UNIVERSITÄT
ZU KÖLN

BOZEK LAB
DATA SCIENCE OF BIOIMAGES

Computer Vision

Prof. Dr. rer. nat. Katarzyna Bozek

Faculty of Mathematics and Natural Sciences

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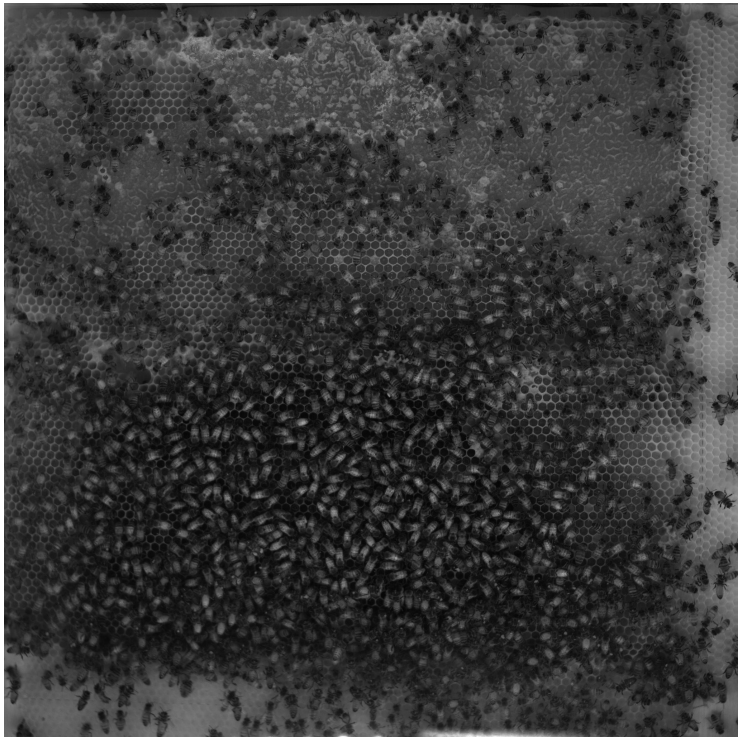
Projects

Determining Object Orientation

Paper, Supplement Material

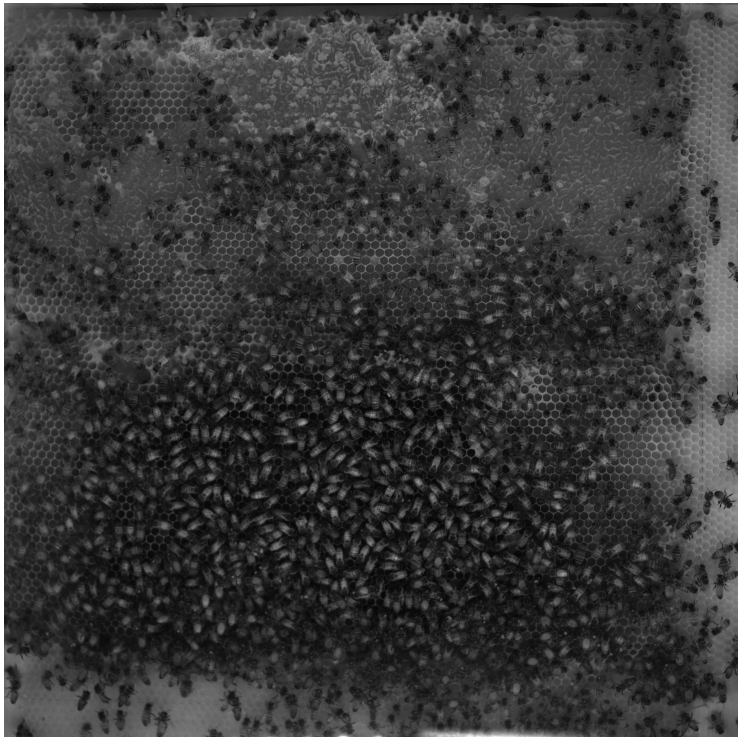
- There are no gold-standard methods for determining object orientation using neural networks
- The Honeybee dataset contains of images of bees on a 2D plane
- Manually annotated positions of individual bee center points and their orientation angles
- Task
  - Investigate and propose a method that given a small cropped image of a bee outputs this orientation angle.
  - Limit your dataset to the fully visible bees, that is, exclude those that are hiding inside of the honeycomb.



