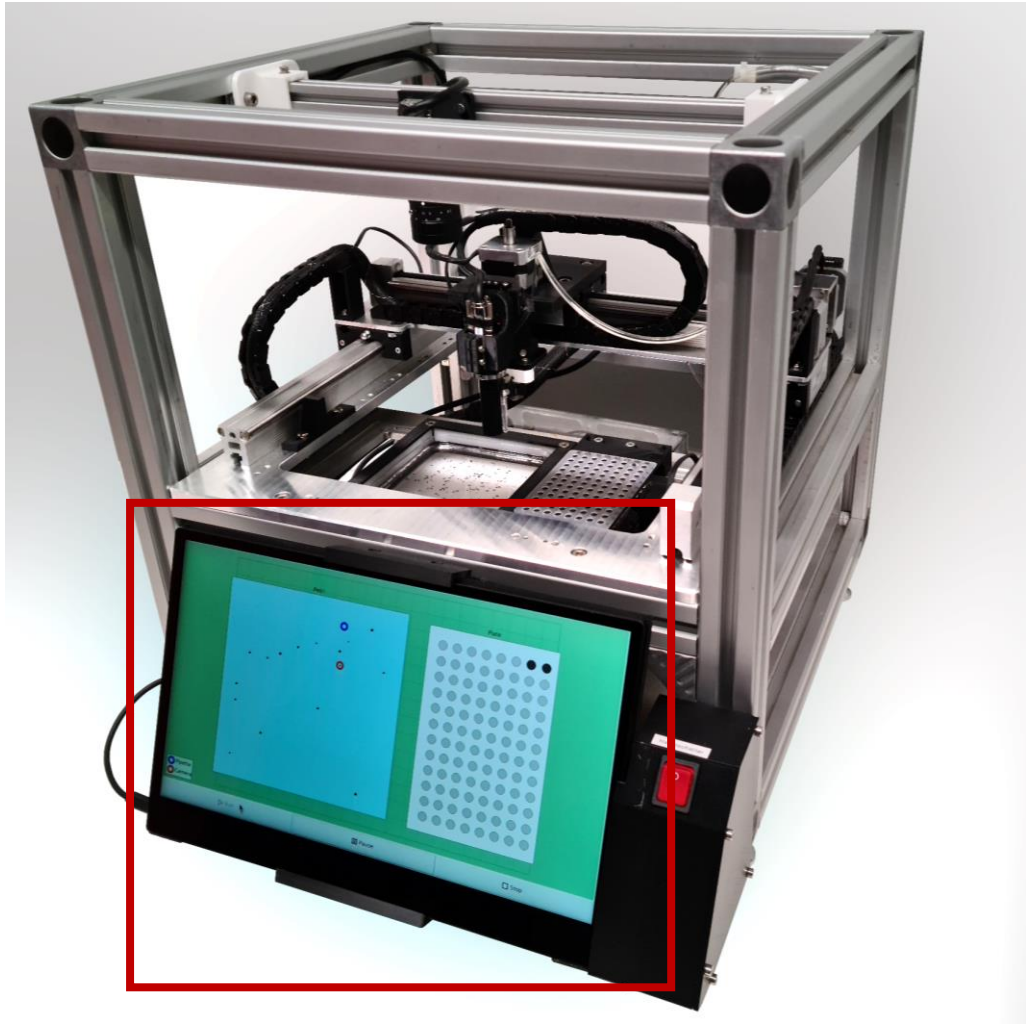

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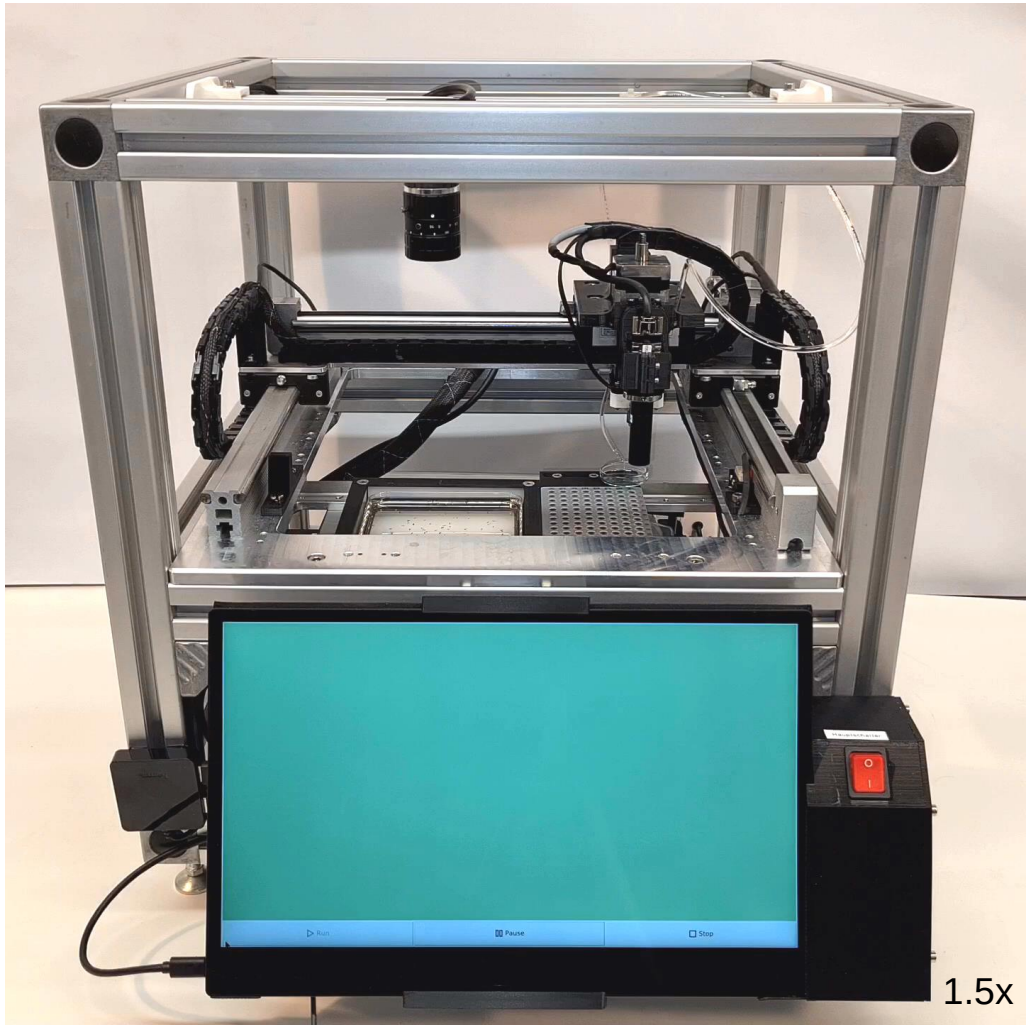

