

Aerial Robotics for Liquid Level Detection & Inventory Management

Advisor:

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Team:

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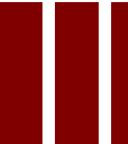
Nicolas Ferreira

Peter Ryan

Chen Feng Tsai

Zhuoya Zhang





Meet Our Team



Zeyu Chen



Nicolas Ferreira



Peter Ryan



Zhuoya Zhang



Chen Feng
Tsai



Agenda

Our Project

Methodology

Results

Future Work &
Key Takeaways



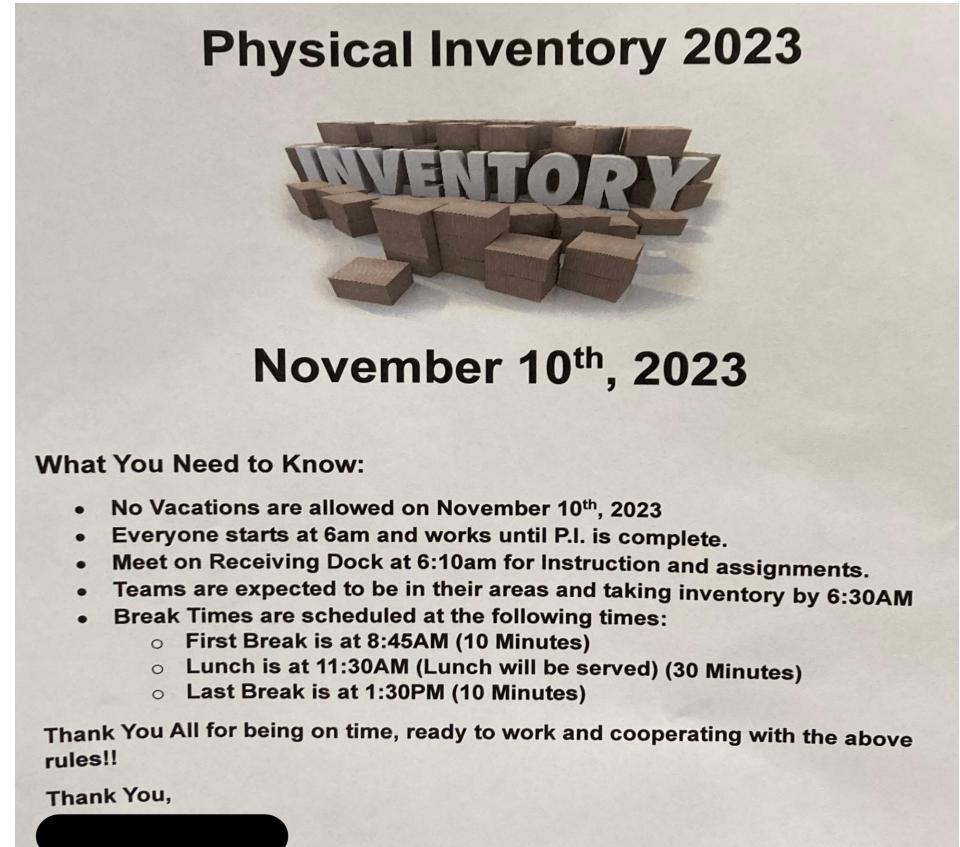


Our Project

Current State

Our Story

- ❖ Intensive manual labor
- ❖ Annual business interruption
- ❖ Resource misallocation
- ❖ Inefficient inventory tracking



Example of a company's notice



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Why Aerial Robotics?



Business Decision

- Expanding Market
- Compact and Cost-Effective
- Various Commercial Applications



Drone Features

- DJI RoboMaster TT
- Interactive programming with Python
- High resolution camera
- Object detection models



Please see Appendix for more industry research



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Our Vision



Real-time Automated Inventory Solution

- Computer Vision
- Aerial Robotics (Drones)



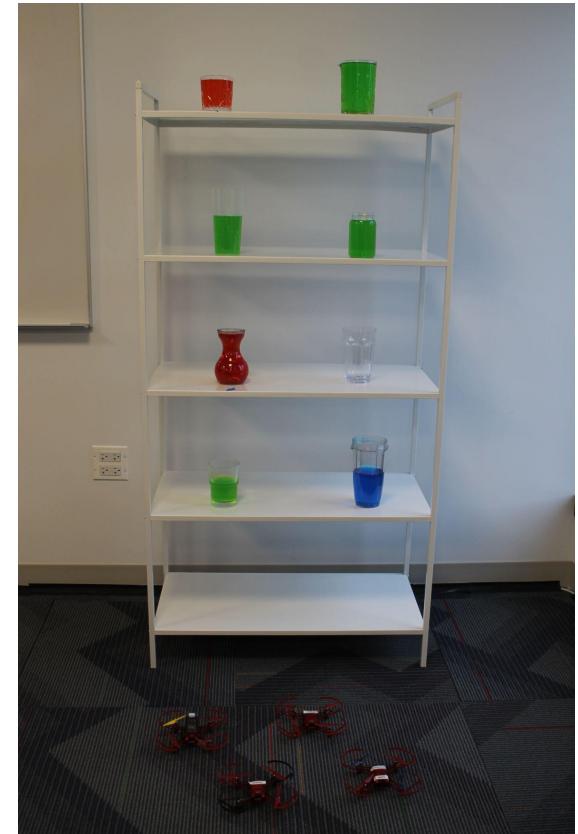
Resource-Efficient and Precise:

- Eliminate business interruption & manual counting
- Precision identification: full, half-full, empty
- Automated decision-making support



Flexible Customization:

- Diverse use-cases*
- Multiple industries



*Please see Appendix for more use cases



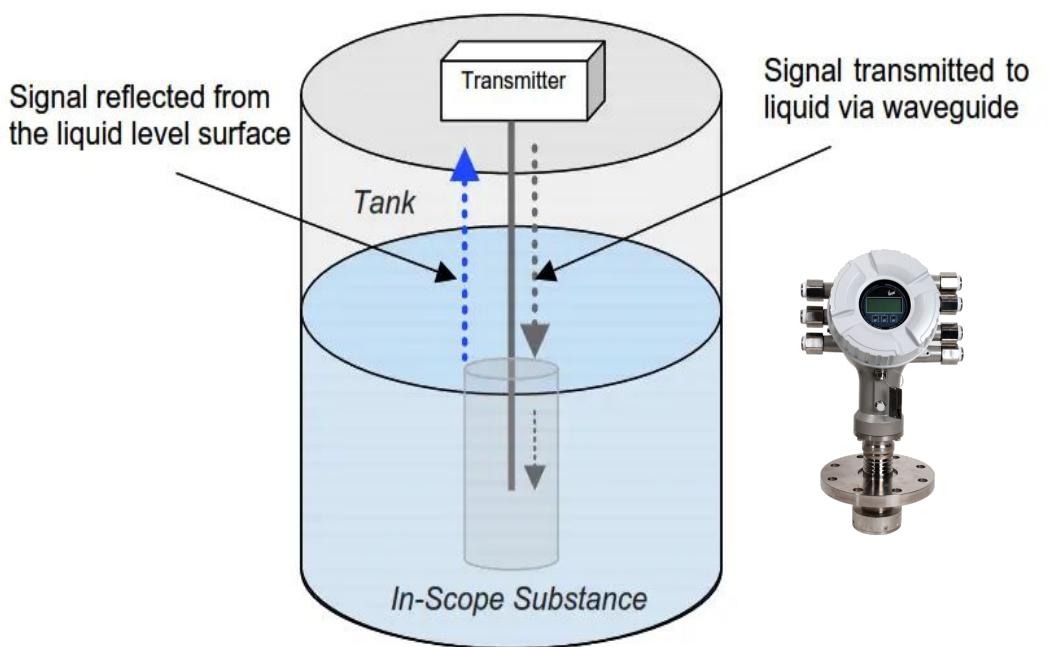
Why Liquid Level Detection?

