Mosquito Vision Checkpoint Presentation

EN.601.456 Computer Integrated Surgery II

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Project Summary

Goal: To create a ROS-integrated computer vision system for mosquito detection and keypoint identification to guide an automated mosquito dissection robotic system for live malaria vaccine production

Background:

- Malaria is a global problem, causing over 400,000 deaths and $12 billion USD of loss in 2017
- Sanaria has developed a live malaria vaccine shown to be 100% effective in clinical trials
- Extraction of salivary glands vital for vaccine production
- Currently done manually; but automatic mosquito microdissection system (MMS) proposed

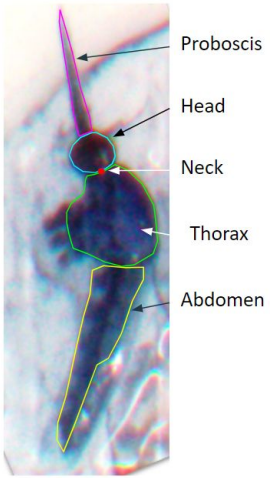

Figure 1. Parts of a mosquito

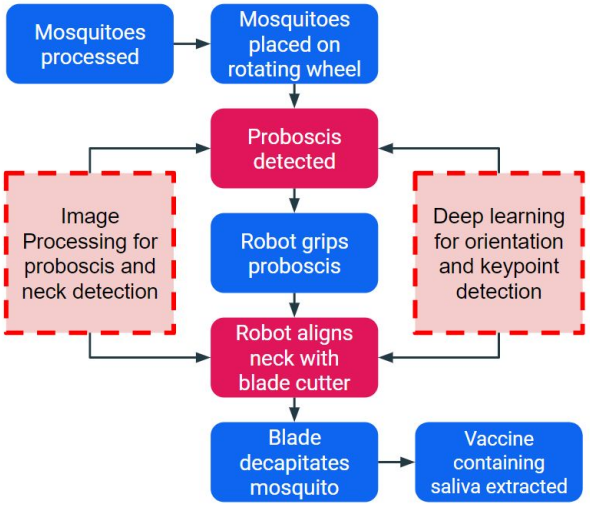

Figure 2. Process flow diagram for mosquito keypoint localization

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Deliverables - Update (Image Processing)

Minimum

- Algorithm for location of mosquitoes in the field of view of the camera
- Algorithm for location of the mosquito neck
- Algorithm for location of the two ends of the mosquito proboscis
- Thorough documentation of design choices, algorithms, and code usage

Expected

In addition to minimum..

- Fully integrated library for aforementioned computer vision methods
- Documentation detailing implementation and usage of library
- Integration of library with ROS to communicate with robot system

Maximum

In addition to expected...

- ~~Full validation of end-to-end workflow with robot system and mosquitoes~~
- Validation of all algorithms on large dataset of mosquito images
- Documentation of validation methods and results

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Deliverables - Update (Deep Learning)

Minimum

- Algorithm for determination of orientation of mosquitoes
- Framework for training model on detection of mosquito keypoints (abdomen, thorax, head, neck, proboscis)
- Thorough documentation of design choices, algorithms, and code usage

Expected

In addition to minimum...

- ~~Integration and validation of DL orientation model with ROS for real-time classification & detection~~
- Implementation of DL orientation algorithm in a ready-to-be-integrated class-based model

Maximum

In addition to expected...

- Creation and validation of library to streamline process of training mosquito keypoint detection
- ~~Integration and validation of DL keypoint and mosquito detection with ROS~~

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Deliverables - Progress

	Minimum	Expected	Maximum
IP	• Mosquito finder algorithm • Neck finder algorithm • Proboscis finder algorithm • Algorithm + design documentation	In addition to minimum... • Library creation • Library documentation • Integration with ROS	In addition to expected... • Validation of CV algorithms • Validation methods + results documentation
DL	• Orientation algorithm • Framework for training keypoint detection • Documentation of design choices, algorithms, and code usage	In addition to minimum... • Implementation of DL orientation algorithm in a ready-to-be-integrated class-based model	In addition to expected... • Creation and validation of library to streamline process of training mosquito keypoint detection