1.5x

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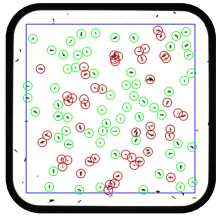
DiversityScanner
Workflow of the DiversityScanner

Overview Image



Insect positon detection

Detail Image

Detailed specimen image for further processing

Specimen sorting

Sorting specimen from Petri dish in a microplate

Specimen classification

Biomass estimation

DiversityScanner
Workflow of the DiversityScanner

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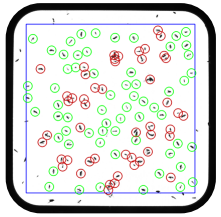

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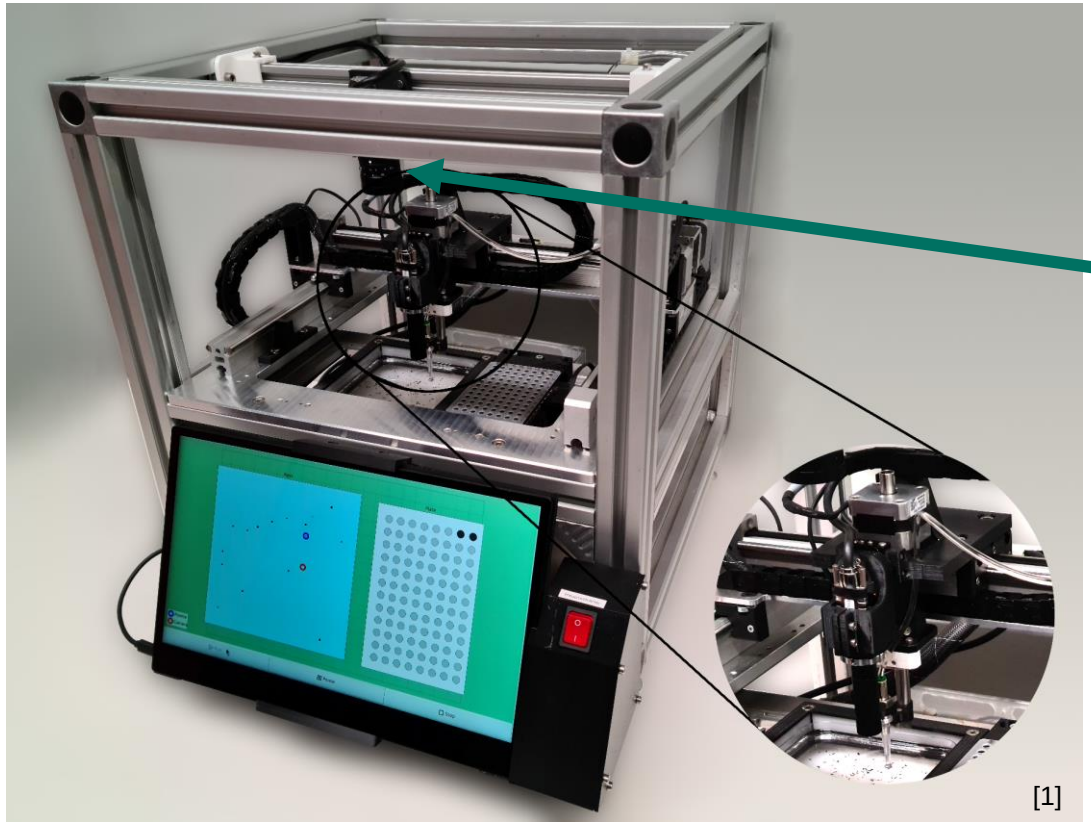
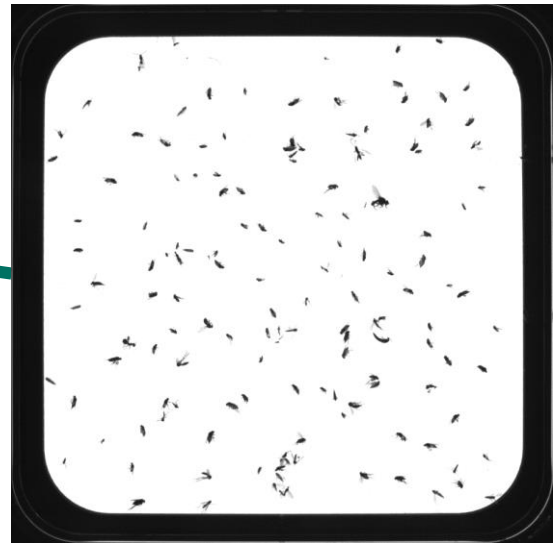
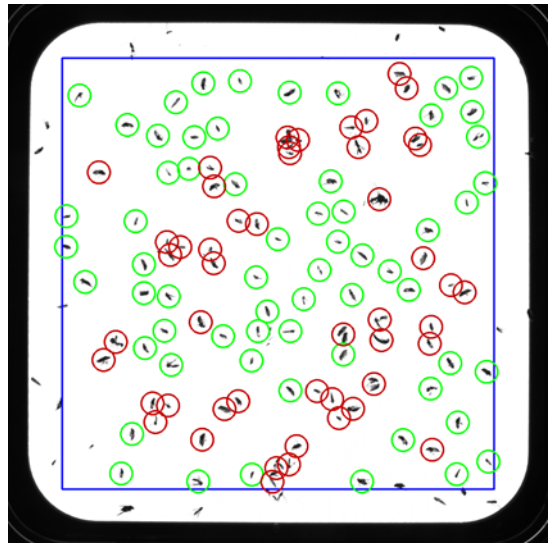
DiversityScanner
Specimen Position Determination

