Computer Vision and Machine Learning Integration for real-time Straw Level Monitoring

DTU

David Ari Ostenfeldt, Dennis Chenxi Zhuang
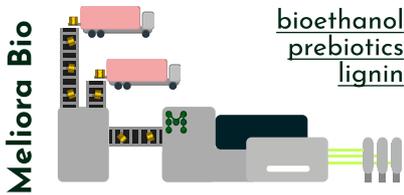MSc. Students, DTU Compute
{s194237, s194247}@student.dtu.dk

Marjan Mansourvar
Supervisor, DTU BioEng
marjma@dtu.dk

Steffen L. Poulsen, Allan Hedegaard
Supervisors, Meliora Bio
{sap, alh}@meliora-bio.com

Meliora Bio
Helix Lab

I. Introduction

- Meliora Bio upcycles straw into *bioethanol, prebiotics* and *lignin*.

- During a typical production cycle, **4 tonnes an hour** of straw is processed.

- All straw must pass through a chute during production, which aims to be **50% full** as much as possible.

- Currently, the fullness of the chute is measured with **sensors**.

- **Problem:** The sensors are prone to reporting incorrect straw level, and easy to dislodge during maintenance.

Meliora Bio

bioethanol
prebiotics
lignin

State of the art biorefinery of straw.
Something out of Nothing...

The current method uses light-sensors
- Connected to a PLC with PROFINET protocols.
- 11 yellow sensors on the side.
- Prone to physical disturbances and can't be optimised.

II. The Solution?

- An integrated **computer-vision** and **machine-learning** system, taking input from a mounted CCTV camera pointed at the chute, and outputting a **straw level prediction.**

What is required?
- Straw level predictions that are within a **±5% threshold** of the *actual* level.
- Needs to report straw level at minimum every **2 seconds.**
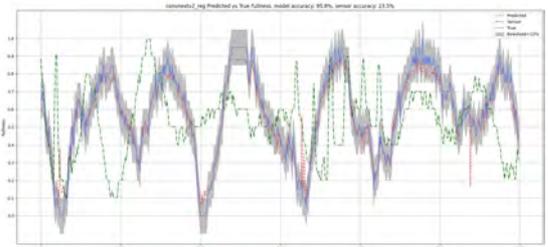- Should be **robust** to changes in the environment, e.g. brightness and murky straw conditions.

60%

CV **ML**

Prediction: 60% full
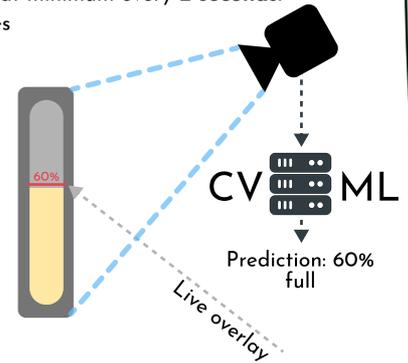
Live overlay

Our method requires advanced machine learning and AprilTags.
- Requires a PC with GPU
- Can predict and overlay the scores live.
- Deficiencies can be solved on the backend.

III. Methodologies

- We have a series of different pipelines for the various steps in this project.

1. Data collection

Video Feed → Annotate →

3. Inference

Overlay Prediction — Predict Live
Report level to ctrl. — Find AprilTags

2. Model Training

Train Model → Validate
Test

Models
- **Goal:** Predict straw level, with **invariance** to chute position.
- 2 Model Methods:
  - YOLO for straw bbox (pixel value), AprilTags for straw level (pixel --> %).
  - YOLO to detect chute, crop+rotate, ConvNeXtv2 or ViT to detect straw level (regression).
- Manual feature additions for input, e.g. Canny Edge Detection and image difference between current and previous frame.

Training
- Utilise data augmentation to **increase robustness**
- Transfer learning
- Cross-validation
- Hyper-parameter tuning

Reporting level to control
- Convert digital signal to analog, using Arduino
- 0-1 fullness -> 4-20mA

Live overlay
- AprilTags for higher level resolution
- Camera distortion makes the different levels non-equidistant.
- Smoothing prediction with weighted average

Input (rgb)   Convolutions, pooling, etc.   Fully Connected Network   Output

IV. Outcome

- 95.8% test accuracy
  - Production tests to come...
- Still many improvements to make...
- 4-19 predictions per second (depending on model)
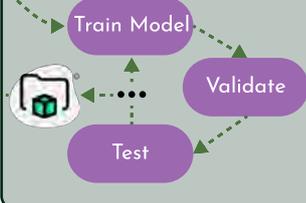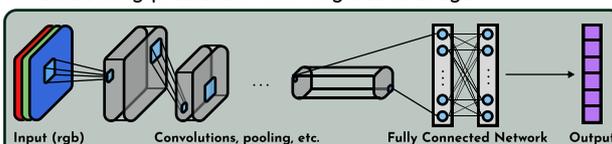- Complete YOLO frame-works seems to work the best currently.

V. Perspective

- Computer Vision and Machine Learning can solve many problems.
- Exciting opportunities at Meliora Bio to apply these techniques, and might be relevant for other industry stakeholders.
- Can automate many tedious tasks.
  - But also challenging tasks!