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Institute of Computer Science

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PENGUIN: Aquatic Plastic Pollution Sensing Using Autonomous Underwater Vehicles (AUV)s

Huber Flores, Agustin Zuniga, Naser Hossein Motlagh, Mohan Liyanage, Monica Passananti, Sasu Tarkoma, Moustafa Youssef and Petteri Nurmi

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Importance

- Aquatic plastic pollution is a global concern, affecting everything from marine ecosystems to climate change and even human health.

Floating

Source: https://www.naturepl.com/stock-photo-divers-swimming-past-a-plastic-bag-floating-underwater-resembling-a-nature-image01619091.html

Underwater

Source: https://www.pikrepo.com/frqdg/plastic-bottle-floating-on-water

Mixing with the ecosystem

Source: https://www.pinterest.com/pin/484840716132563124/

Preventing the pollution caused by plastics is extremely important

Finding plastics underwater is non-trivial

- Visual inspections (humans) and object recognition fail to identify plastics

Plastic bottle blended with coral

Source: https://www.independent.co.uk/environment/plastic-pollution-coral-reefs-disease-damage-seas-oceans-cornell-university-a8178156.html

Coral wrapped in a plastic bag

Source: https://www.independent.co.uk/environment/plastic-pollution-coral-reefs-disease-damage-seas-oceans-cornell-university-a8178156.html

Degraded plastic bottle in sea floor

Source: https://twitter.com/4ocean/status/993913424332673025/photo/1

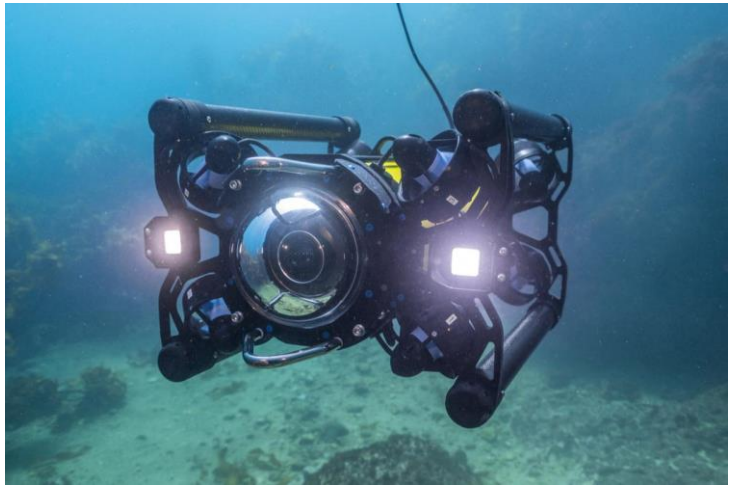
How to identify and classify plastics underwater accurately?

PENGUIN: Contributions

- **New system:** We present PENGUIN, a novel AUV system and architecture for plastic pollution monitoring underwater
- **New method:** PENGUIN integrates a low-cost and low-power sensing solution that uses off-the-shelf green light sensors
- **New insights:** We demonstrate that PENGUIN can identify and classify plastics underwater

State-of-the-art solutions

- On the water surface
  - (aerial UAVs, boats, buoys, satellite images)
- Underwater
  - Visual inspection by experts (diver expeditions)
  - Cameras and object recognition (ROVs)
  - Infrared spectroscopy (very costly, not scalable)