- Overview image to find specimen position in 120 x 120 mm Petri dish


[1]



Overview image of Petri dish

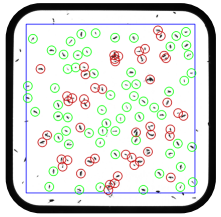


Marked image
green: sortable insects
red: not sortable insects
blue: ROI

[1] Wührl et al., "Diversityscanner: Robotic handling of small invertebrates with machine learning methods" 2022.

DiversityScanner
Workflow of the DiversityScanner

Overview Image



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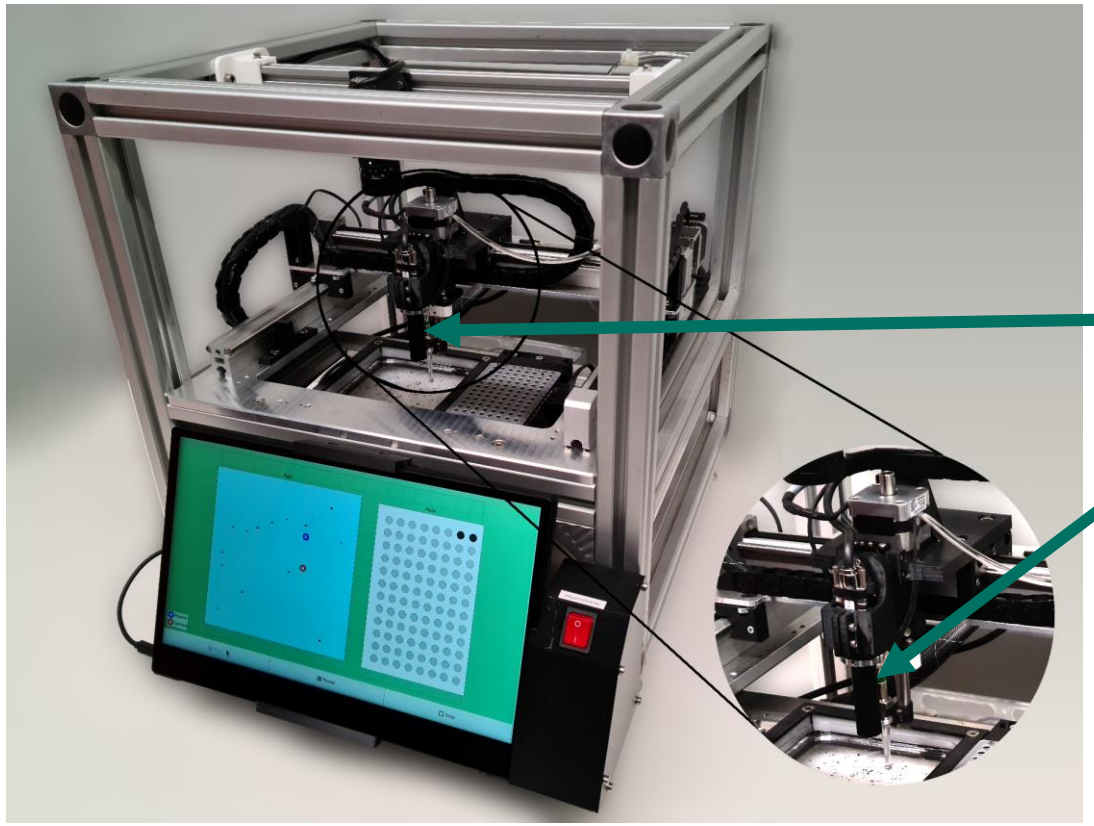
DiversityScanner
Imaging