- Strict requirement for installation
- Frequent maintenance to ensure accuracy
- High cost, especially for heavy inventories

Capacity/Accuracy	Unit Price
330 lbs. x .1 lb.	\$630
2,500 lbs. x .5 lb.	\$1,210
5,000 lbs. x 1 lb.	\$1,925

Example of warehouse weighing scale price chart*

Traditional liquid level measuring methods exhibit **limited flexibility** and require **higher expense**.



Example of a radar gauging system

*Please see Appendix for reference





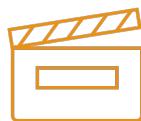
Methodology

Preparing our Solution

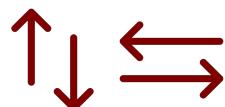


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How will it work?



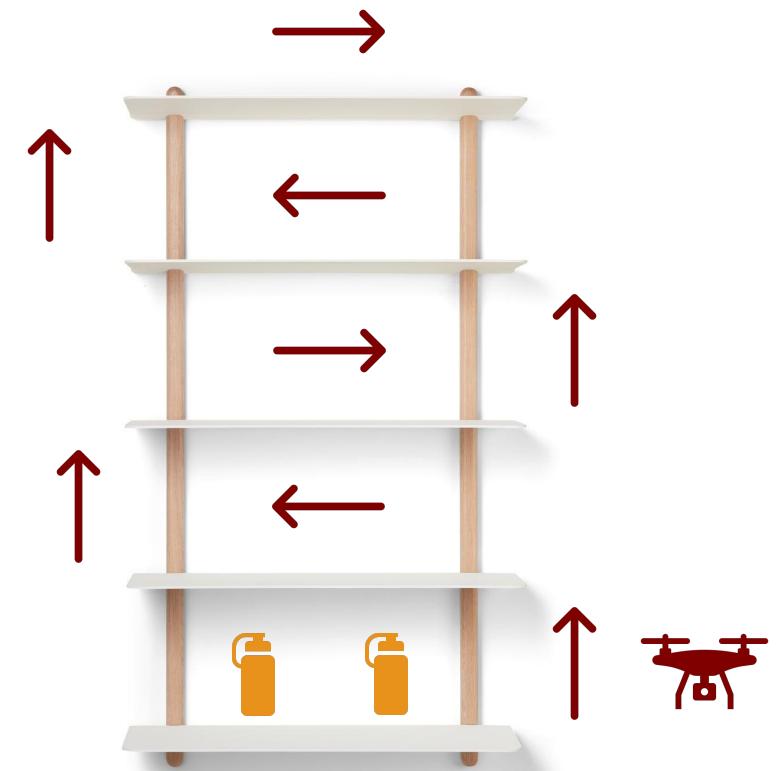
- Predetermined starting position
- Repeatable shelving units & path



- Automatic navigation (lawn-mower)
- Centering on Containers
- Containers classified at each position



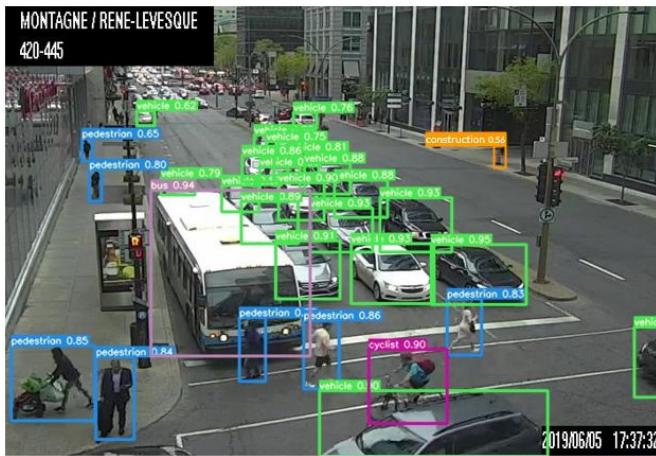
- Automated status reporting
- Supply chain integration



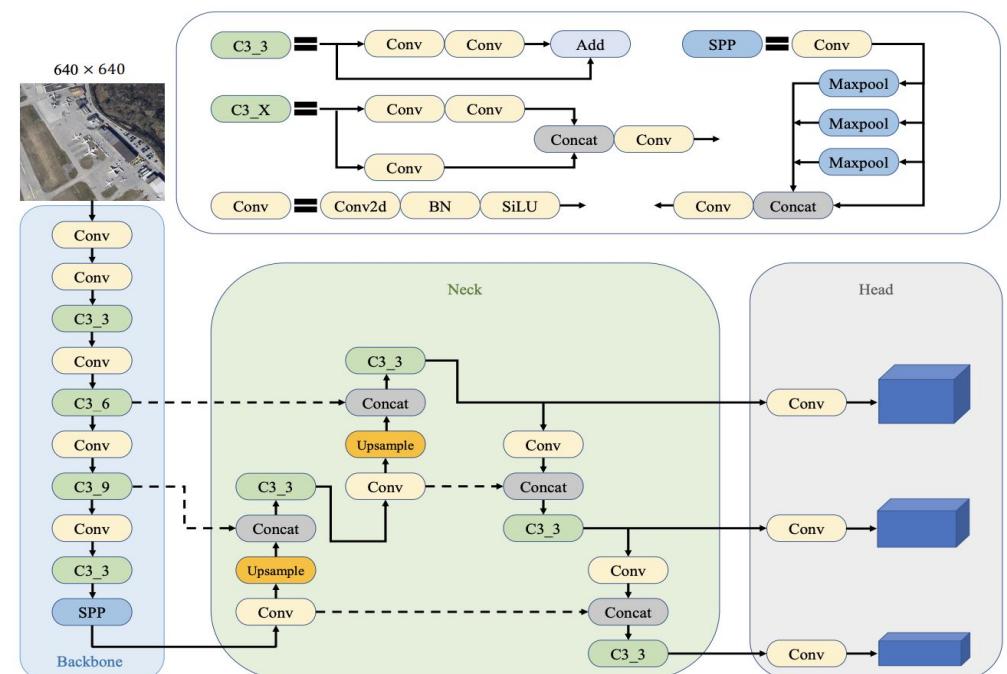
Model Selection: YOLOv5

Model Output

- Bounding boxes for location
- Classification and confidence



Algorithm Framework



Source: [KCFS-YOLOv5: A High-Precision Detection Method for Object Detection in Aerial Remote Sensing Images](#)

YOLO Model: Data Collection & Preprocessing

Image Data:

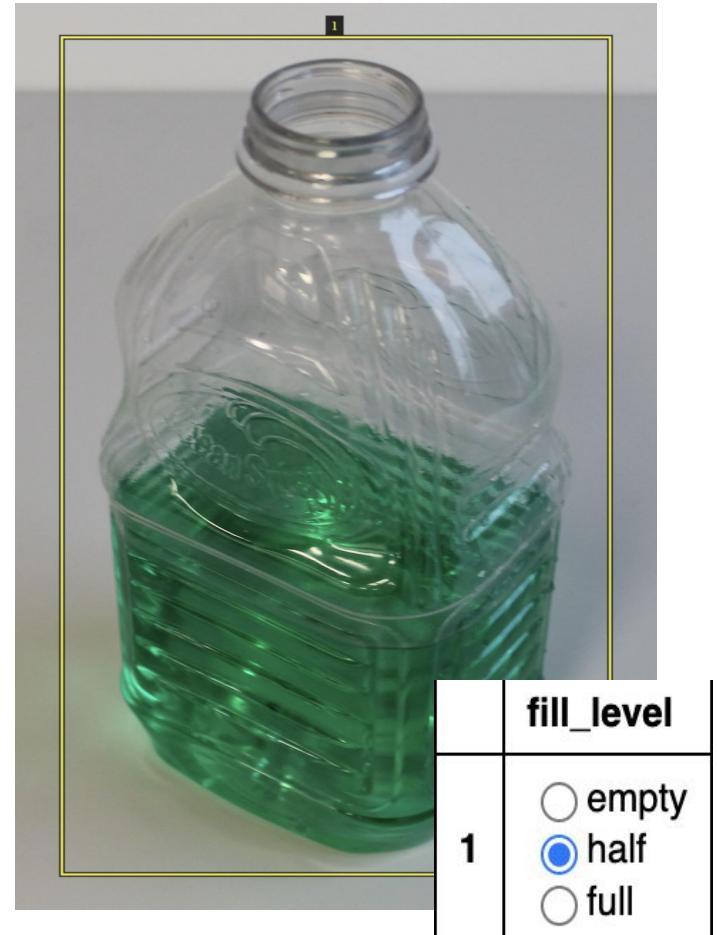
- 16 containers
- RGB Color liquids
- Liquid level at full, half, and empty
- Viewing at 8+ angles

Data Annotation:

- 3 labels: full, half, empty
- Manual annotation

Data Preprocessing:

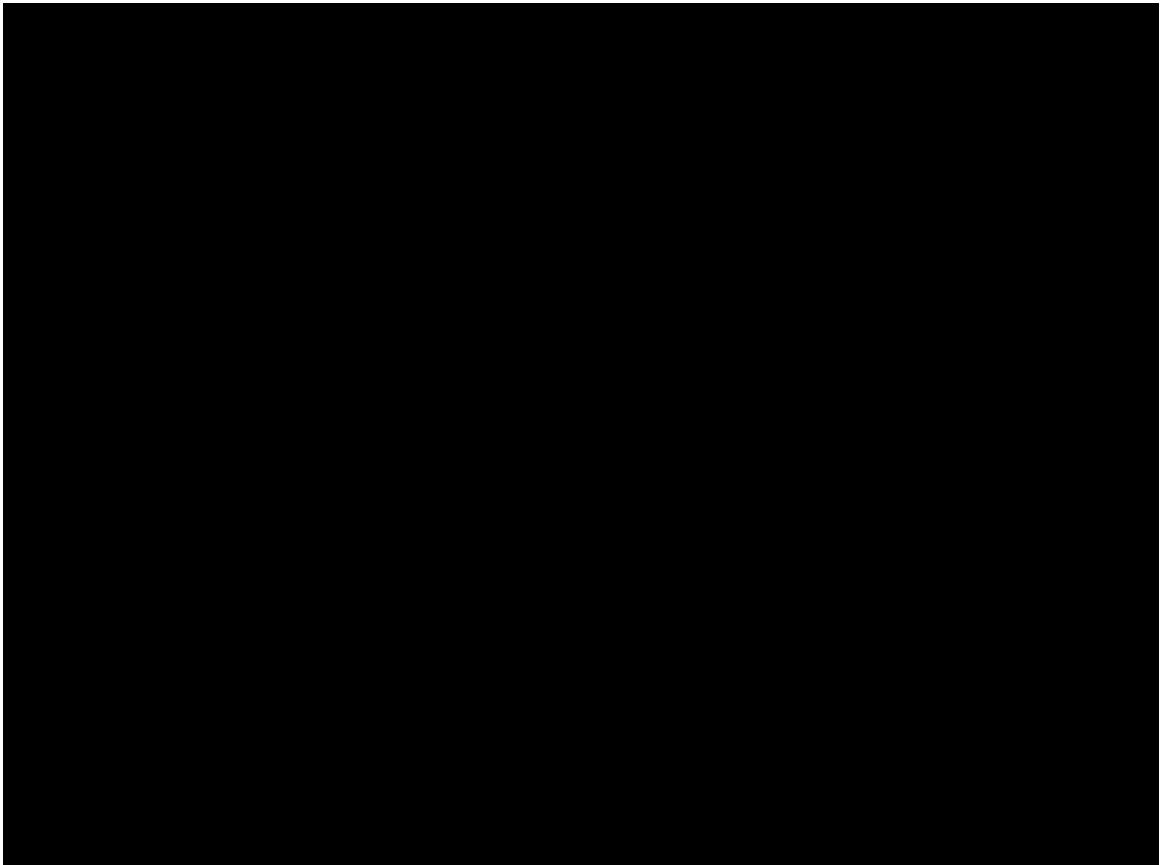
- Augmentation of empty bottles
- 80/20 split for training



Example of a labeled glass half-filled with green liquid at half.



