

Détection de turbidité sans contact, à faible coût et basée sur une caméra : l'avenir des mesures de la qualité de l'eau pour l'IoT

Non-contact, low-cost, camera-based turbidity sensing: the future of water quality measurements for IoT

Stephen Catsamas¹, Canwei Pang¹, Eric Zhu¹, Baiqian Shi¹, David McCarthy*^{1,2}

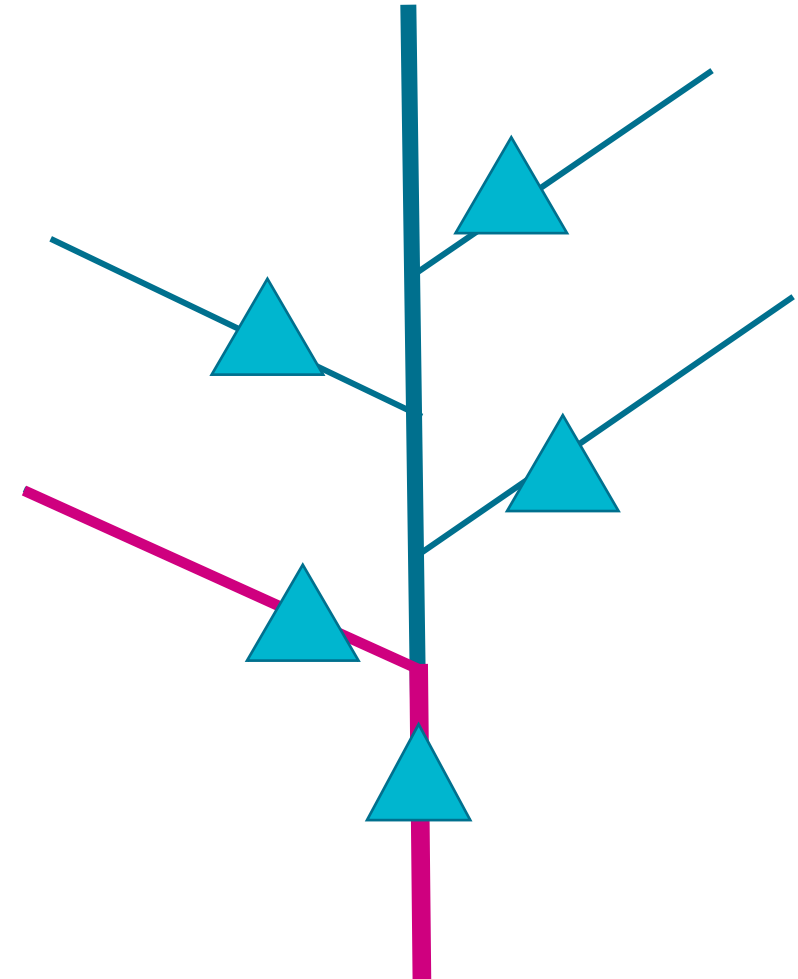
¹ BoSL Water Monitoring and Control, Monash University

² School of Civil and Environmental Engineering, Queensland University of Technology

Low-Cost Sensor Networks

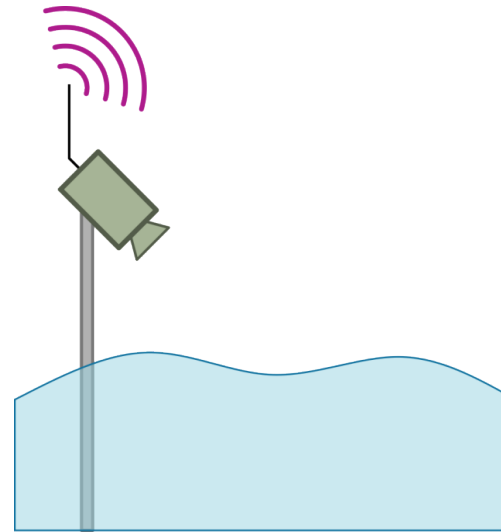
Monitoring sewer & urban water systems

- Turbidity: indicator of health
- Real-time network alerts
 - Illicit connections
- Data for real time control
 - Constructed wetlands
- Prediction models
 - TSS temporal dynamics
- Commercial Solutions:
 - Expensive
 - In-water: high maintenance
 - ⇒ Low resolution
- Sensor network: high resolution
 - Need low-cost low-maintenance turbidity sensors



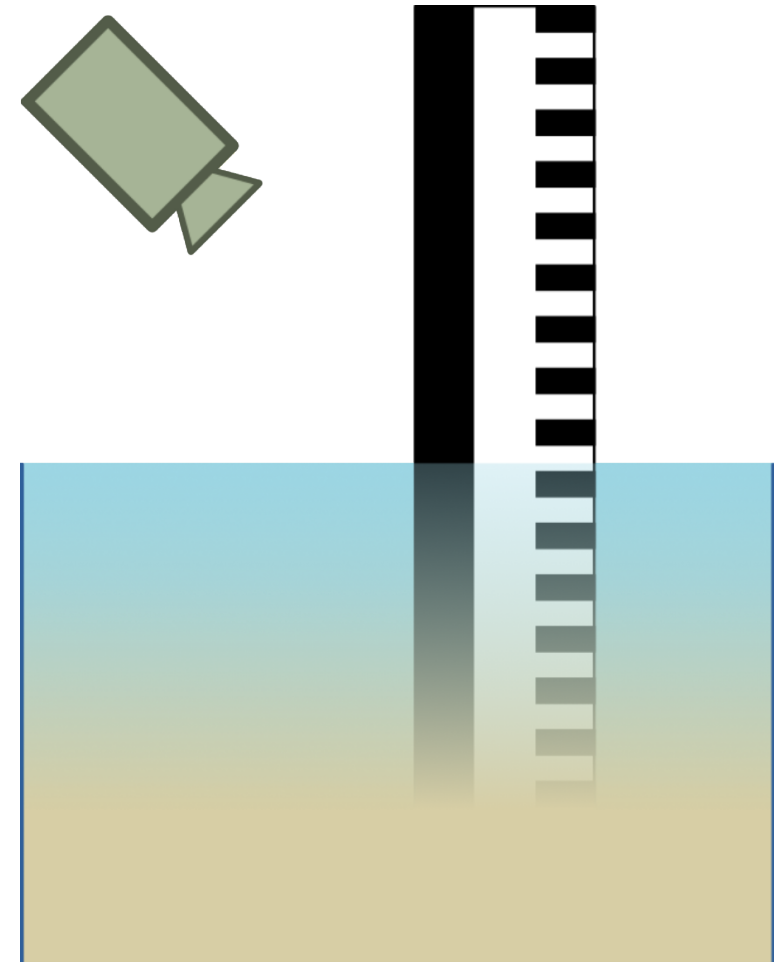
Out-of-water sensing

- Installation: no confined space entry
- Reliability: no water ingress
- Performance: no biofilm
- Connectivity: cellular reception
- Out-of-water \Rightarrow lower costs, lower maintenance