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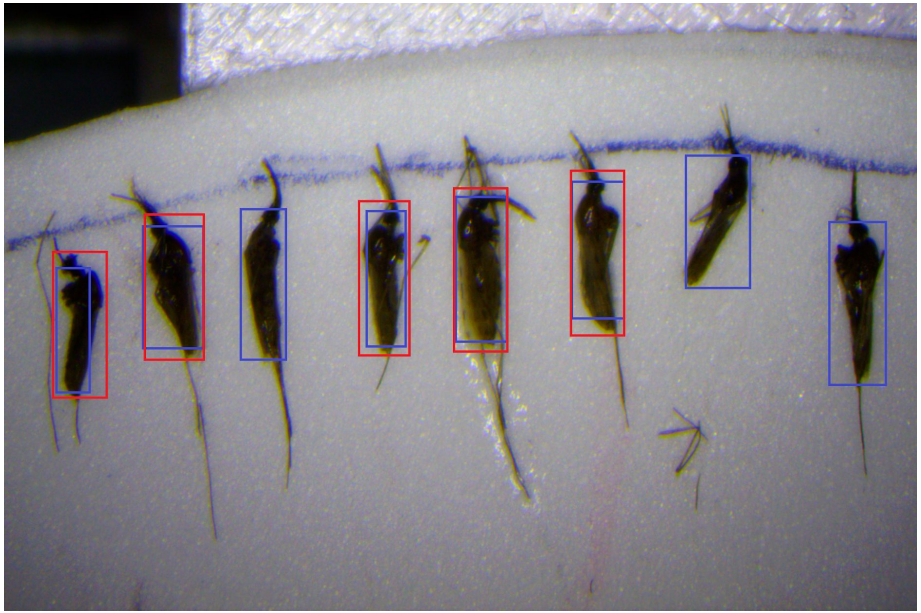
Image processing: Mosquito Finder

- Proof of concept for mosquito identification developed
- C++ Algorithms integrated with ROS
- Algorithms tested on 126 images with 303 annotated mosquitos
  - Algorithm sensitive to ROI, causing some mosquitos to be excluded
- Next steps include documentation, further testing

Total mosquitos	303
Mosquitos found	188 (62%)
Average IOU	0.705
STDEV	0.112



Blue: ground truth. Red: computer detection

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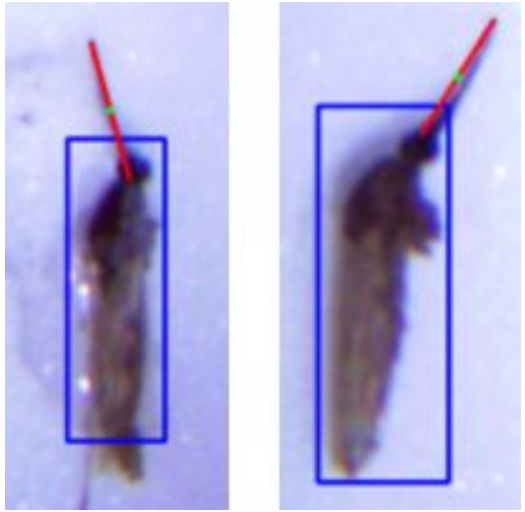
Image processing: Proboscis Finder

- Proof of concept for proboscis finder developed
- C++ Algorithms integrated with ROS
- Testing framework developed, data annotation in progress
- Next step: quantify error



Successful identification of proboscis (red) and proboscis midpoint (green)

Successful ROS integration of proboscis finder

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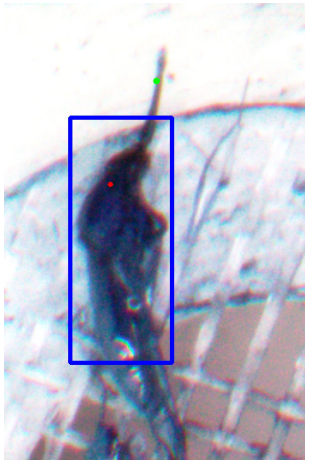
Image Processing: Neck Finder

- Proof of concept for neck finder developed
- C++ Algorithms integrated with ROS
- Testing framework developed, data annotation in progress
- Next step: quantify error