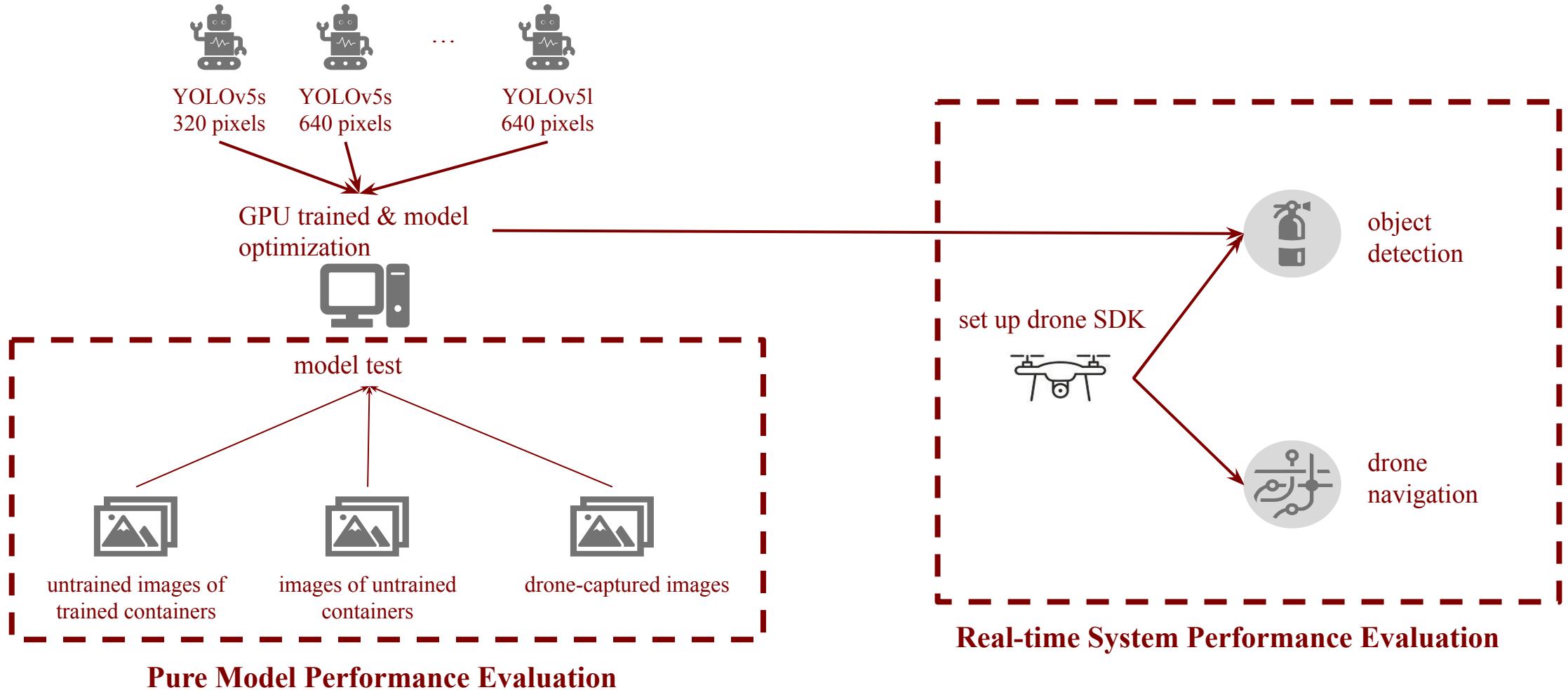
Video Demo



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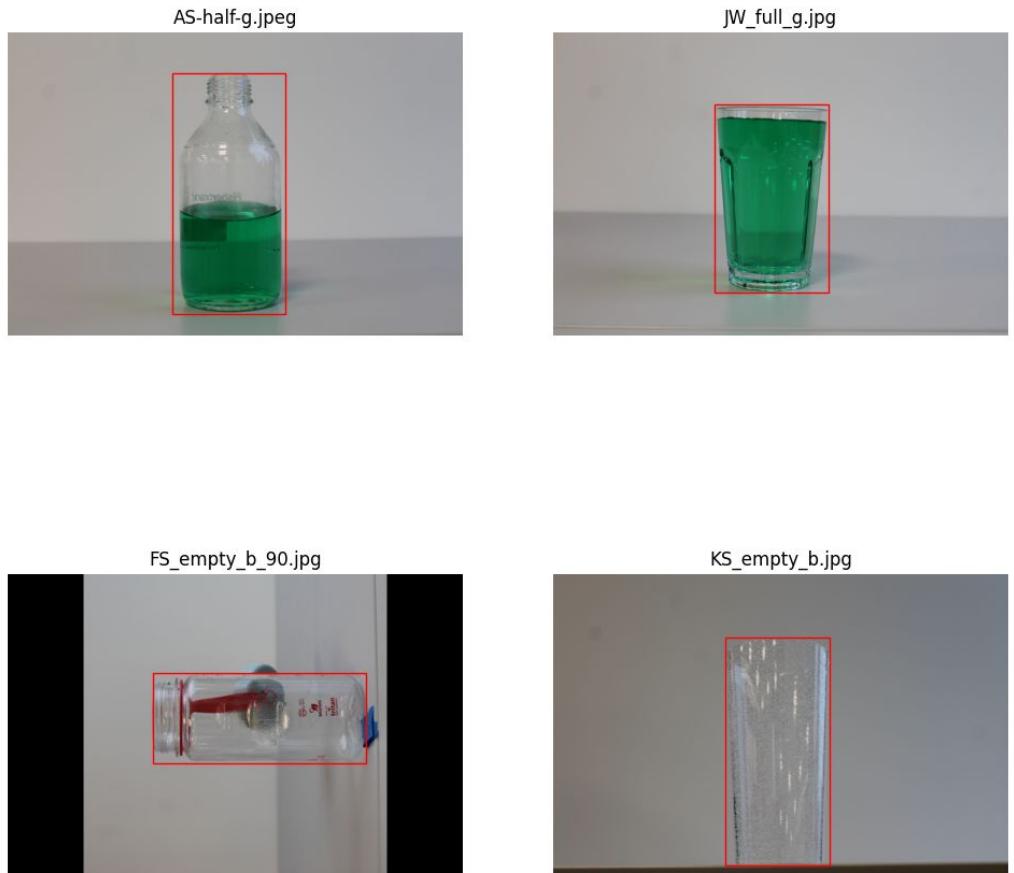
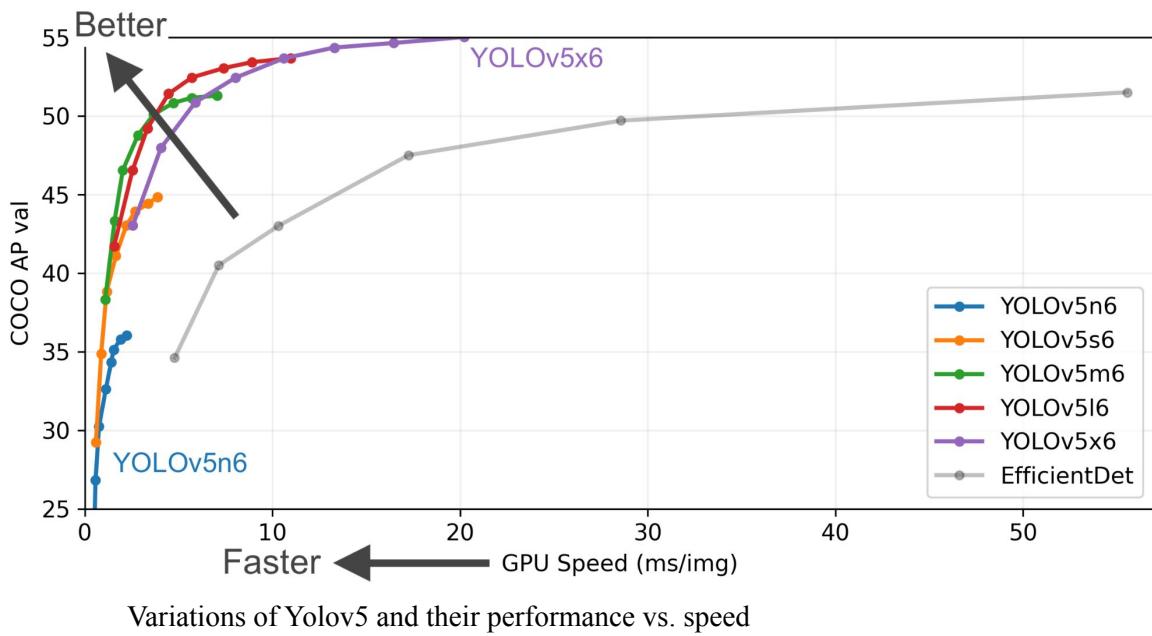


Model Process and Deployment



Model Training

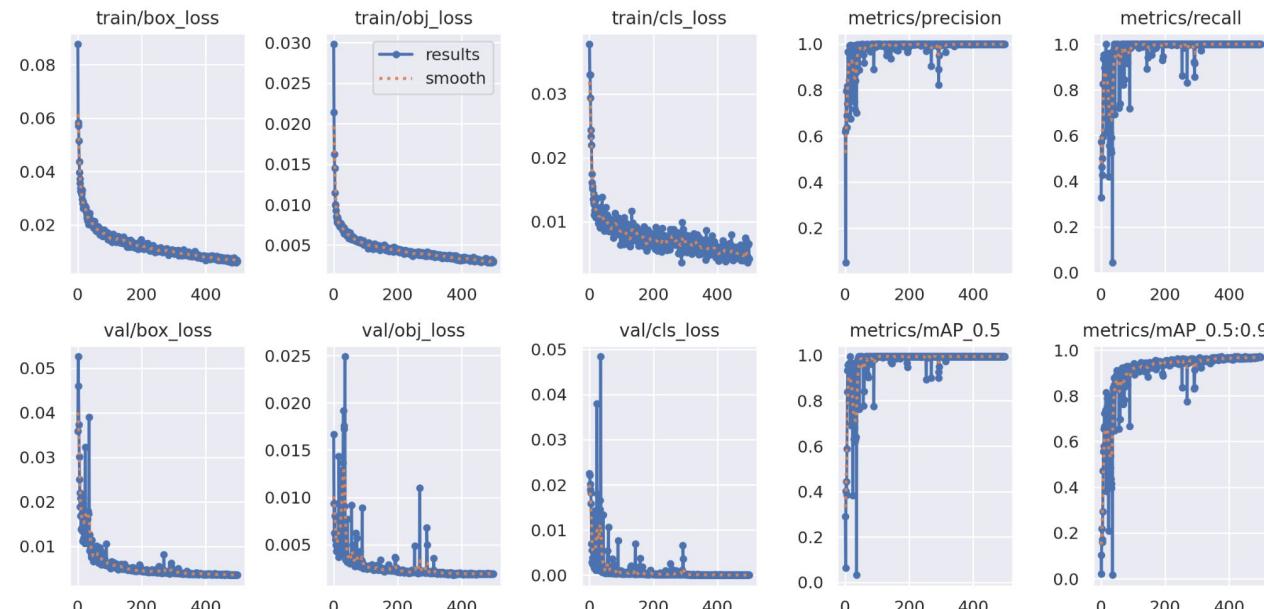
- ❖ 1000+ Images
- ❖ 3 models varied in YOLOv5 version