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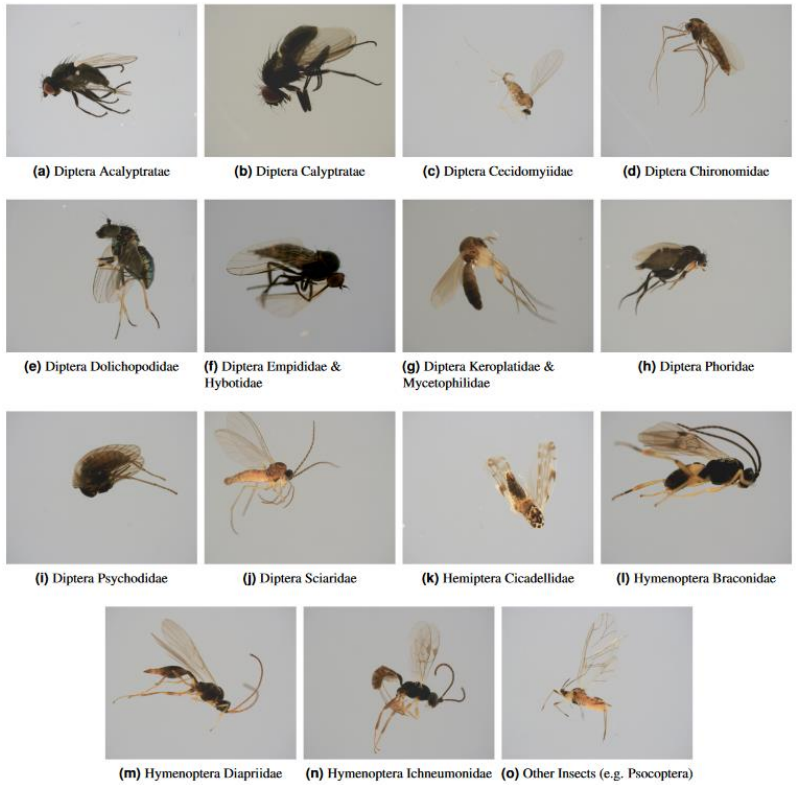


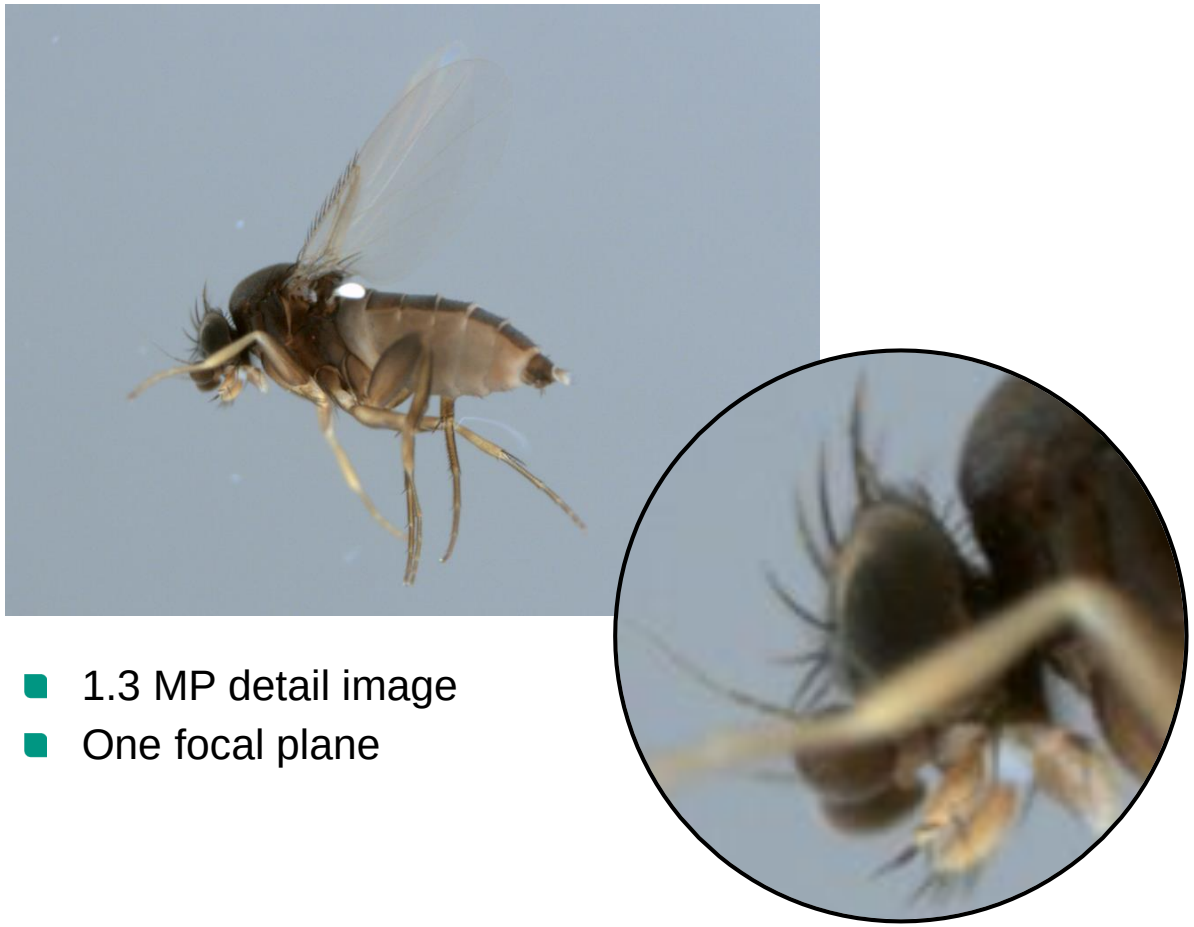
Detail image for classification and volume estimation