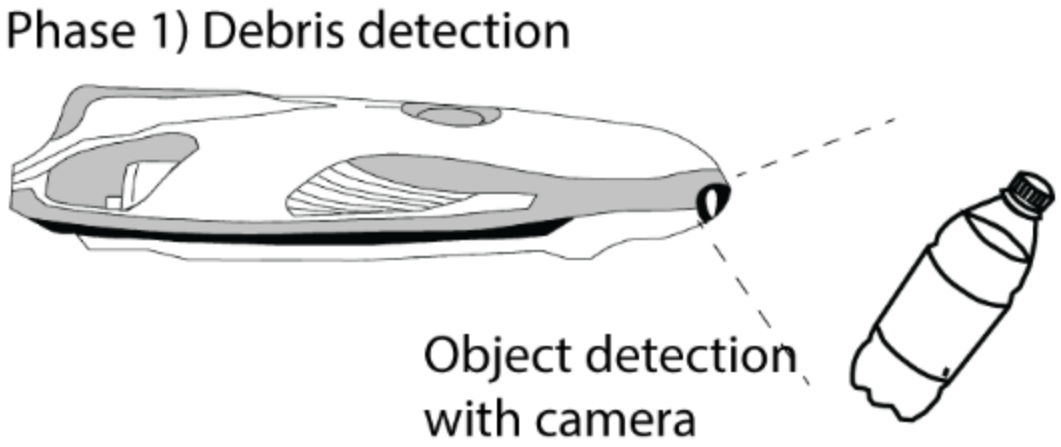


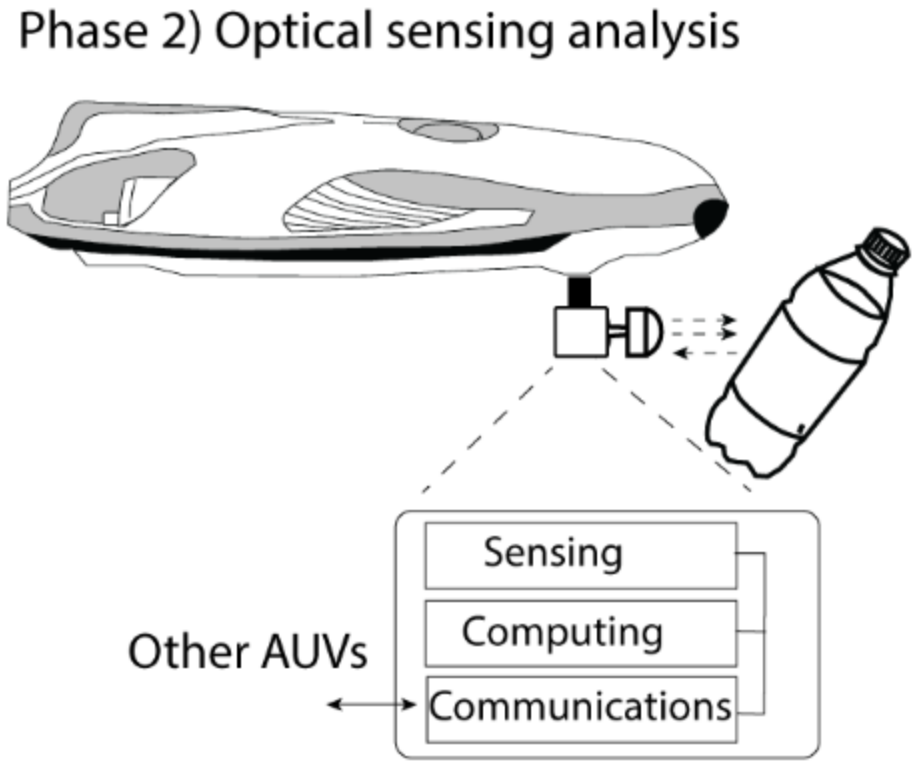
Source: https://newatlas.com/boxfish-rov-underwater-camera-drone/55612/

Source: https://www.pinterest.com/pin/558094578803524390/

Current solutions can identify plastics (at some extent) but it is not possible to classify them