Samples of Training dataset with Annotations



Model Optimization



- ❖ Hyperparameter tuning:
 - **Image size:** 320x320 pixels, 640x640 pixels
 - **Epochs:** 100 – 500
 - **Batch size:** 16 images

Model Validation & Testing



Validate models on untrained images of trained containers

1



Test models on images of untrained containers

2



Test models on images captured by drone

3



Test on real-time drone captured images with drone navigation

4



Results



Evaluation: Pure Model Performance

- ❖ Evaluated the performance of 6 models by 4 metrics
- ❖ All YOLOv5 models unveiled a robust performance
- ❖ YOLOv5s has the best performance on images of untrained containers

1 Validate models on untrained images of trained containers

Model	Images	Precision	Recall	mAP50	mAP50:95
YOLOv5s img320	169	0.999	1.000	0.995	0.975
YOLOv5s img640	169	0.997	1.000	0.995	0.971
YOLOv5m img320	169	0.998	1.000	0.995	0.970
YOLOv5m img640	169	0.999	1.000	0.995	0.962
YOLOv5l img320	169	0.999	1.000	0.995	0.975
YOLOv5l img640	169	0.999	1.000	0.995	0.962

Model Evaluation on untrained images of trained containers

2 Test models on images of untrained containers

Model	Images	Precision	Recall	mAP50	mAP50:95
YOLOv5s img320	99	0.900	0.934	0.964	0.863
YOLOv5s img640	99	0.860	0.697	0.819	0.72

*Performance of YOLOv5s on images of untrained containers**

*Please see Appendix for model evaluation on images of untrained containers



Evaluation: Pure Model Performance

3

Test models on **drone-captured images** of trained and untrained containers

Model	Images	Precision	Recall	mAP50	mAP50:95
YOLOv5s img320	81	0.986	0.992	0.994	0.895
YOLOv5s img640	81	0.969	0.962	0.985	0.876
YOLOv5m img320	81	0.992	0.999	0.995	0.893
YOLOv5m img640	81	0.903	0.976	0.981	0.836
YOLOv5l img320	81	0.993	0.99	0.995	0.888
YOLOv5l img640	81	0.962	0.966	0.901	0.841

Model Evaluation on Drone-Captured Dataset

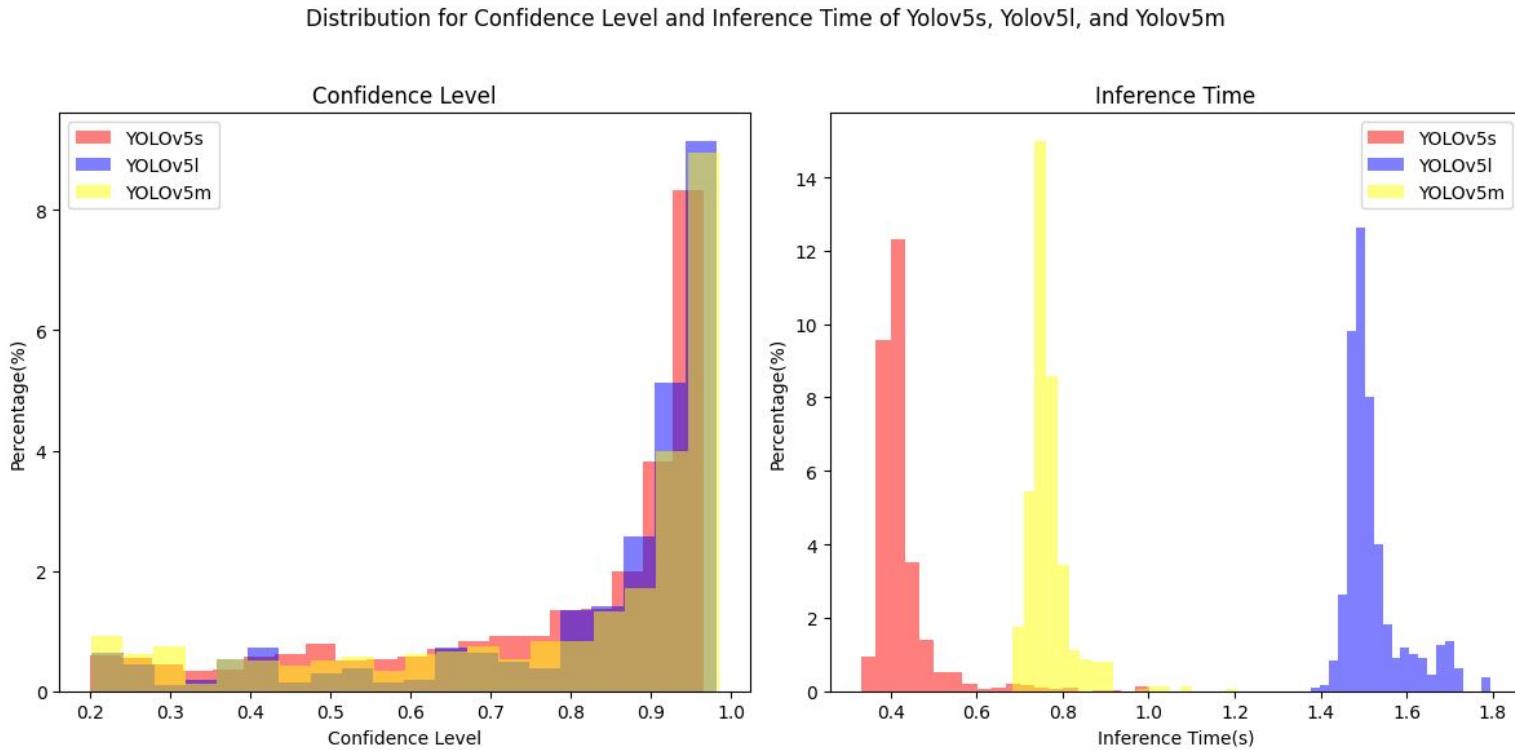
All YOLOv5 models
demonstrate outstanding
performance in a simulated
real-world feed, achieving a 50%
IoU threshold above **90%**



Evaluation: Real-Time Performance with Drone Navigation

- ❖ Evaluated the integration between **model's accuracy** and the **drone's functionality**

4 Test on real-time live streaming data with drone navigation



YOLOv5s (median)

Accuracy: 92.9%

Latency: 0.4s

Confidence level: 0.875



Comparison Analysis: Sizes and Fill Levels

- less confidence in **Empty**
- larger **Variance** in YOLOv5s

Confidence Level Across Models and Fill Levels



Latency Across Models and Fill Levels





Future Work & Key Takeaways

Limitations

Physical Limitations

- Drone status
- Physical obstructions
- Environmental conditions
- Video streaming stability
- Flight stability