[1]

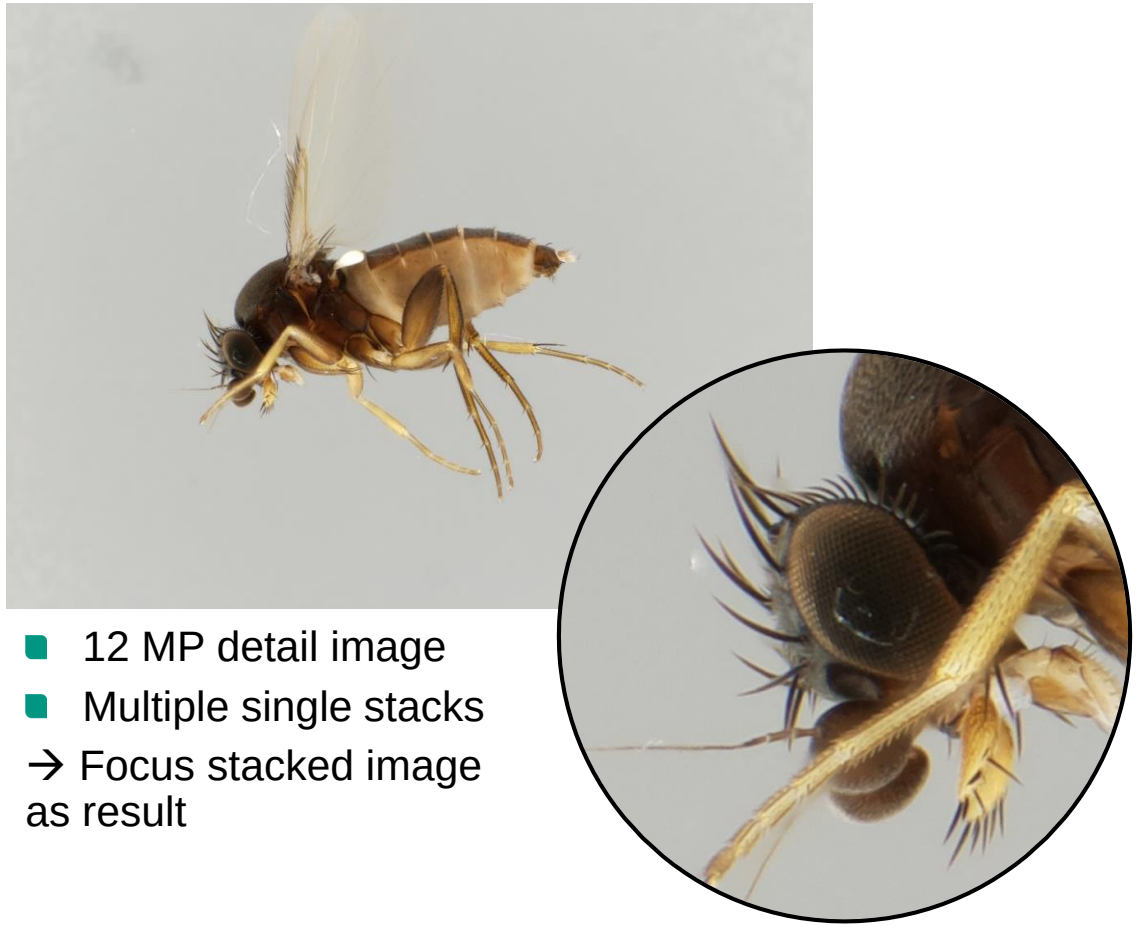
[1] Wührl et al., "Diversityscanner: Robotic handling of small invertebrates with machine learning methods," 2022.