Representation Learning of Honeybees

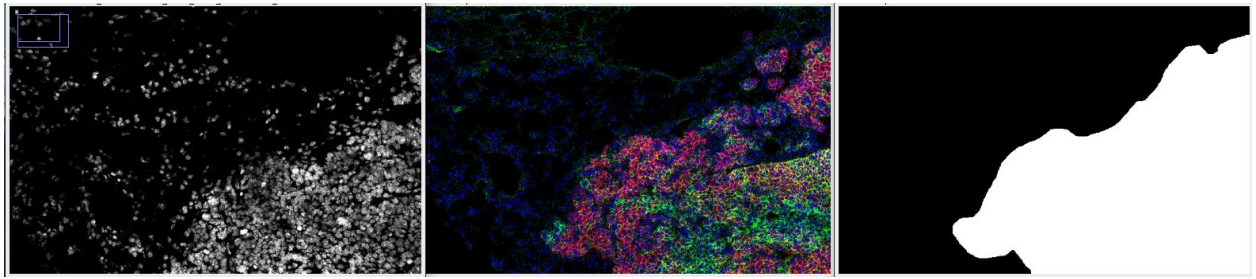
Paper, Supplement Material

- Same Honeybee dataset
- Task
  - Propose neural network–based representations of cropped images of individual bees
  - Your representations can be derived from a self– or unsupervised learning method
  - They should reflect key visual information about these bees such as their orientation or position
  - You can verify what kind of information do the representations capture using visualization and clustering methods



Tumor Segmentation from Multiplex Mass Spectrometry Imaging

- Mass spectrometry imaging (MSI) is a powerful tool that enables untargeted investigations into the spatial distribution of molecular species in a variety of samples
- It emerged as a way to bypass the spectrum overlap problem of traditional microscopy
- However, it is difficult to image more than 4 channels at the same time without compromising the quality of the signal
- Task
  - Binary segmentation of tumors
    - Build a classification network on a few extracted channels
    - Use available channels and compare the performance with hand selected channels
    - An automated selection method (neural network layer or other) can be developed
  - Challenges: Low resolution and high number of channels



Instance Segmentation of C. Elegans

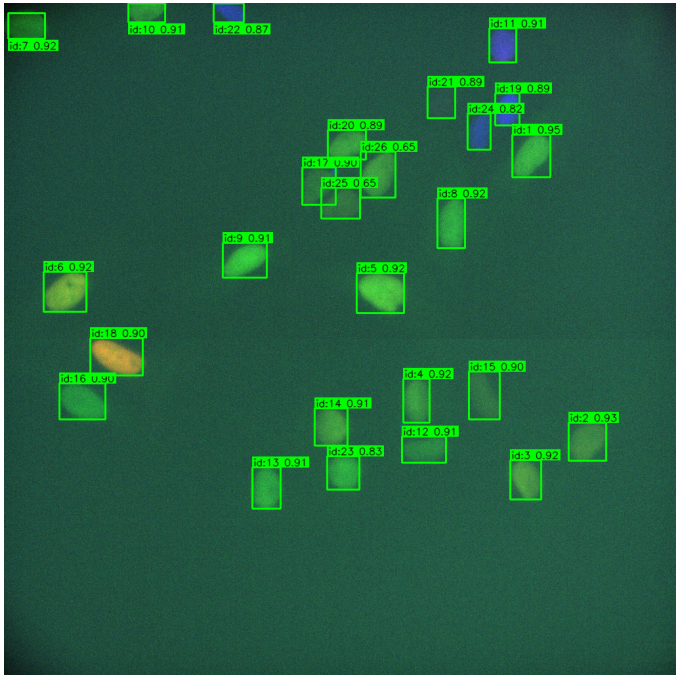
- C. elegans, a tiny nematode worm, is used to study a broad range of questions in biology, from diseases to neural function
- This apparently simple organism shows a broad repertoire of behaviors incomprehensible to human observers
- These behaviors might be representative of its health and disease phenotype
- To be able to evaluate the behavior of a single nematode it is beneficial to first segment them in video/image data
- This can be a challenging task as C. elegans tend to highly overlap
- Task
  - Use the video dataset
  - Investigate and compare approaches for instance segmentations to segment the C. elegans in the frames/videos
  - And/Or come up with your own approach
- Dataset: https://zenodo.org/records/7456803