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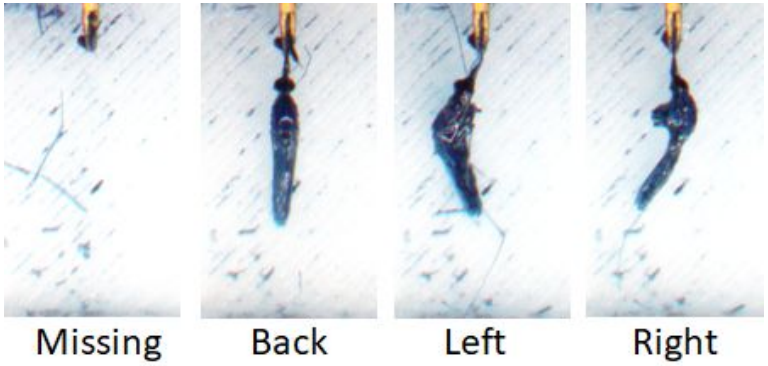
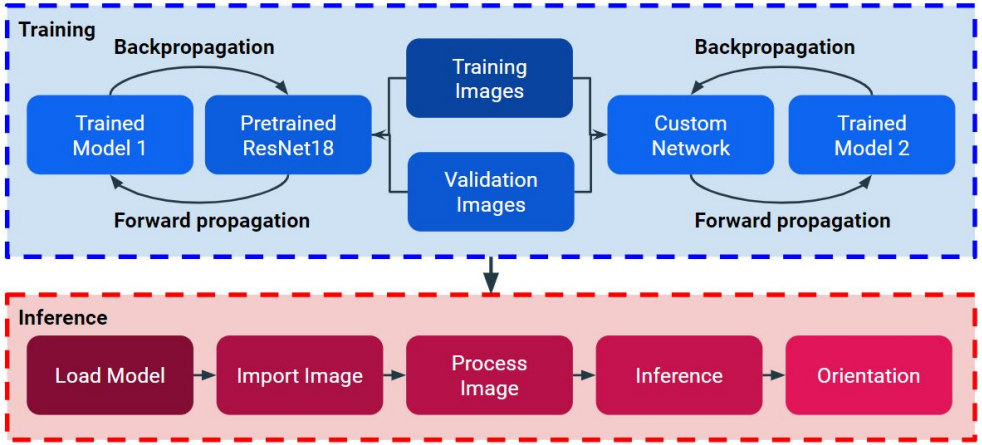
Orientation Detection



- Transfer learning via PyTorch
- Pretrained models available
  - ResNet18
  - ResNet152
  - DenseNet121
  - VGG16
- Fine tuning
- Feature extraction



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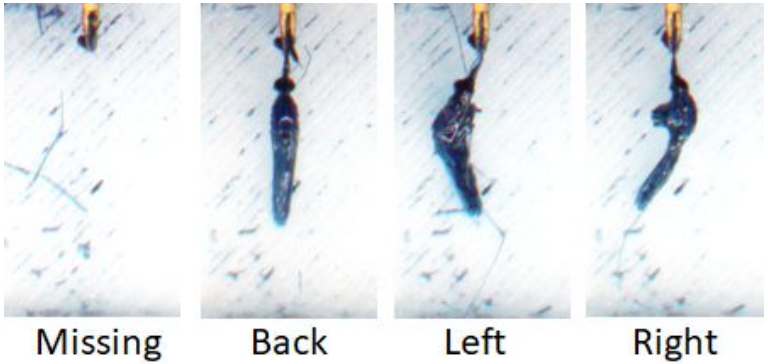
Orientation Detection

- 433 Images
  - Split 70:30 training:validation
- Labels
  - 0 = missing/invalid
  - 1 = back/stomach
  - 2 = left
  - 3 = right



Model	Mode	Data Augmentation	Success Rate
ResNet18	Feature Extract	Yes	~76%
ResNet18	Fine-Tune	Yes	~94%
ResNet18	Fine-Tune	No	~96%
ResNet152	Fine-Tune	Yes	~97%
DenseNet121	Fine-Tune	Yes	~93%
DenseNet121	Fine-Tune	No	~94%
VGG16	Fine-Tune	Yes	~89%
VGG16	Fine-Tune	No	~93%

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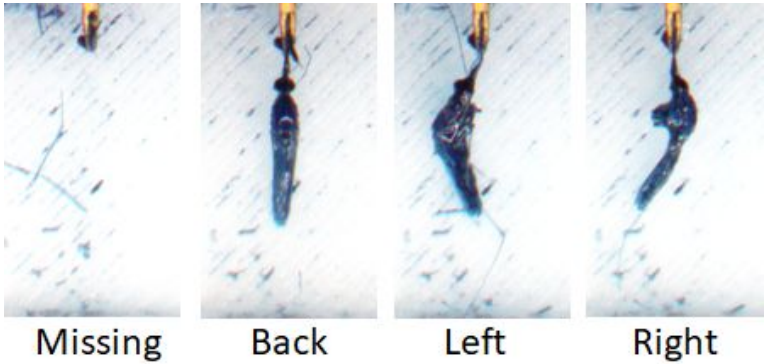
Orientation Detection

- Inference time needs to be < 1 second
- Need full integration of finalization of vision system to choose between ResNet18 and ResNet152