DiversityScanner

Imaging: 4K Camera Upgrade for the DiversityScanner 4K



- 1.3 MP detail image
- One focal plane



- 12 MP detail image
- Multiple single stacks

→ Focus stacked image as result

DiversityScanner

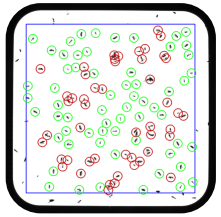
Imaging: 4K Camera Upgrade for the DiversityScanner 4K

Single focus image

Stacked image

DiversityScanner
Workflow of the DiversityScanner

Overview Image



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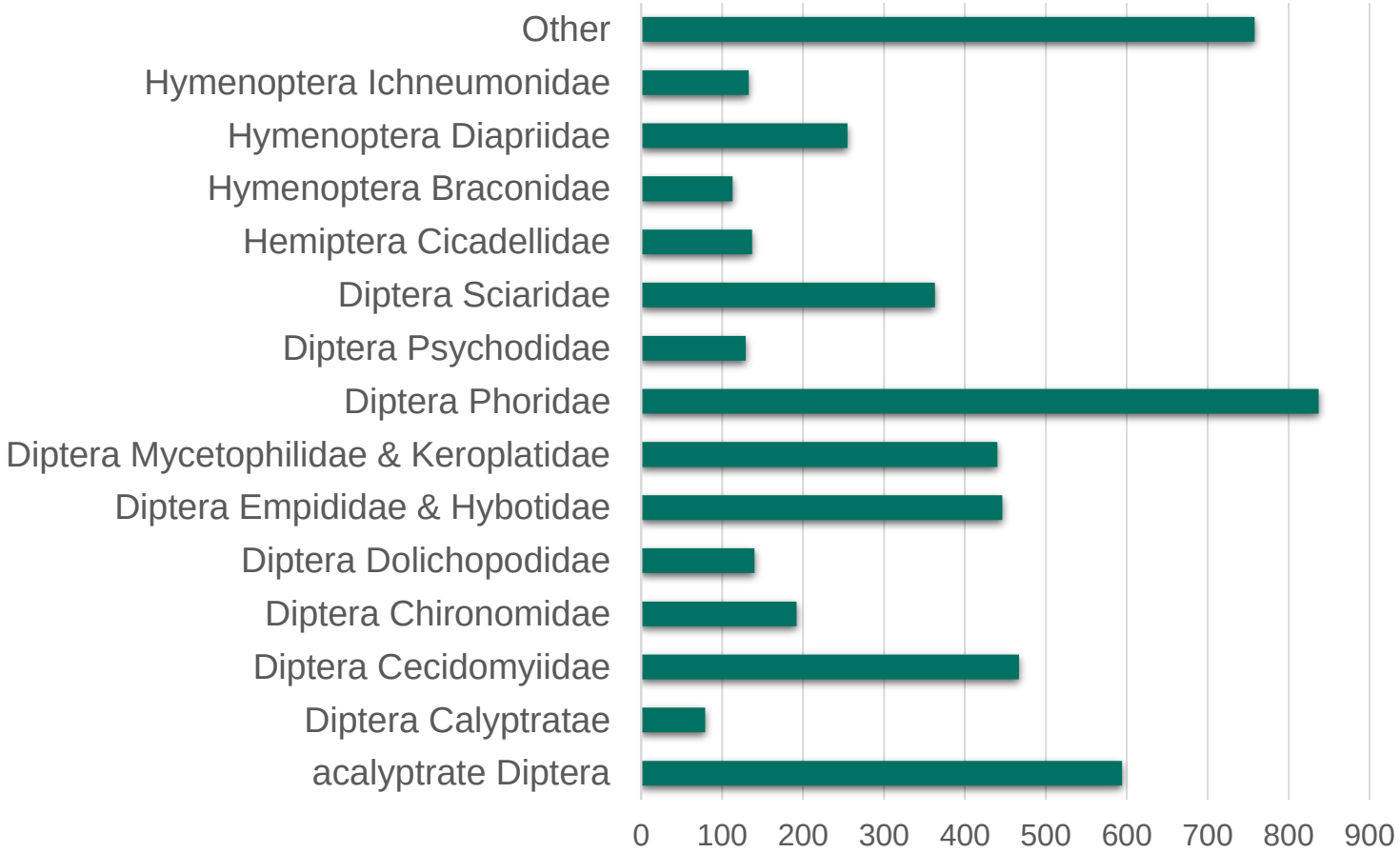
DiversityScanner
Specimen Classification

Total number of Images per class



- Self generated Dataset with **5083 images** for **15 classes**
- Images from five Malaise traps
  - Classes were selected from which sufficient images were available
- Image data from databases proved to be problematic
  - Often same view
  - Scales, writing or other artefacts in image

Data Availability: https://doi.naturkundemuseum.berlin/data/10.7479/4tbx-qm72

Data from: Wührl et al., "Diversityscanner: Robotic handling of small invertebrates with machine learning methods," 2022.