Out-of-water turbidity

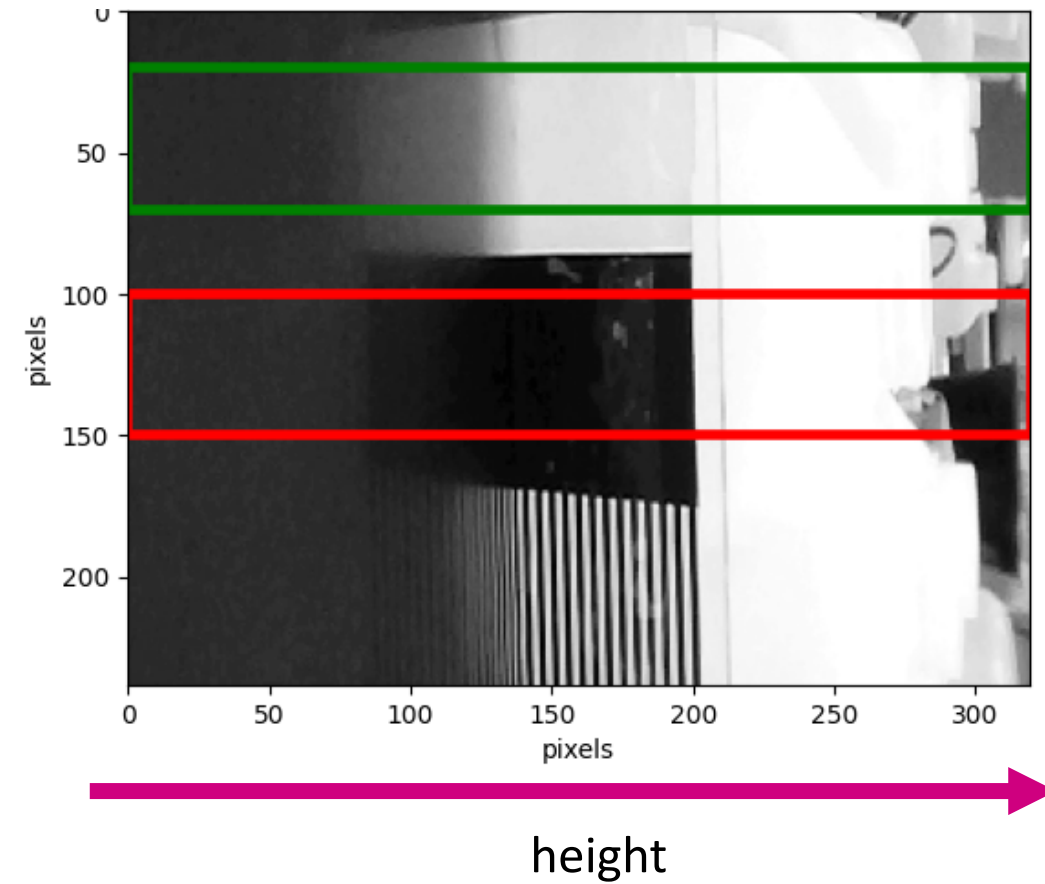
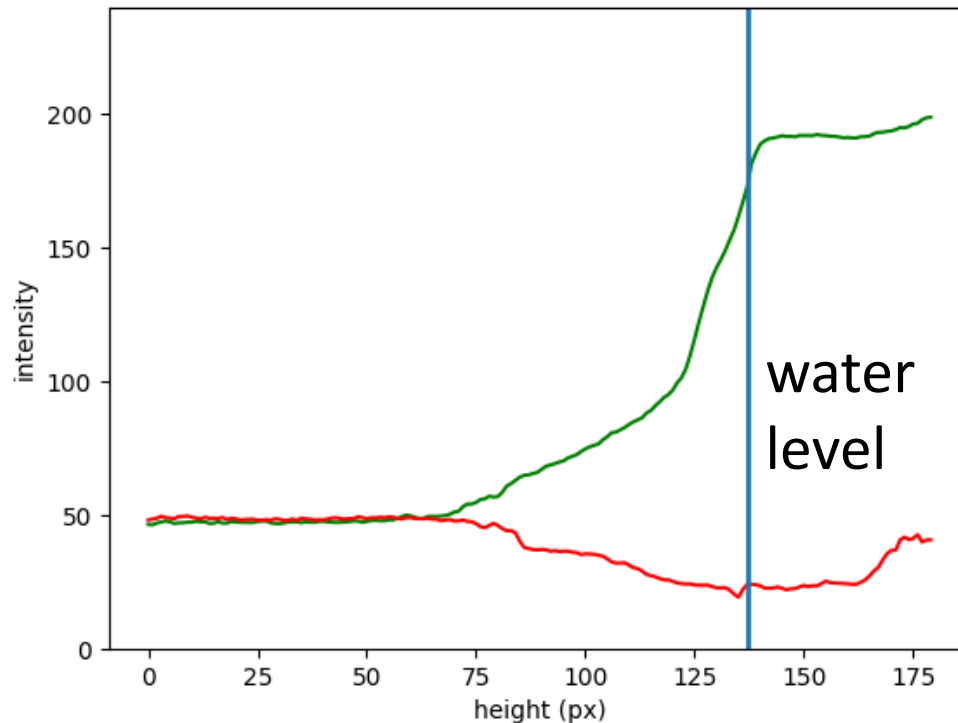
- Colour changes
 - Complications:
 - Water level
 - Light level
 - Surface turbulence
 - “Secchi disk” principle
- } Reference background biofilm?



Algorithms

- Low power \Rightarrow simple algorithms:
 - Low memory usage
 - Short processing time