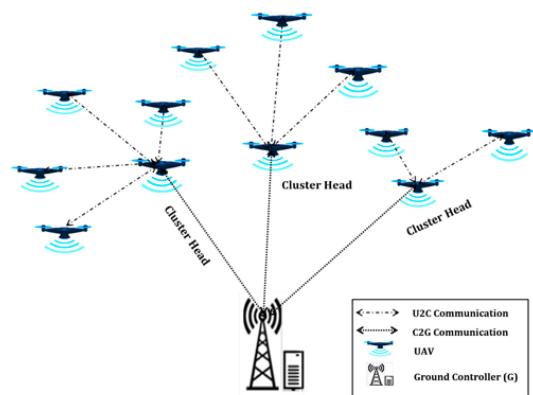
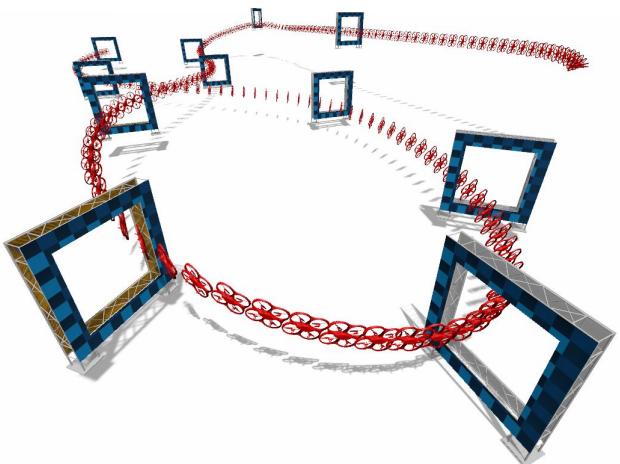
- Lack of variety in training dataset
- Generalizability to untrained objects
- Overfitting

Model Limitations



Future Work

Adaptability of Drones in Dynamic Environments



**Swarm Deployment
Capabilities of
Multiple Drones**

Precise Percentage of Liquid Portion



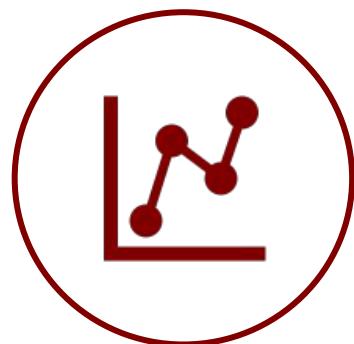
Key Takeaways



YOLOv5 Drone
Implementation



Industrial Setting
Scenario



Explored Model
Variations



Monitoring
System Factors



Thank you!

Questions?





Appendix

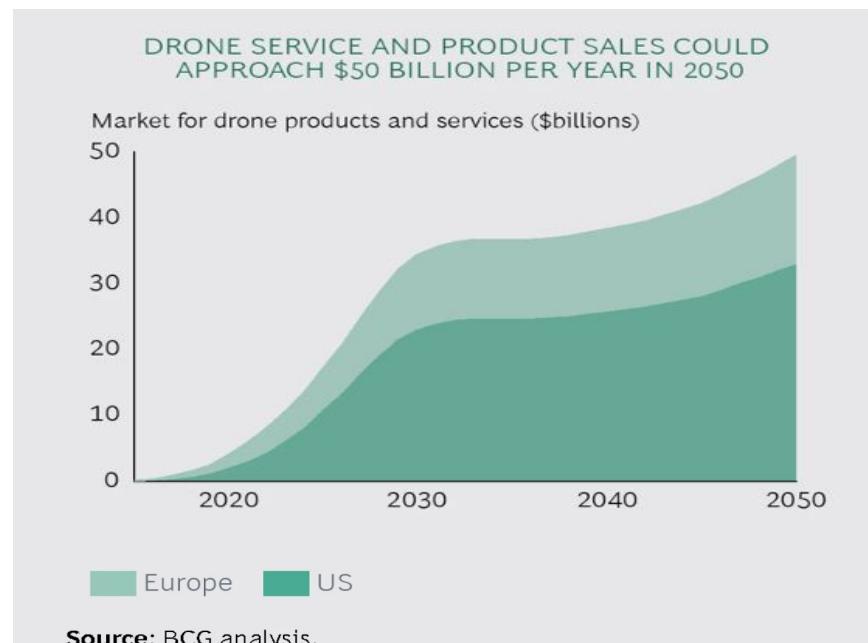
Additional Information



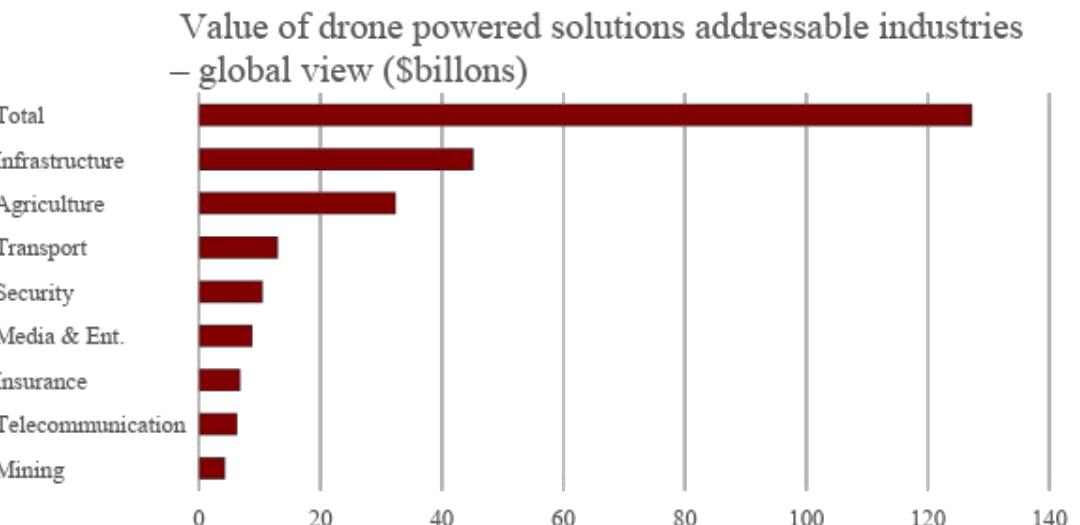
Why Aerial Robotics?

The drone market continues to experience **rapid growth**, presenting numerous potentials.

◆ Drone technology is in high demand



◆ Drone technology has various commercial applications



*Please see Appendix for reference



Flexible Use Cases

External Financial Audit



Highly efficient counting with accuracy comparable to human counting, especially in wide areas.*