Detection of insects caught by Yellow Sticky Traps

- Yellow Sticky Traps are used e.g. for pest control in greenhouses
- Images are automatically recorded in a controlled environment
- Depending on the caught pest insects counter measures can be initiated
- Precise identification and counting of insects enables the use of specialized environmental-friendly pest control like the release of predatory insects
- This way the use of harmful pesticides can be reduced
- Task
  - Apply and compare novel/SOTA methods to detect labeled pest insects
  - And/Or come up with your own approach
- Dataset: https://github.com/md-121/yellow-sticky-traps-dataset

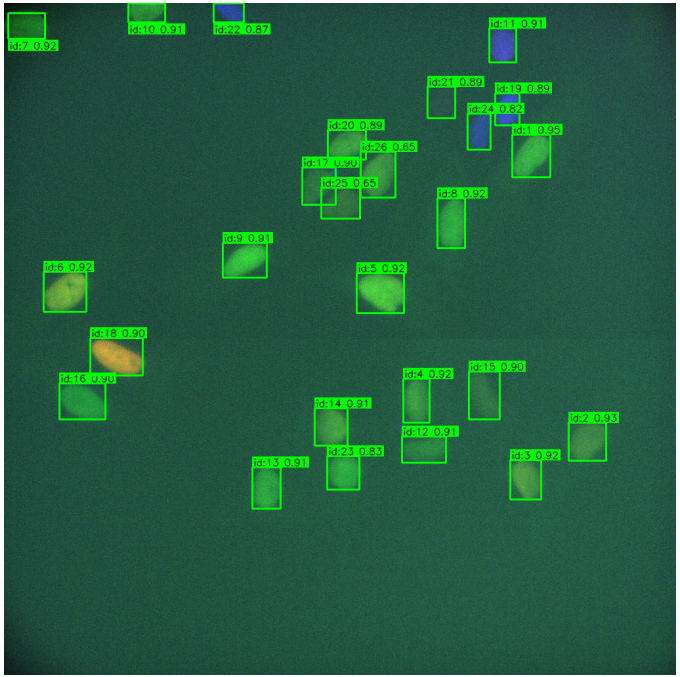
Unsupervised Representations of Cells

- Annotating microscopy images of cancer cells is labor-intensive and requires expert knowledge
- Unsupervised methods can learn useful representations without the need for extensive labeled data, reducing reliance on costly and time-consuming annotation processes
- In cancer research, rare events such as specific mutations or cell states can be critical. Characterizing these rare events without needing a large number of labeled examples can be very beneficial
- Task
  - Select features (handcrafted/deep learning)
  - Cluster cells based on feature representations
  - Classify cell types or cell cycle phase
  - Evaluate your method with GT data
  - Identify (most) predicative features