Machine	Model	Success Rate	Model Size (MB)	System	Inference (s)	Inference + Processing (s)	Inference + Processing + Importing (s)
Lab Computer	ResNet18	96%	43	CPU	0.112	0.112	0.204
Lab Computer	ResNet152	97%	227	CPU	0.680	0.682	0.771
Lab Computer	VGG16	93%	524	CPU	0.623	0.634	0.725
Lab Computer	DenseNet121	94%	30	CPU	0.297	0.299	0.391

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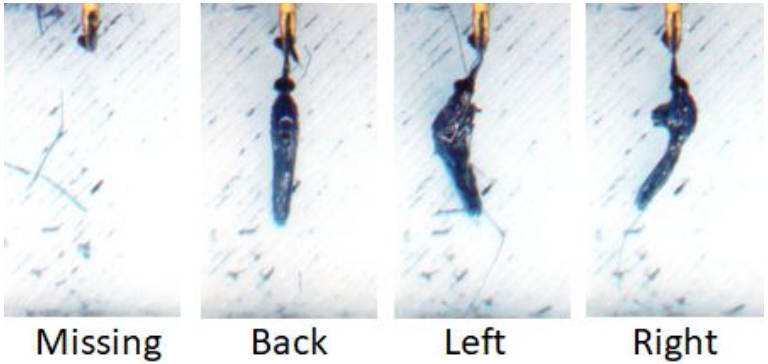
Orientation Detection

Integration with ROS

- Started preliminary steps, finished the class-based model for integration with the ROS-system
- Coronavirus prevent access to the robot
- Unable to fully integrate and validate the model



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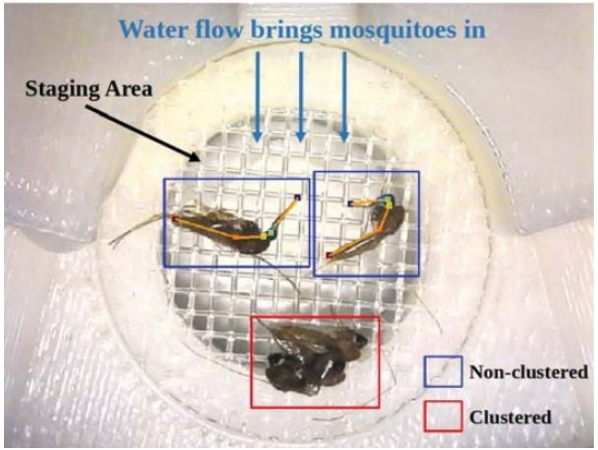
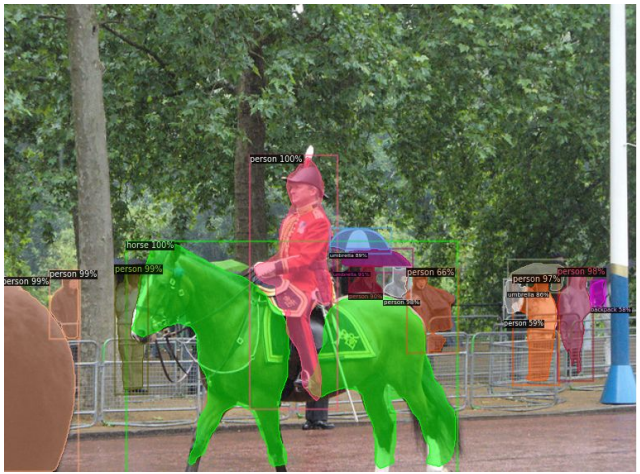
Bounding Box Detection

- Approach adopted from Wu et al.
  - Multi-mosquito object detection and 2d pose estimation for automation of PfSPZ malaria vaccine production
- Facebook AI's Detectron2
  - Based on Mask RCNN
  - Supports object detection, keypoint regression
- Data from Wu paper
  - Already labeled



[Wu]