NTU



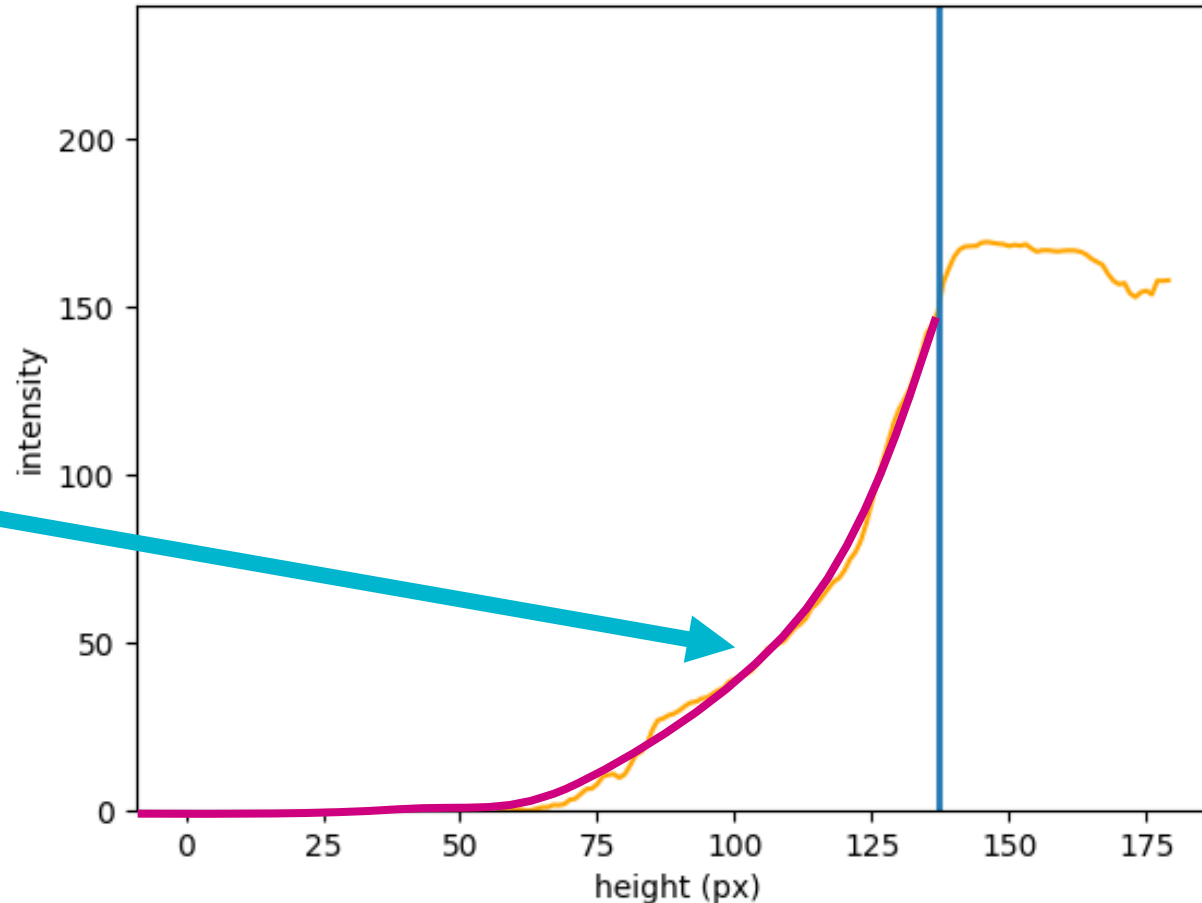
Exponential Fit

- Beer-Lambert's law
- White - black:
compensate for
illumination
- Fit exponential:

$$Ae^{-Bd_{\text{pixel}}}$$



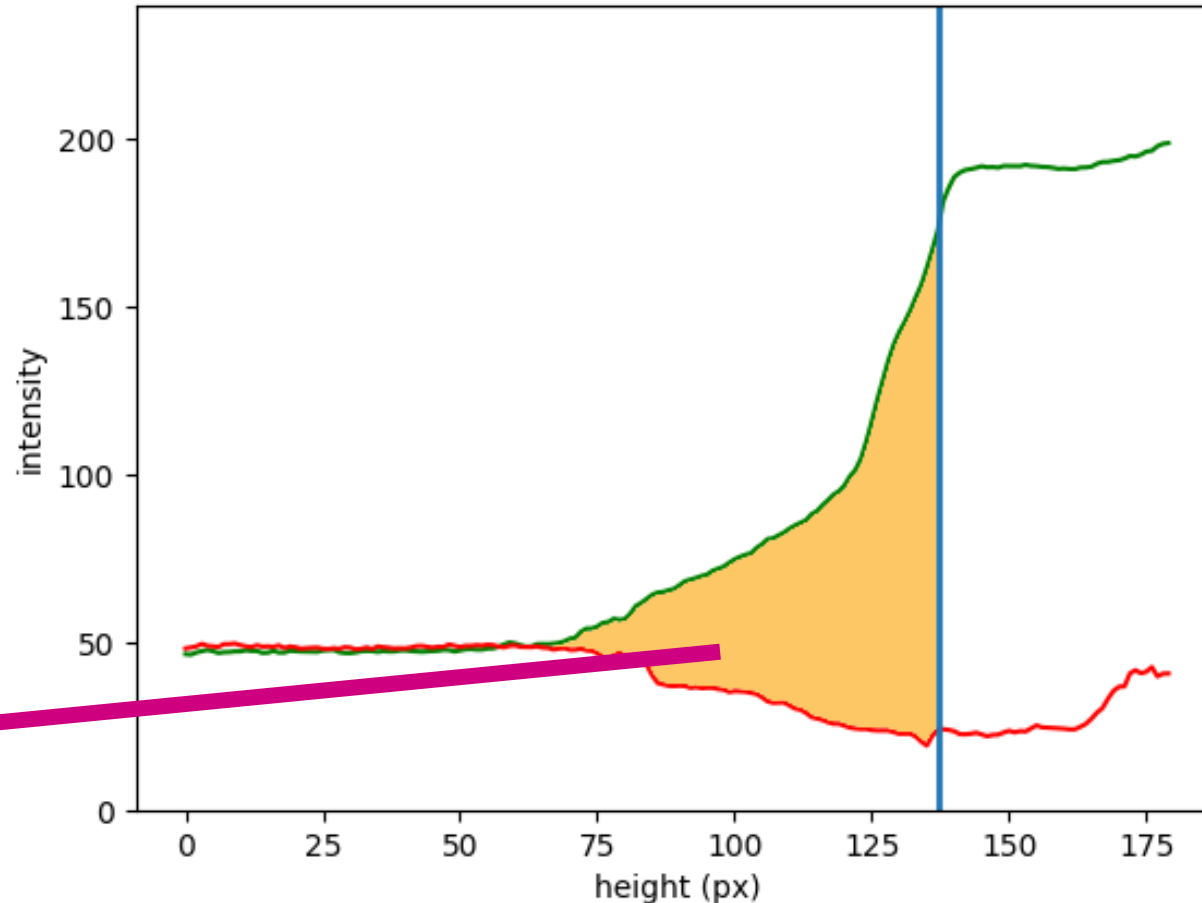
turbidity



Contrast Integral


- Bounded area up to water surface
- Integral:
 - robust to turbulence

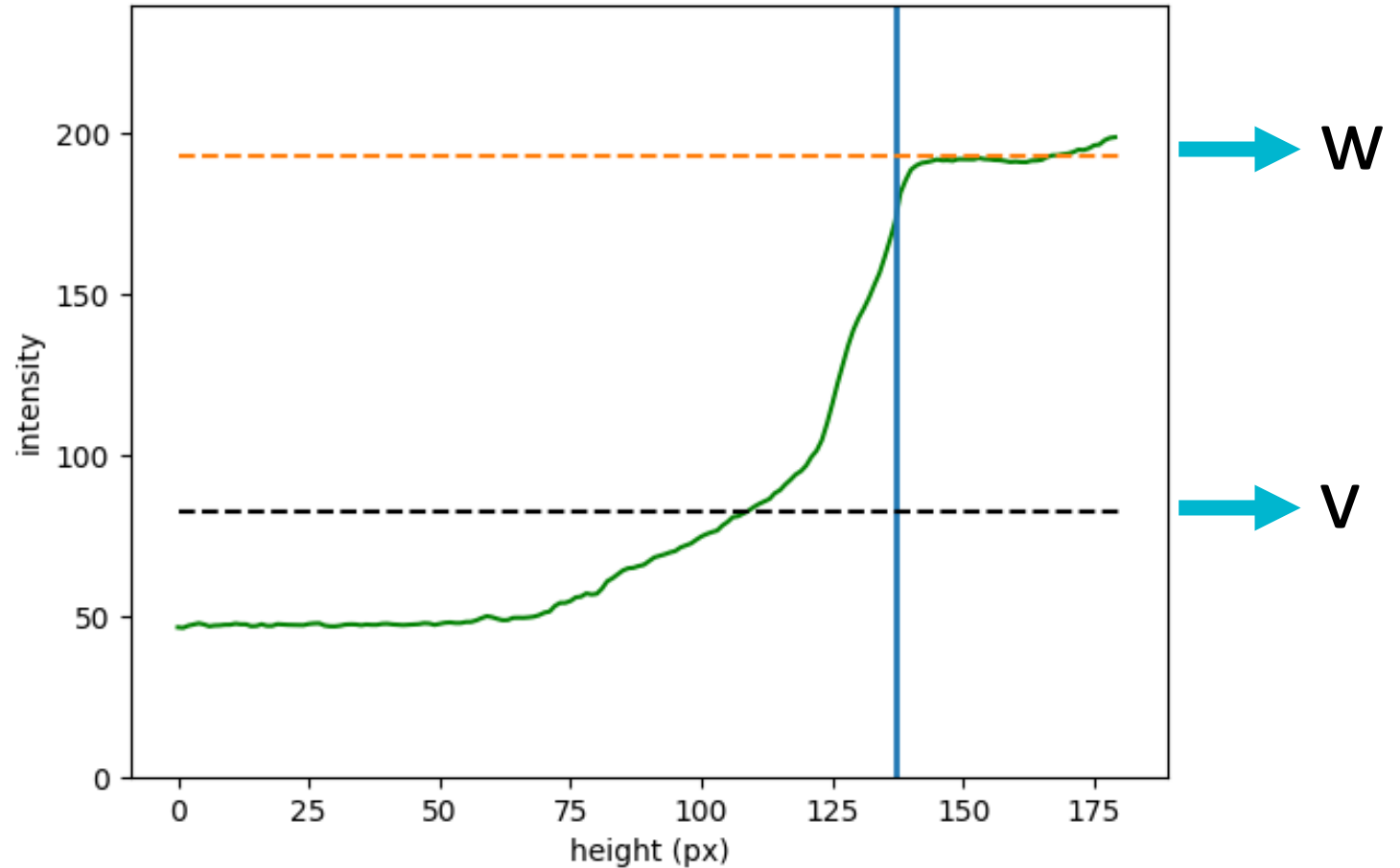
turbidity ←



Contrast Ratio

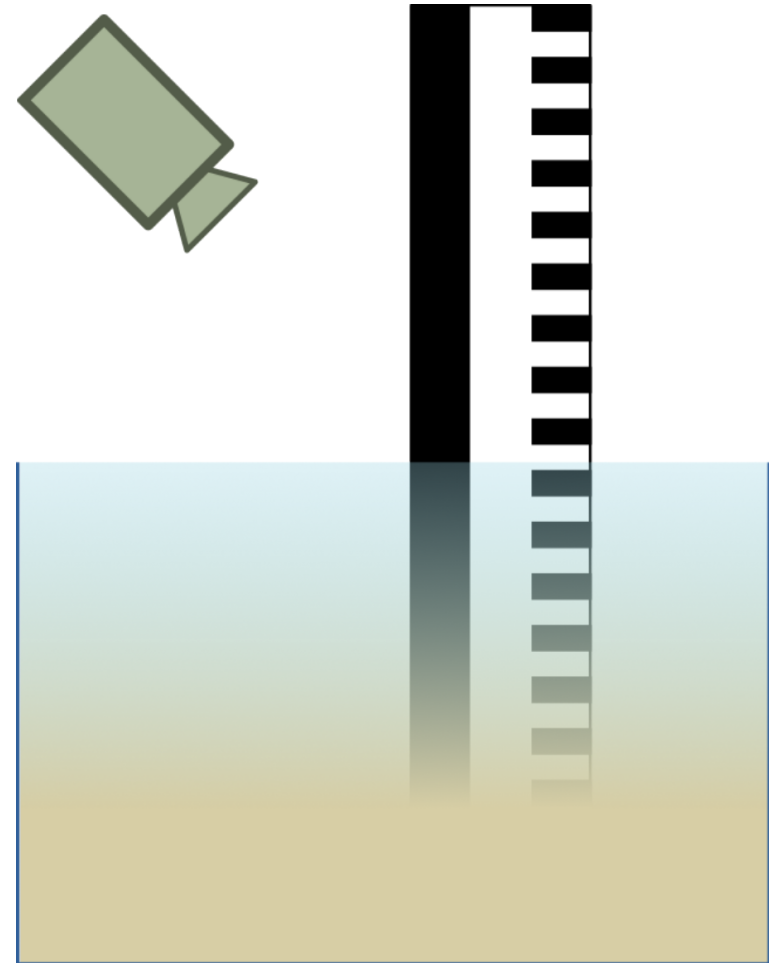
- Ratio out/in water
- Large region:
 - robust to turbulence
- Simplest

w/v

 turbidity



Method

- OV7675 QVGA camera
- 1 – 200 NTU
 - Expected in stormwater
- Orion AQ4500 turbidity meter
- Still and turbulent surface