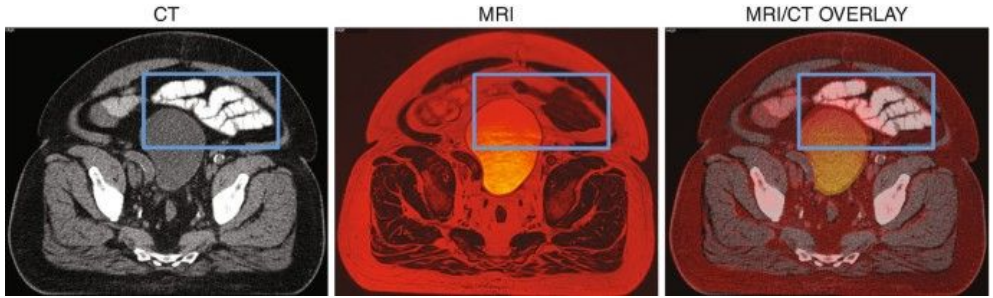
Cell Tracking

- Studying the response of cells to chemotherapeutic drugs and estimating their proliferation behavior precisely requires manual analysis of an expert
- Documentation of cell deaths and cell divisions is time-consuming and costly
- Task
  - Investigate a suitable method to match given detections across frames
  - You can use two consecutive frames or multiple frames at once
  - Output the tracklets of the cells and evaluate your approach with suitable metrics



Medical image registration

- Image registration is essential for aligning different scans for accurate comparison and analysis, for example:
  - To simultaneously analyze different image modalities of the same sample, like MRI and CT scans.
  - To facilitate surgical planning.
- Both classical methods and deep learning methods are valid in different scenarios.



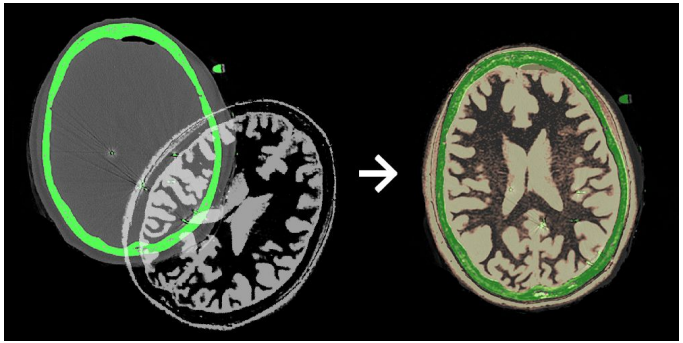
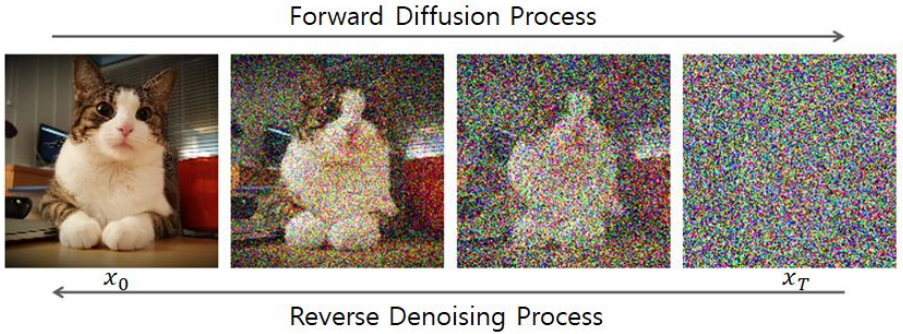


Image synthesis

Possible projects:

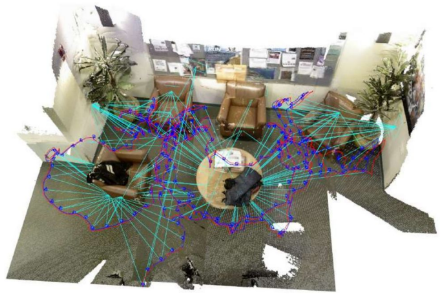
- Implement a **Diffusion Model**, compare it with a **Variational Autoencoder.**
- Implement a **Neural Style Transfer** model, compare it with the **Image Quilting algorithm.**