Subscription-based Profitability

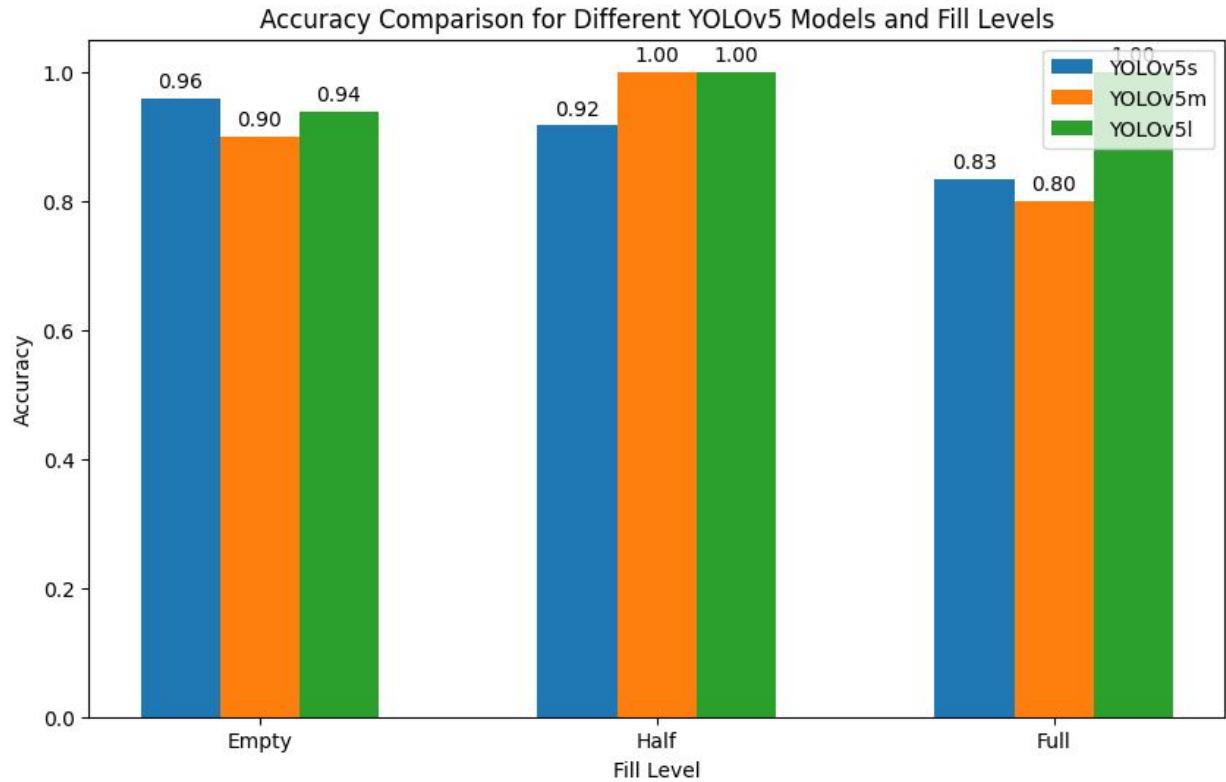


Subscribed users can upload container photos, enhancing detection accuracy, while benefiting from ongoing technical support and updates.

*Please see Appendix for reference



Appendix



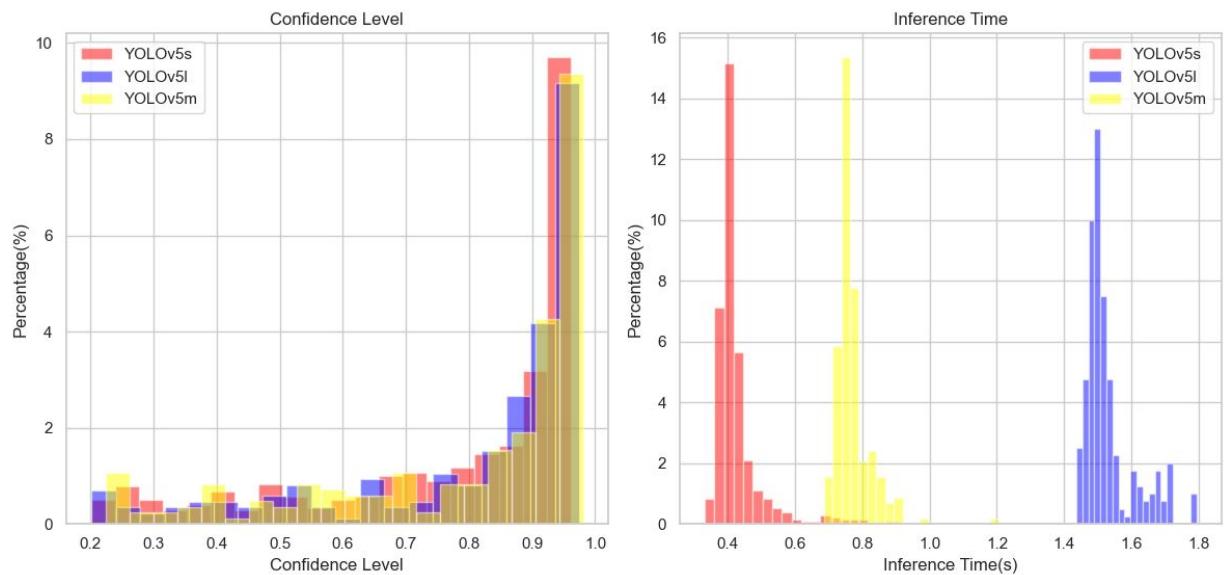
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YOLOv5s img640	99	0.860	0.697	0.819	0.72
YOLOv5m img320	99	0.935	0.718	0.880	0.725
YOLOv5m img640	99	0.925	0.735	0.906	0.767
YOLOv5l img320	99	0.875	0.776	0.890	0.754
YOLOv5l img640	99	0.935	0.763	0.902	0.749

Model Evaluation on untrained images of trained containers

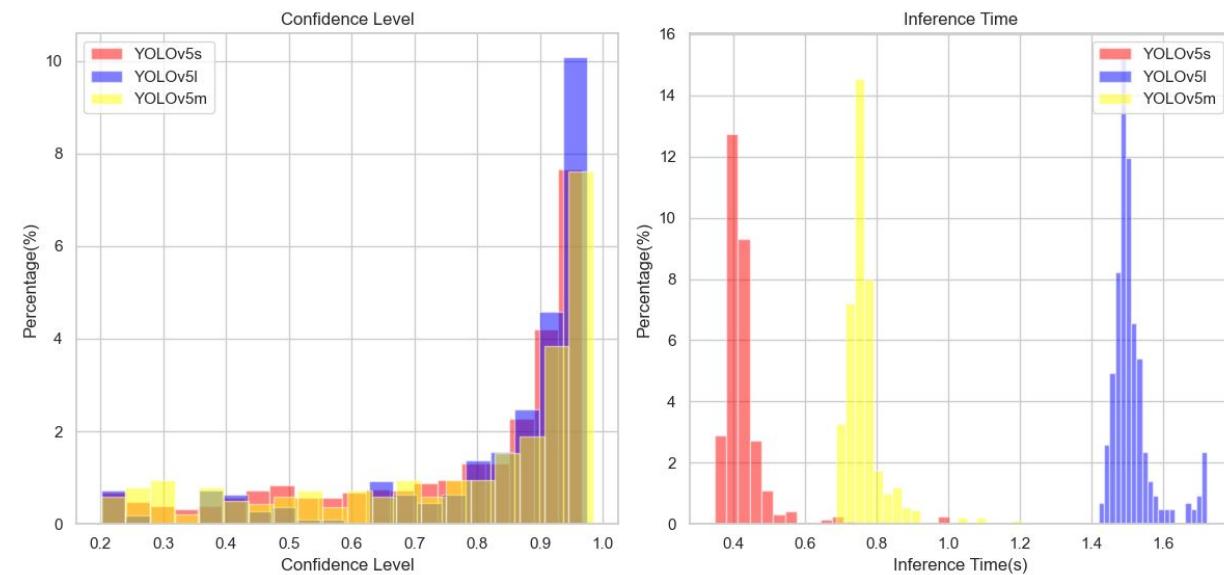
Methods	Size (MB)	Accuracy	Median Latency	Median Confidence Level
YOLOv5s	13.6	0.929	0.410s	0.875
YOLOv5m	40.2	0.914	0.758s	0.914
YOLOv5l	88.5	0.964	1.500s	0.923

Real-Time Performance in Real-Time

Appendix



Real-Time Performance of Detection Confidence and Inference Time on unseen containers



Real-Time Performance of Detection Confidence and Inference Time on seen containers