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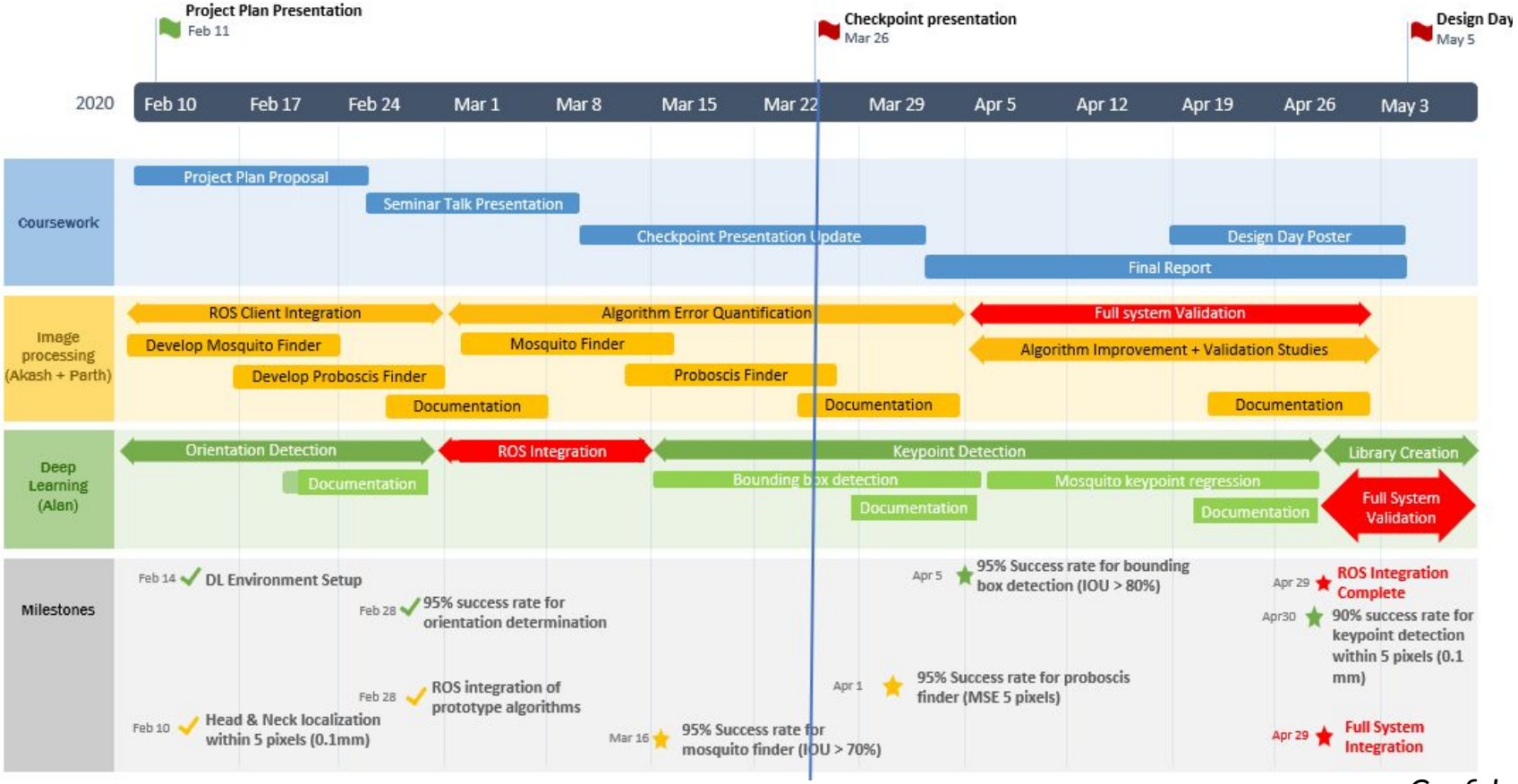
Updated Project Timeline



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Next Steps

Image Processing

- Further validation testing of mosquito keypoint identification algorithms
- Documentation of algorithms, library, and validation methods + results

Deep Learning

- Implement Mask RCNN for bounding box detection
- Setup learning framework for keypoint detection

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Thank you! Questions?

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Goals

Head/Neck/Proboscis Detection

- Improve accuracy for head & neck detection
- Flesh out workflow for proboscis detection (pre-processing, outputs, etc.)
- Document steps of workflow
- Integration with ROS

Orientation and Keypoint Detection

- Improve accuracy for orientation determination
- Create a DL-based system for keypoint detection
- Thorough documentation of DL techniques and process
- Integration with ROS

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References

[1] Wu, H., Mu, J., Da, T., Xu, M., Taylor, R. H., Iordachita, I., & Chirikjian, G. S. (2019). Multi-mosquito object detection and 2d pose estimation for automation of PfSPZ malaria vaccine production. In 2019 IEEE 15th International Conference on Automation Science and Engineering, CASE 2019 (pp. 411-417). [8842953] (IEEE International Conference on Automation Science and Engineering; Vol. 2019-August). IEEE Computer Society. https://doi.org/10.1109/COASE.2019.8842953

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