DiversityScanner
Specimen Classification

- VGG19 – Architecture
- Worst result for:
  - Hymenoptera Ichneumonidae (75%)
- Best result for
  - Hymenoptera Diapriidae (100%)
  - Hemiptera Cicadellidae (100%)

→ **Total accuracy: 91.4%**

Class	Accuracy
Other	**0.810**
Hymenoptera Ichneumonidae	**0.750**
Hymenoptera Diapriidae	**1.000**
Hymenoptera Braconidae	**0.818**
Hemiptera Cicadellidae	**1.000**
Dipt. Sciaridae	**0.922**
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Dipt. Empididae & Hybotidae	**0.866**
Dipt. Dolichopodidae	**0.857**
Dipt. Chironomidae	**0.939**
Dipt. Cecidomyiidae	**0.915**
Dipt. Calyptratae	**0.833**
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Workflow of the DiversityScanner

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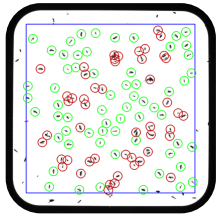

Insect positon detection

Detail Image

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Sorting specimen from Petri dish in a microplate

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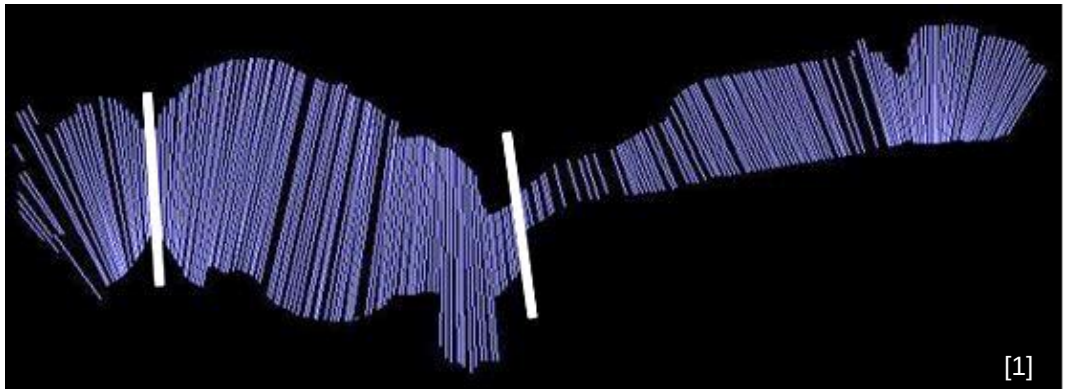
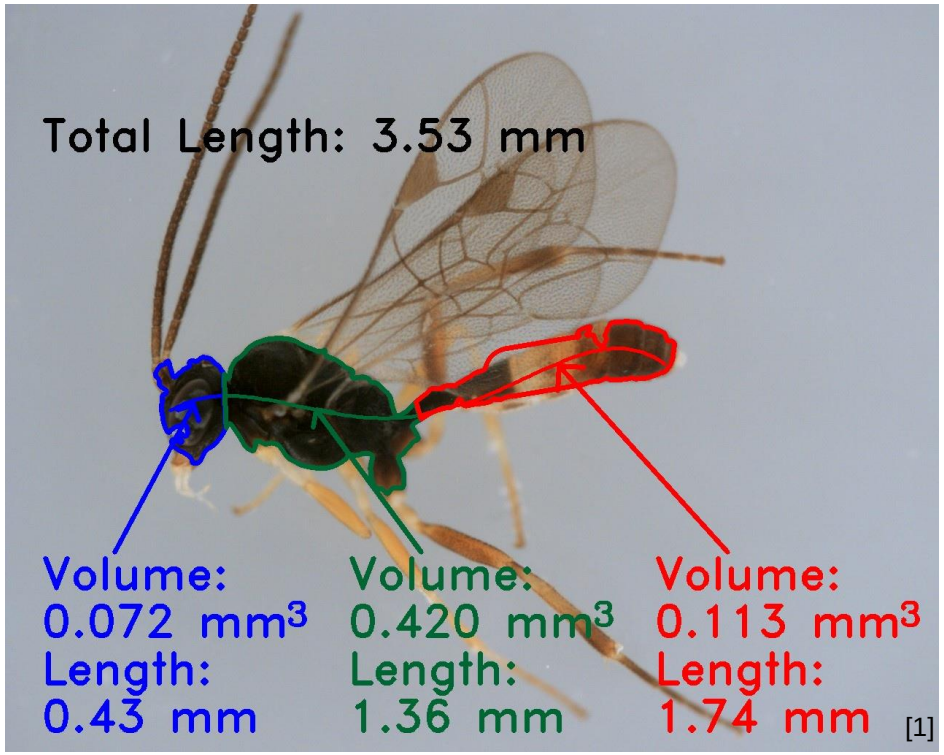
Biomass estimation

DiversityScanner
Biomass Estimation

- Detail images to estimate biomass and length of individual specimens
- Classical image processing
  - Good results without labeling and training data
- Volume is estimated using circular disks





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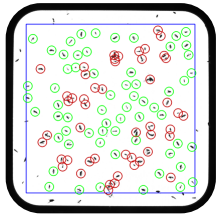