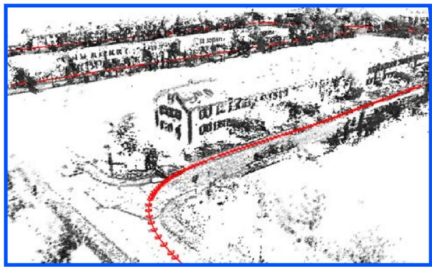


3D Computer Vision

Possible projects:

- **Simultaneous Localization and Mapping (SLAM)**, essential for autonomous navigation without requiring GPS/LPS.
- Depth estimation from **stereo images.**
- 3D reconstruction with **Structure from Motion** and **NERF.**





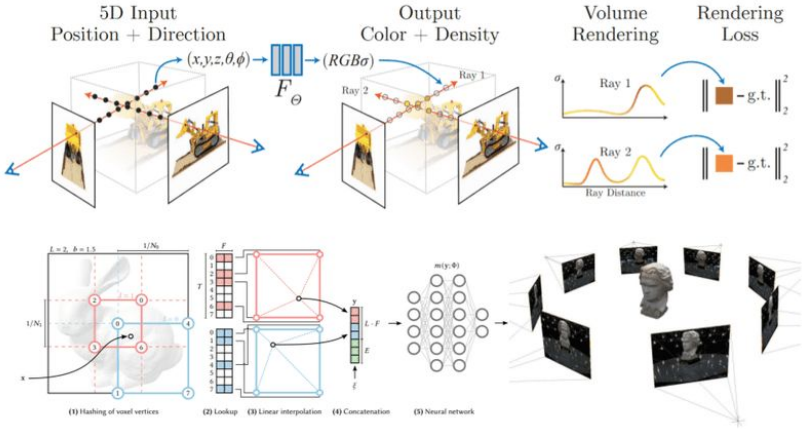
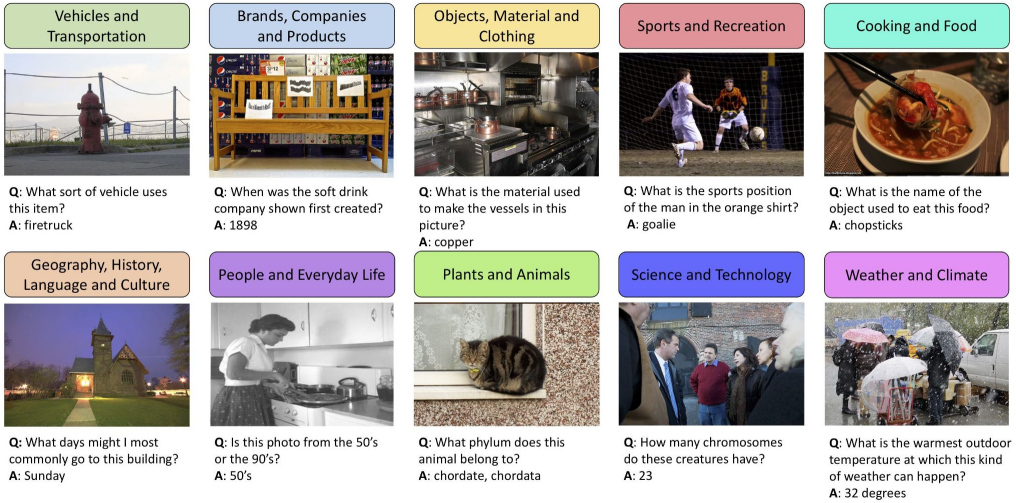


Image-text multimodality

- Implement a multi-modal model capable of **image captioning** or **visual question answering.**
- Compare a CNN-LSTM model vs a transformer architecture.