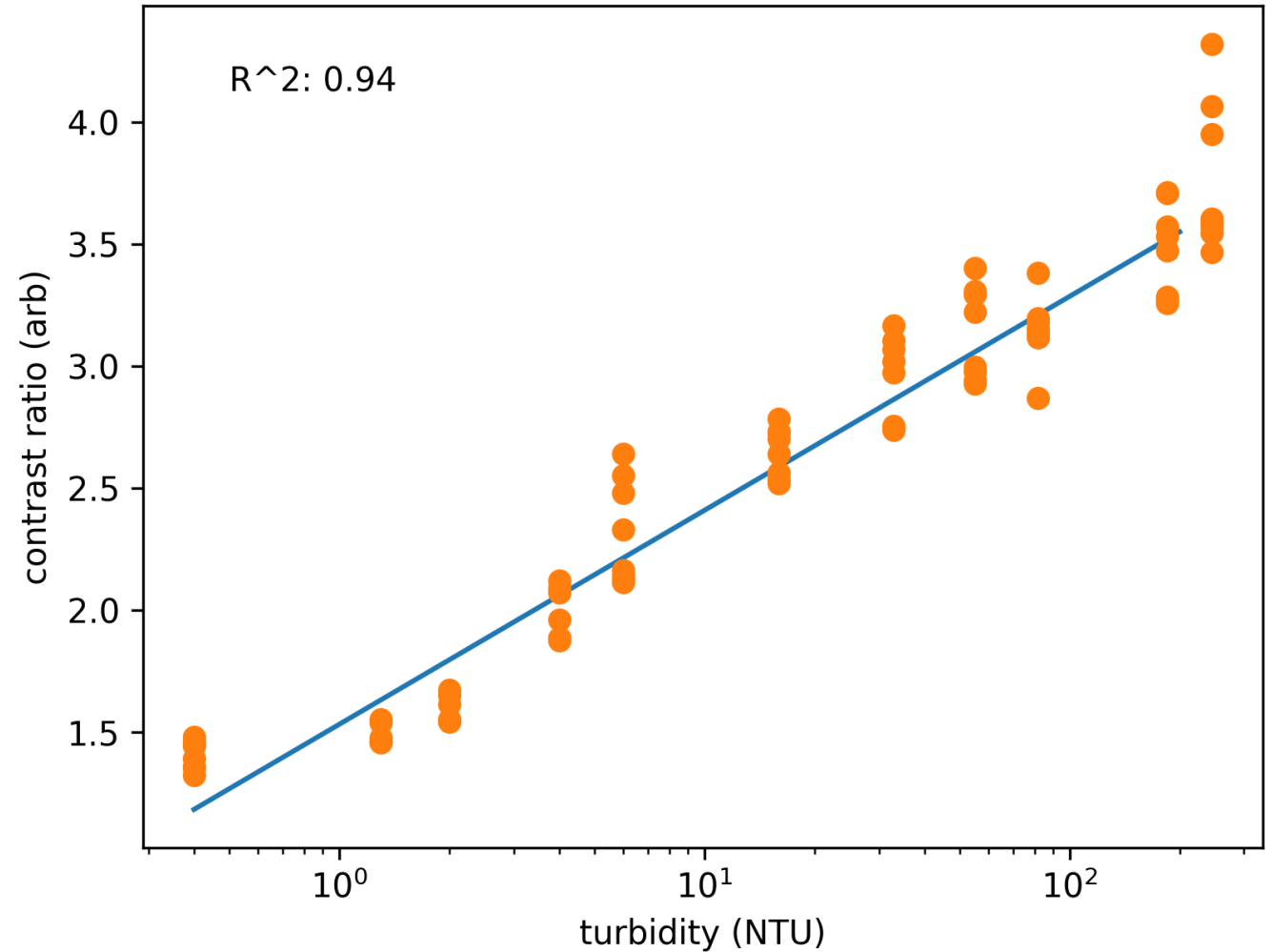


Results

	Exponential Fit	Contrast Integral	Contrast Ratio
Memory usage			
Processing time			
R^2			
Range			
Coefficient of Variance			

Contrast Ratio

- Output-turbidity correlation
- Turbulence \Rightarrow spread
- Spread large
 - Useful for event detection
- Lab illumination

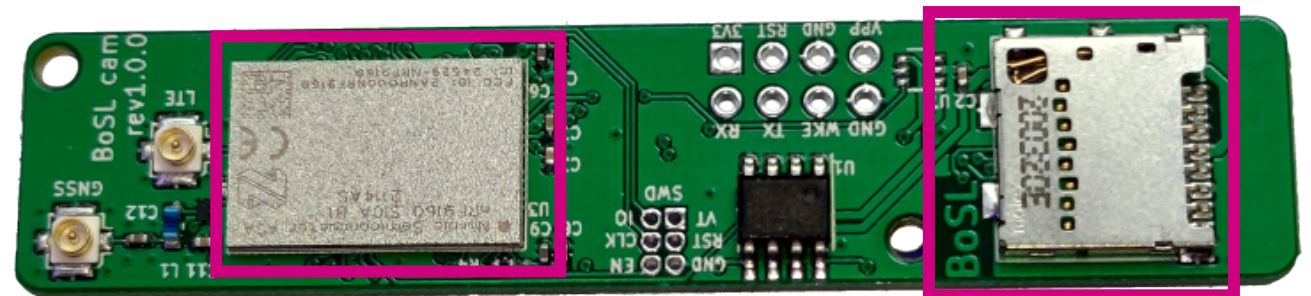
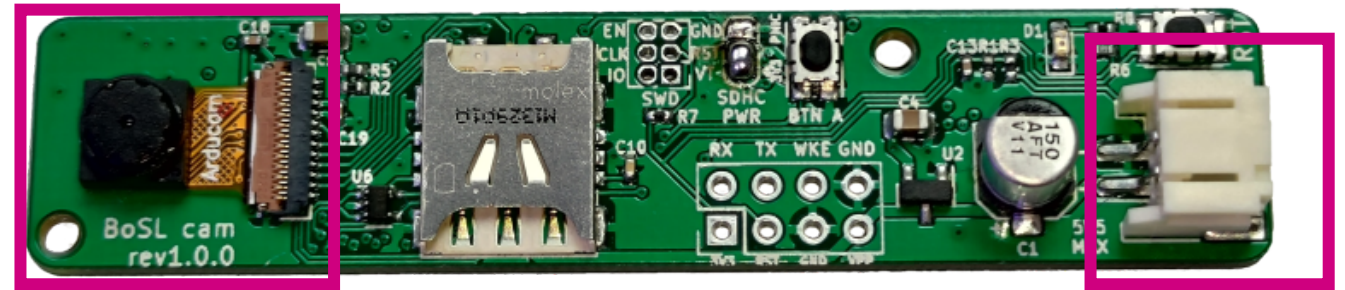


Next Steps

- Water-level detection
- Integrated camera datalogger
- Scaling setup
- Field testing

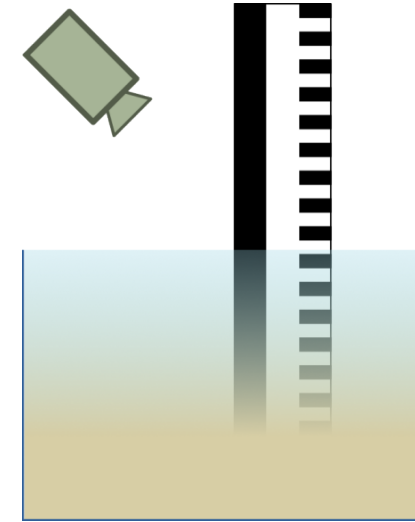
BoSLcam

- Cellular connected camera datalogger
- OV7675 camera
- nRF9160 MCU+LTE modem
 - CAT-M1
 - NB-IoT
- SD card
- Low power: 3.7 V Li-ion battery
- User programmable
- Open-source
- Total cost: < 50 EUR



Summary

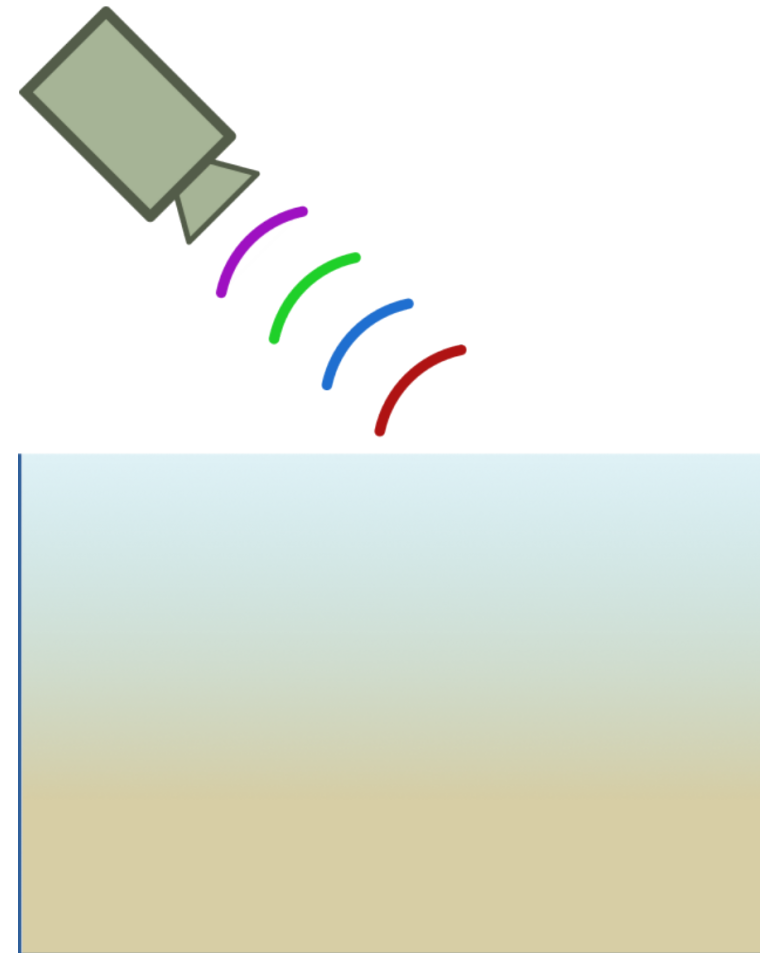
- Camera turbidity concept
 - Modified Secchi disk method
- Compared imaging processing algorithms
 - Contrast ratio
- BoSLcam:
 - Colour analysis
 - Computer vision
- Next: Field testing
 - Comparison to existing methods