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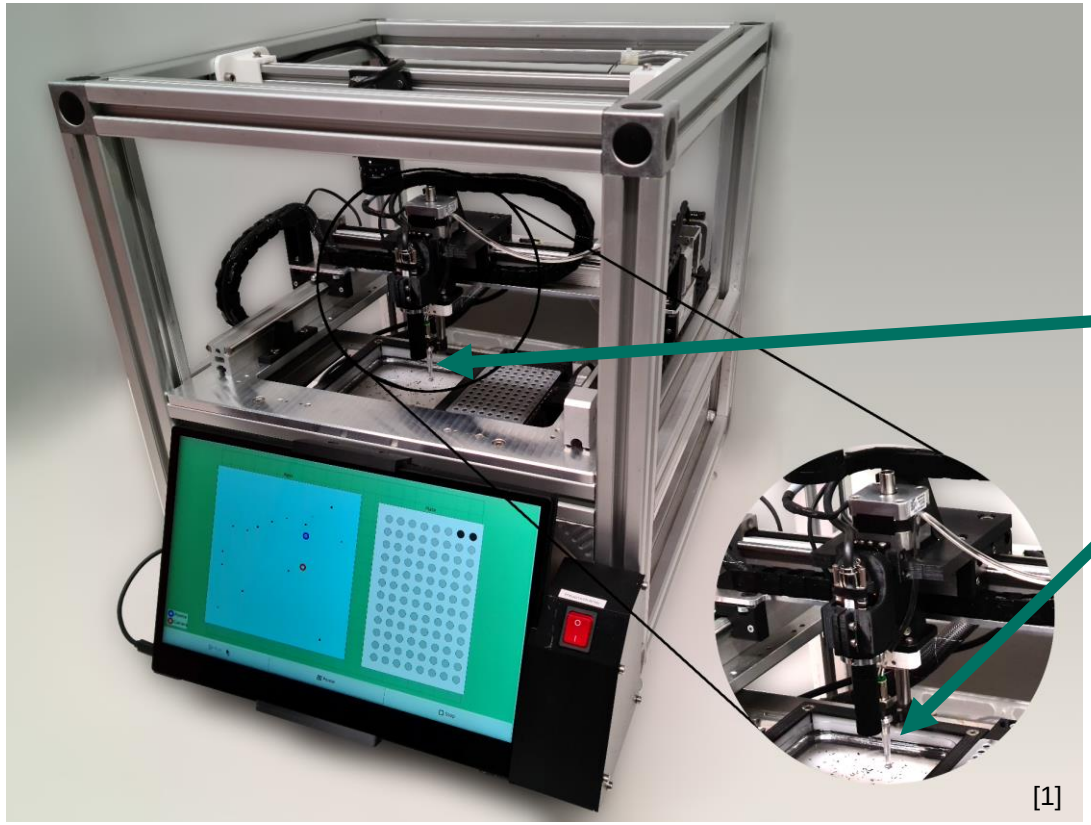
DiversityScanner
Sorting

- Sorting specimens into 96-well microplate (invertebrates < 3mm)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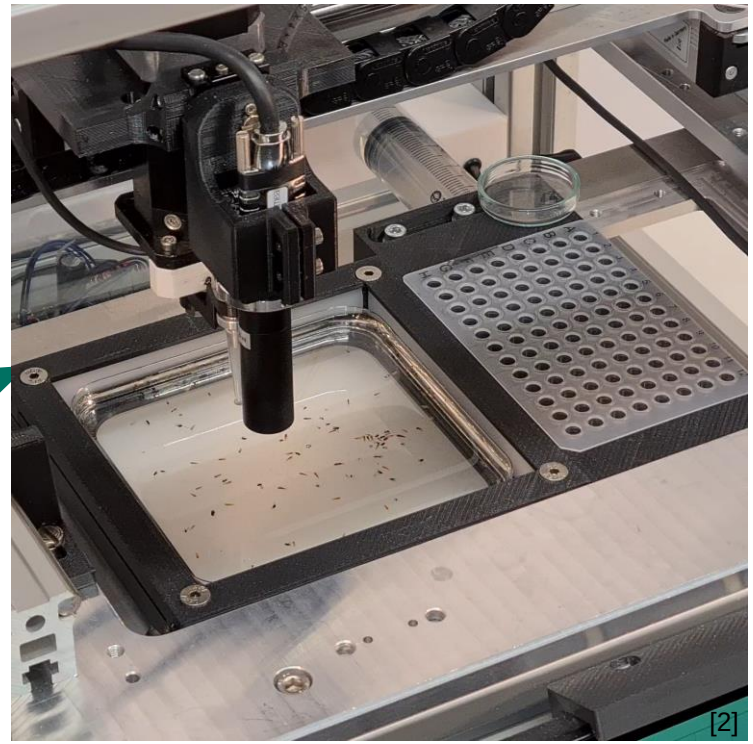
[2]

Sorting insect into a microplate

[1] Wührl et al., “Diversityscanner: Robotic handling of small invertebrates with machine learning methods,” 2022.
[2] https://www.youtube.com/watch?v=ElJ5VSHa4OI

DiversityScanner
Summary

- Robotics and AI can be utilized to accelerate species discovery in „dark taxa“
- Robotics can be used to perform repetitive and tedious tasks
  - Upscaling and parallelization enable high throughput
- AI enables classification of the specimens for e.g. pre-sorting
- Generated image data for:
  - New training sets
  - Classification to higher taxonomic level

DiversityScanner
Video

https://www.youtube.com/watch?v=ElJ5VSHa4OI