Your own project idea

- Do you have an own project idea?
  - Maybe connected to your hobby (sports, biology, travel, food)
  - Maybe for a topic that moves you (environment protection, politics, curing illness)
  - Maybe you just don’t like our proposals
- You are free to suggest us your own idea (we highly encourage this)
- We discourage picking an existing challenge from the internet
- Keep in mind:
  - The difficulty needs to be feasible for this final project
  - You need data
  - We might not be able to answer all questions
  - You have to “convince” us that your project idea is doable
- We are open for discussions but reserve the right to reject you idea, e.g. if we:
  - think the project is too easy/challenging
  - are not able to grade it (too exotic method/data)
  - **ethic concerns**

Projects

1. Determine object orientation
2. Representation learning of honeybees
3. Justified referral in AI glaucoma screening
4. Tumor segmentation from multiplex mass spectrometry imaging
5. Instance segmentation of C. elegans
6. Detection of insects caught by yellow sticky traps
7. Unsupervised Representations of Cells
8. Cell Tracking
9. Medical Image Registration
10. Image synthesis
11. 3D Vision
12. Images and text
13. Own Ideas

Project Proposal

The proposal should answer the following questions:

- **What** is the **problem**/question that you will be investigating?
- **Why** is the problem **interesting/important**?
- What are the most **relevant** readings (2-4 **papers**)?
- **What data** will you use?
- What are the **existing methods**? Are their implementations available?
- What method or **algorithm** will **you use**, and why? What **motivates your choice** of this approach?
- What **computing resources** will you use to train and run your model(s)?
- **How will you evaluate** your results?
- Qualitatively, what kind of **results** do **you expect** (e.g. plots or figures)?
- Quantitatively, **what kind of analysis** (performance metrics, statistical tests etc.) will you use **to evaluate** and/or compare your results?

Why don’t you just test us with a final exam?

- The **theory** you learned in the lecture is a **starting point and a foundation** in a rapid developing field of computer science
- Computer Vision (and ML/DL in general) is a very **practical field**
- Each project (also in the wild out there) and the data it comes with has different challenges
- Usually it is not as easy to pull the specific method out of your toolbelt and the problem is solved
- A final exam would mostly **test** if you are **able to memorize**…
- That does not help you and it is boring for us

Why don’t you just test us with a final exam?

The final project is your chance to:

- apply the knowledge you gained
- Work on a challenge from a field you are (more) interested in
- learn even more on the way
- Maybe put it on GitHub (e.g. for a job/PhD application in DL)
- If your results are novel and state-of-the-art it could result in your own paper at some point

Work on the project

- A successful project involves:
  - scoping out a feasible problem
  - providing initial experimental evidence to demonstrate the viability of your proposal
- Studies of existing methods applied to a specific challenge
- We want to encourage you to:
  - Develop your **own project idea** or **modify** ours
  - focusing on investigating a scientific question
  - **Modify and improve** existing approaches
  - Come up with a **novel approach**

A note about grading your project

- It is a course final, not your Master or PhD thesis
- We **don't expect** you to beat state-of-the-art methods; but if you do we are **very happy**!
- Grading is not only about how well your method performed
- It's more about:
  - The effort you put in
  - How novel your idea was
  - Reporting of results (what metrics you used, how you compared them, how you explain them)
  - The final presentation and your ability to answer our questions
  - Your ability to show us you worked on the project (and not only your partner)
- Good ideas which yielded bad results but have a solid explanation are better than the opposite
- Be honest! We value good scientific practice
  - No cherry picking, no stealing (cite people), no result tampering
  - Bad results are also results

Your end product

1. A project proposal
2. Source code of everything
   a. Data mining
   b. Pre-processing
   c. Training
   d. Testing
   e. Evaluation
3. Project report (in the format of a paper) → We will talk about that at a later point in time
4. Presentation held by you to us

Next Steps

- Form **groups** of **2 people**
- Create a **ranking list of 3 projects** that you would like to work on
- **One of each group**: send us a **list of the group members and your ranking** as an email (maurice.deserno@uni-koeln.de)
- If you want to do your own project please describe it briefly in the email:
  - The idea and what you want to try
  - The data
- Time: One week (13.06. 23:59)
- We will publish the allocations shortly afterwards

- Write a proposal for the project until 27.06. 23:59
- We might come up with corrections/suggestions

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Questions?