Hyperspectral Sensor

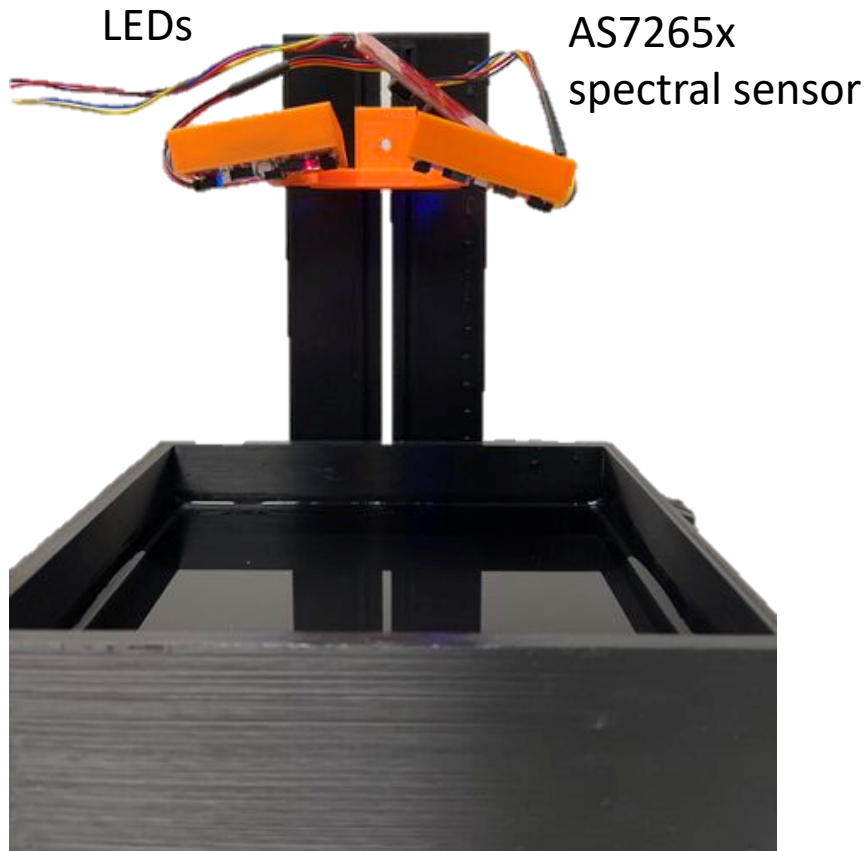
Eric Zhu

- Multi-wavelength potential:
 - Dissolved oxygen
 - Nutrients
 - Turbidity

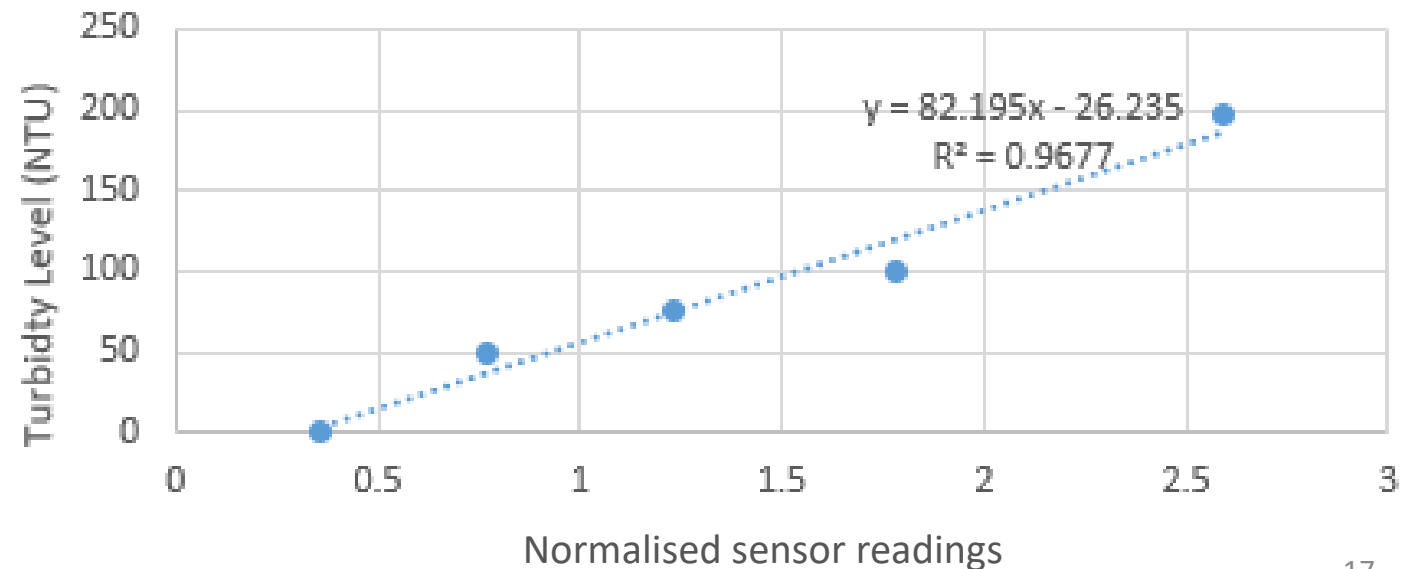


Hyperspectral Sensor

Eric Zhu

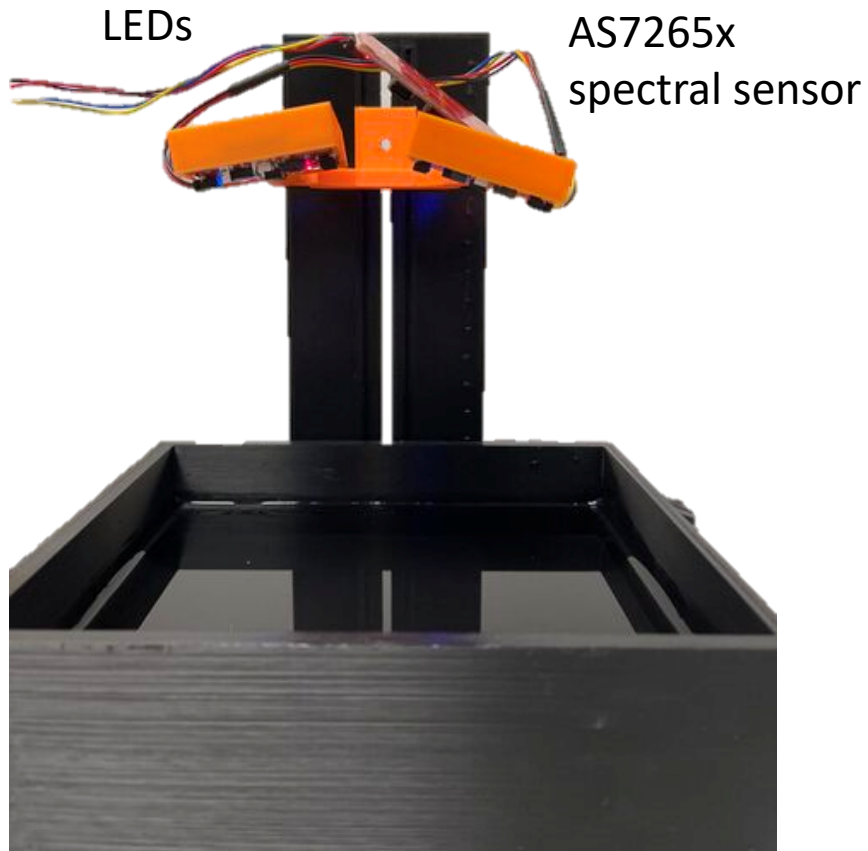


- 988 nm – 350 nm
- 875 nm, visible, and 405 nm LEDs
- Early development
- Low cost
- Promising turbidity results @ 645 nm:



Hyperspectral Sensor

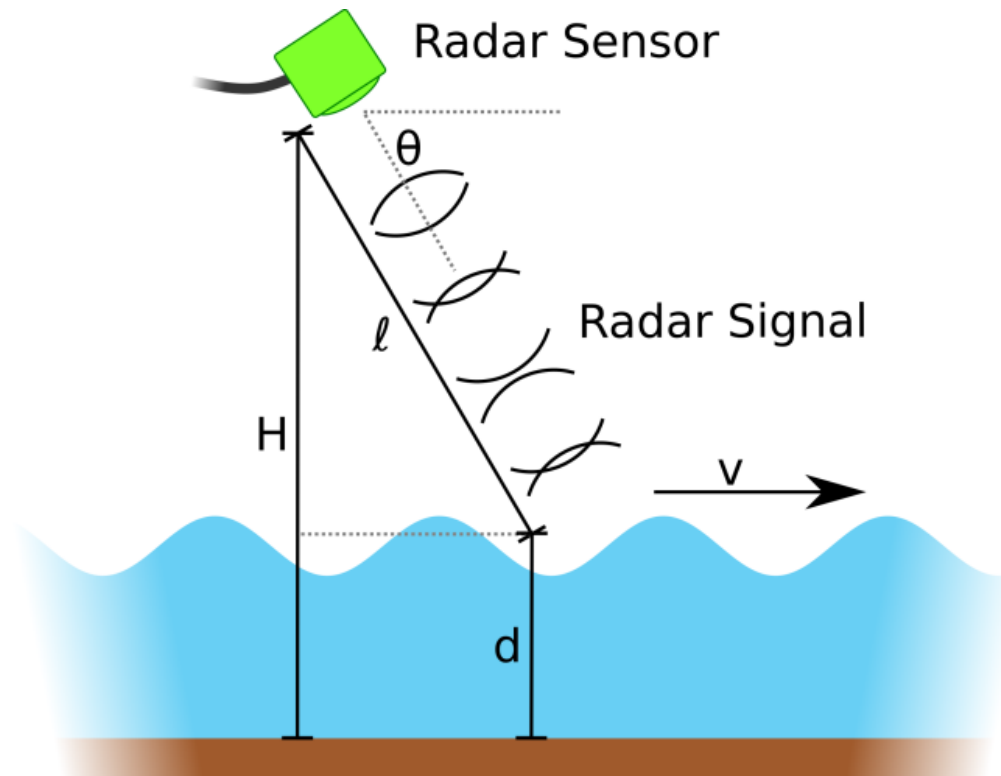
Eric Zhu



- Next steps:
 - Water level
 - Sensor angle
 - Lenses
 - Surface turbulence
 - Field testing

Out-of-water velocity + depth

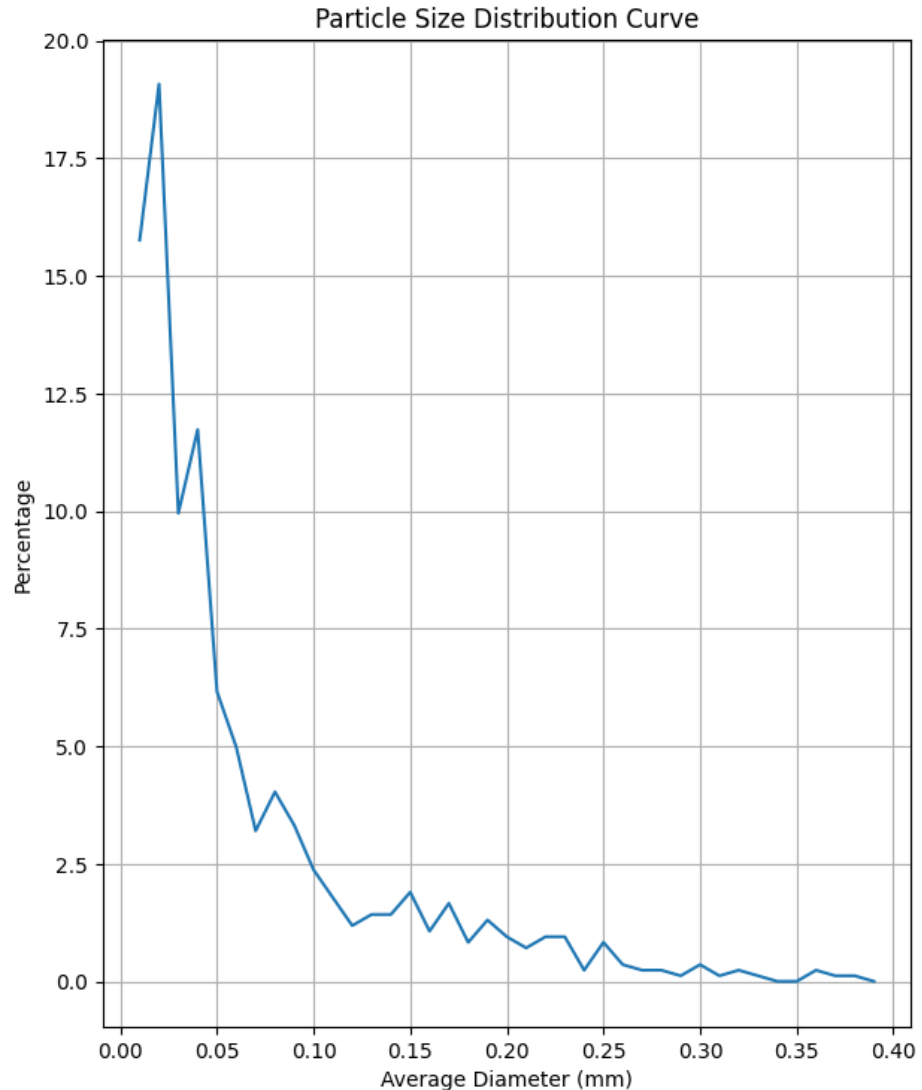
- Radar based
- Water velocity $\pm 36\%$
- Water depth $\pm 6\%$
- Field verified
- Low cost $< 30\text{€}$
- 3D printed
- Open source