Appendix

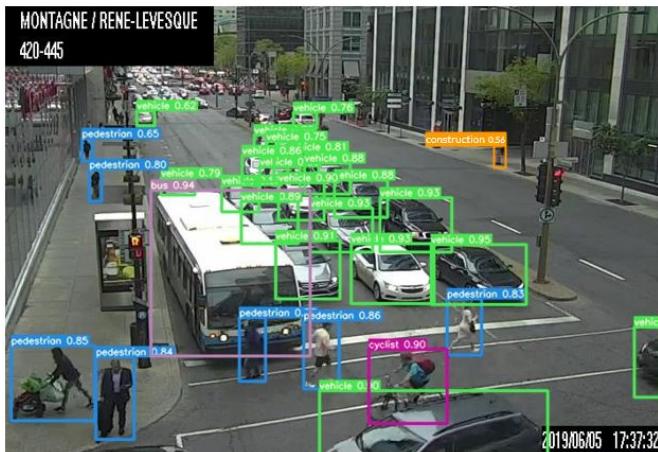
Reference:

- <https://aptus-supplychain.com/inventory-count-with-drone/>
- <https://github.com/ultralytics/yolov5>
- <https://www.ware.ai/blog/what-are-warehouse-drones>
- https://www.uline.com/Cls_23/Scales
- <https://www.forceflowscales.com/products/scales/chemical-day-tank-scale>
- <https://instrumentationtools.com/radar-tank-gauging/>
- <https://www.varec.com/products/>
- <https://new.abb.com/products/measurement-products/level/a-dozen-ways-to-measure-fluid-level>
- <https://www.bcg.com/publications/2017/engineered-products-infrastructure-machinery-components-drones-go-work>
- <https://www.pwc.com/kz/en/services/drone-powered-solution.html>

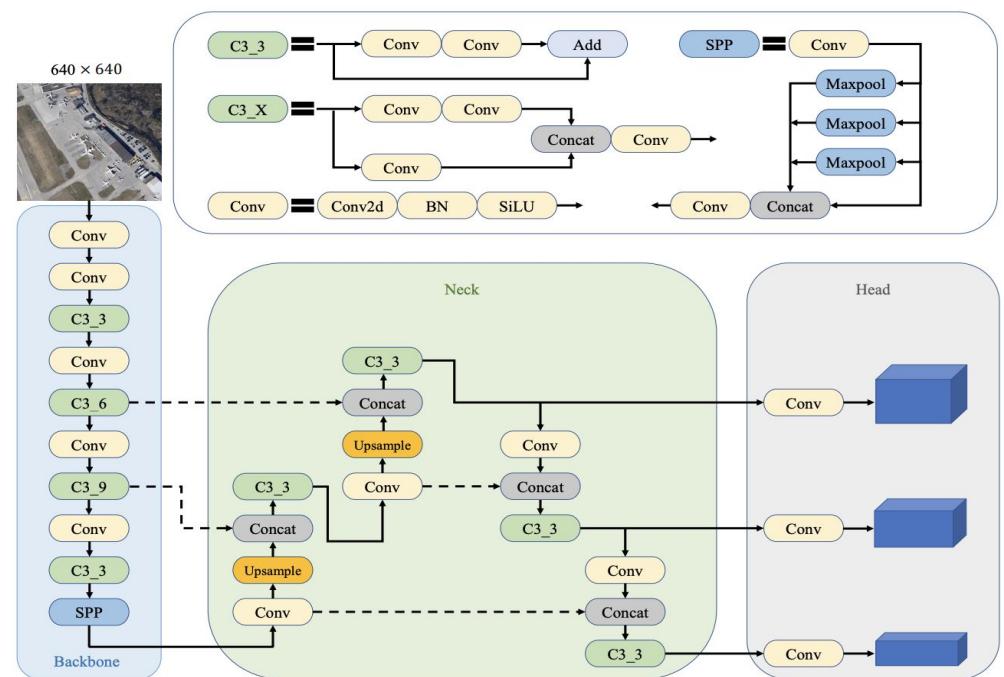
Model Selection

YOLOv5

- You Only Look Once
- One-stage detection



Algorithm Framework



Source: [KCFS-YOLOv5: A High-Precision Detection Method for Object Detection in Aerial Remote Sensing Images](#)

Flexible Use Cases

Robotic Inventory Management



Automated inventory management without interrupting normal business operations or requiring additional human resources.



Upon integration with the Warehouse Management System (WMS), our project not only provides information about the status of liquid inventory but, more importantly, generates valuable decision-making recommendations.

Physical Inventory 2023

INVENTORY

November 10th, 2023

What You Need to Know:

- No Vacations are allowed on November 10th, 2023
- Everyone starts at 6am and works until P.I. is complete.
- Meet on Receiving Dock at 6:10AM for Instruction and assignments.
- Teams are expected to be in their areas and taking inventory by 6:30AM
- Break Times are scheduled at the following times:
 - First Break is at 8:45AM (10 Minutes)
 - Lunch is at 11:30AM (Lunch will be served) (30 Minutes)
 - Last Break is at 1:30PM (10 Minutes)

Thank You All for being on time, ready to work and cooperating with the above rules!!

Thank You,

[REDACTED]



Example of a real-world inventory check notice



Key takeaways

- ❖ Developed an automated liquid level monitoring system using a Tello drone equipped with cv models, YOLOv5.
- ❖ Integrated the drone-based detection system into industrial settings, ensuring product quality and increasing efficiency.
- ❖ Trained YOLOv5 models, explored variations, and analyzed distinctions in classification accuracy and inference time under various configurations.
- ❖ Drone status, data streaming stability, and color of the liquid are crucial factors for the monitoring system.



Data Collection & Preprocessing

- Bounding boxes & labels

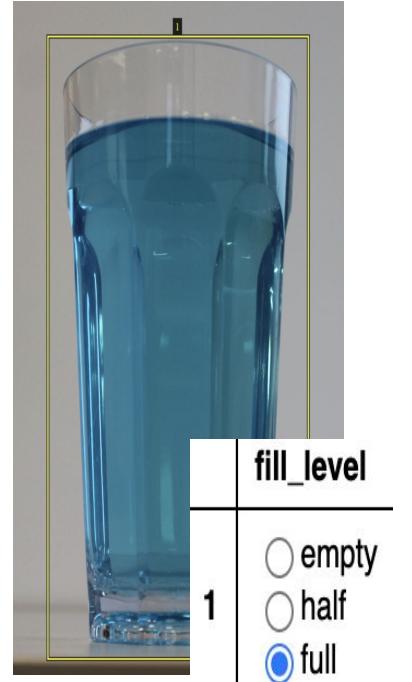
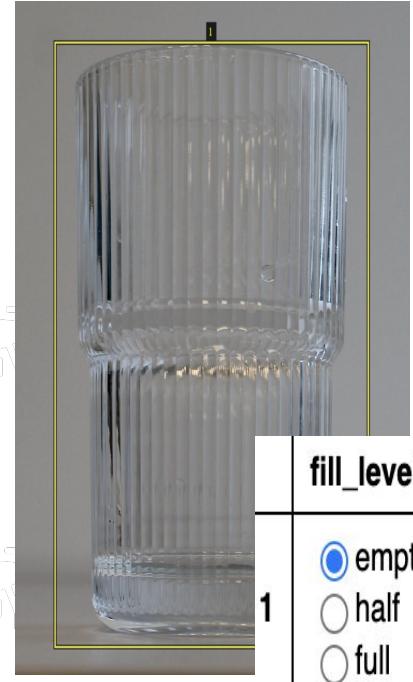
Images Dataset

- 12 containers
- 3 fill levels & 3 colors
- Varying perspectives

Annotation



Feature



Annotated Images