Particle Size Distribution

Canwei Pang

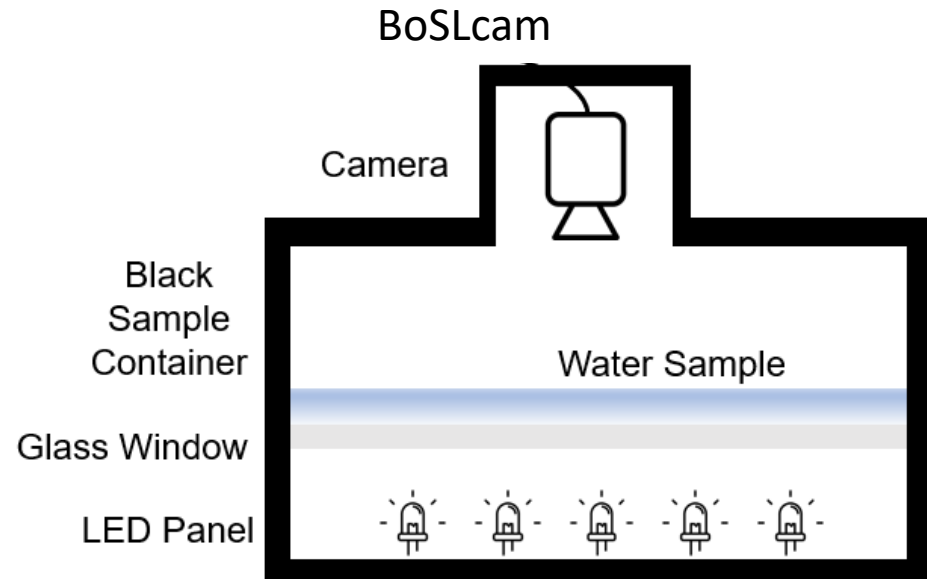
- In-water turbidity:
 - Enhance with imaging
- More than just turbidity:
 - Particle size distribution
 - Real time measurement
- Understand sediments:
 - Pollutant associations
 - Clogging
- Understand biofilm
 - Improve robustness



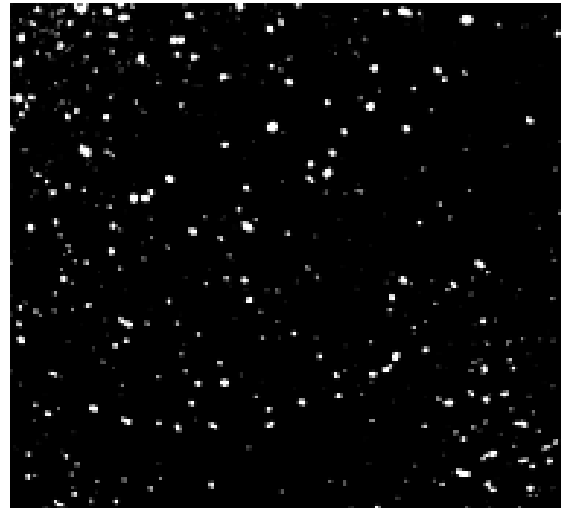
Particle Size Distribution

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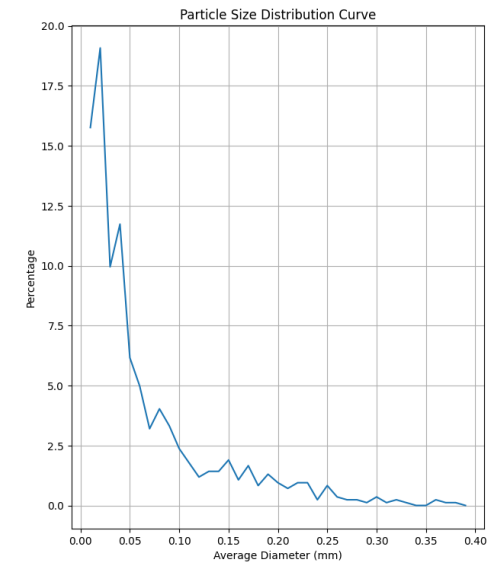
Setup



Image



Distribution



Next steps: lens - μm resolution, field testing, autosampler comparison

More Information

- BoSL website:
 - www.bosl.com.au
- Out-of-water turbidity + BoSLcam:
 - https://www.bosl.com.au/wiki/Out_of_Water_Turbidity
- Out-of-water velocity + depth sensor
 - https://www.bosl.com.au/wiki/Radar_Velocity
- Hyperspectral sensor:
 - <https://www.bosl.com.au/wiki/Spectrophotometer>
- Particle size distribution sensor:
 - https://www.bosl.com.au/wiki/PSD_Sensor



Questions?

Low-Cost Sensor Networks

Monitoring sewer & urban water systems


- Turbidity: indicator of health
- Real-time network alerts
 - Blind commissioning
- Data for real-time control
 - Control-based methods
- Prediction models
 - TSD temporal-dynamics

Commercial Solutions:

- Expensive
- In-situ: high maintenance
- Low resolution


Sensor network: high resolution

- Need low-cost, low-maintenance turbidity sensors



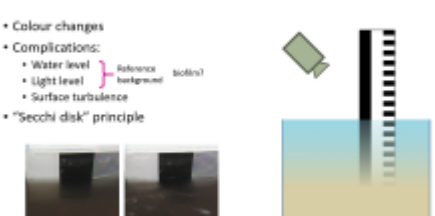
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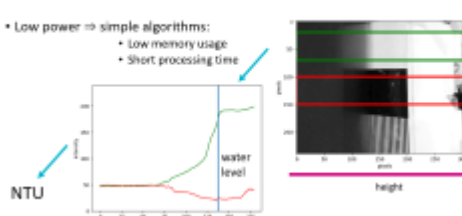
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 - Water level } Reference background (bottom)
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 - Surface turbulence }
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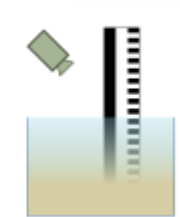
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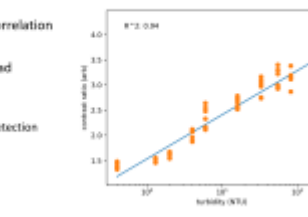


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Range			
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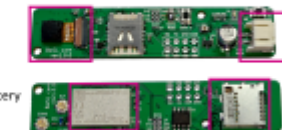
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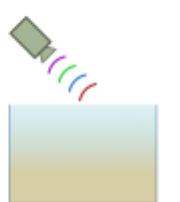
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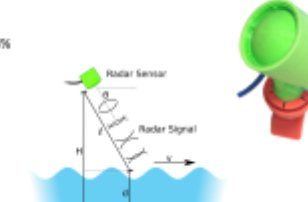
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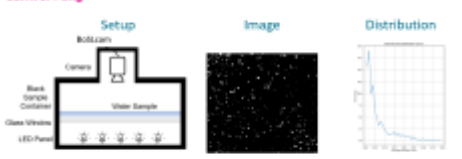
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