PENGUIN: Overview





PENGUIN: Evaluation and Results

PENGUIN: Testbed

RIC

Plastic bottles

Plastic bags

Shampoo bottles

Plastic cards

Six pack rings

Plastic trays

Respiratory masks

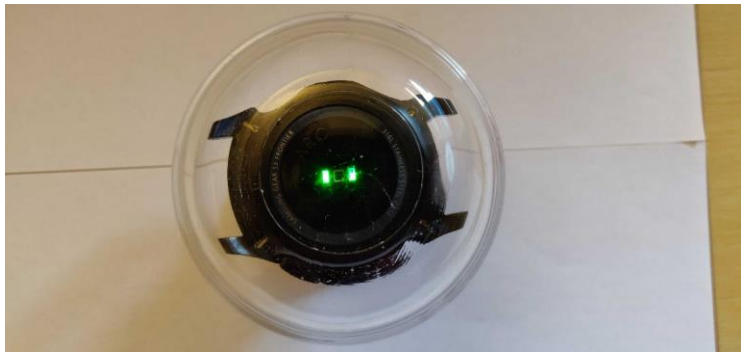
Diapers

Food packing

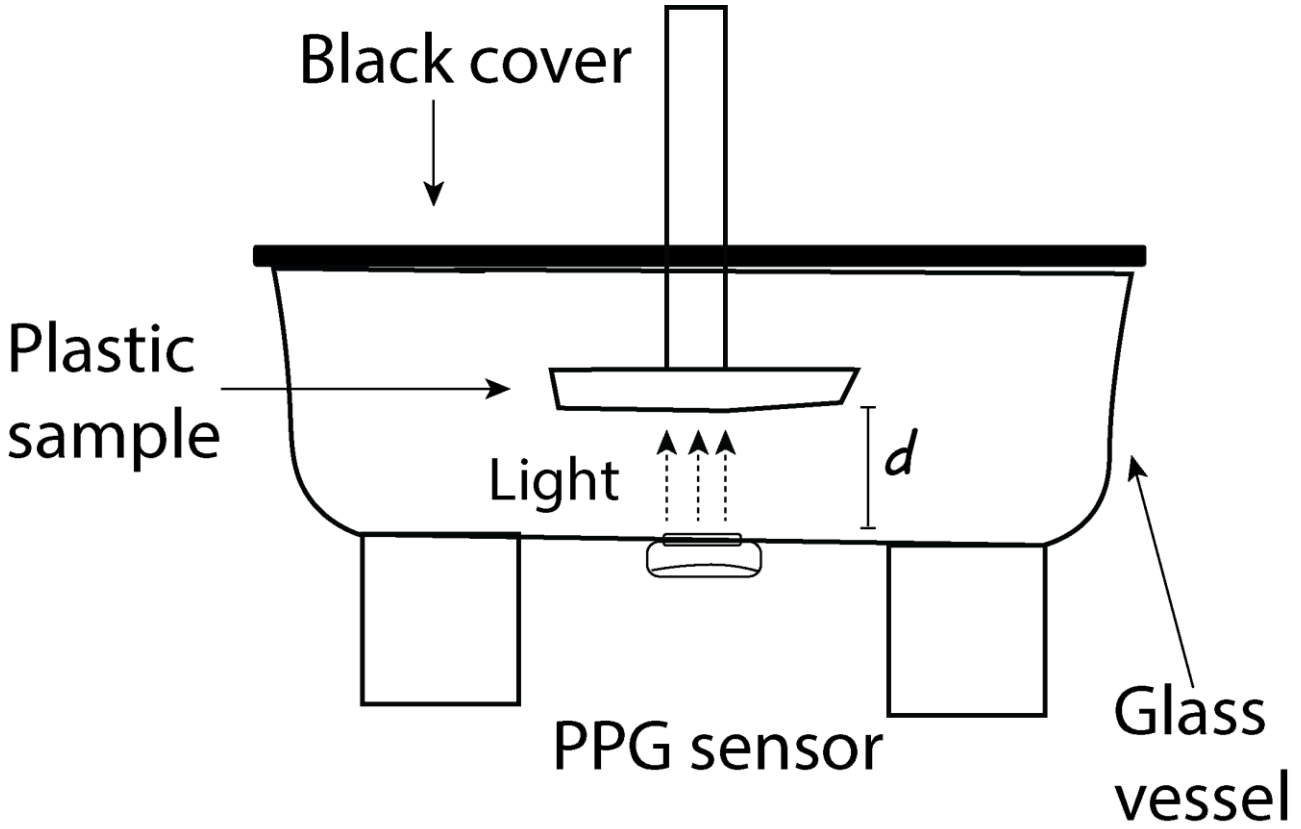
Car panel

PENGUIN: Testbed

Controlled plastic samples



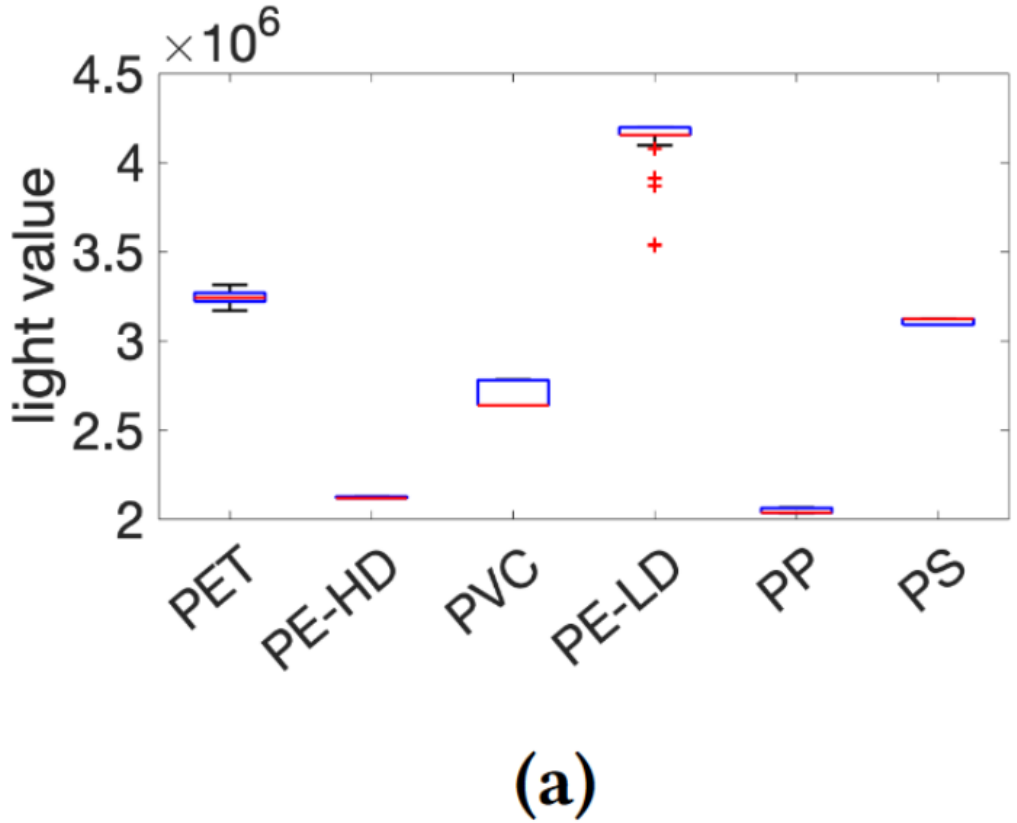
Light sensor through glass



Testbed for plastic recognition underwater

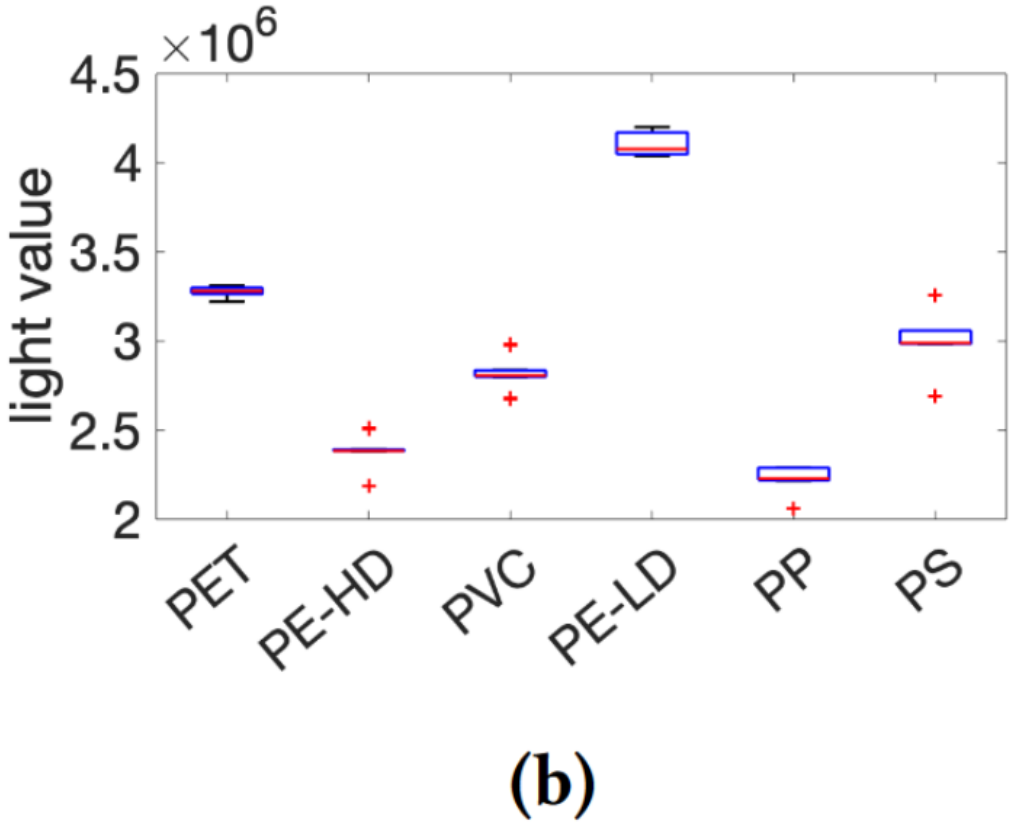
PENGUIN: Evaluation

Result: Green light reflectivity can characterize plastics in different environmental conditions



(a)

Ambient light



(b)

Dark environment

PENGUIN: Evaluation

Result: High accuracy to classify different types of plastics underwater

Test	k-NN	Random forest	Average
Cross Validation			
All conditions 6-folds	0.95	0.95	**0.95**
Ambient 6-folds	0.96	0.95	**0.96**
Darkness 6-folds	0.94	0.96	**0.95**
Model data → Predicted			
Ambient → All conditions	0.80	0.80	**0.80**
Ambient → Darkness	0.69	0.68	**0.69**
Darkness → All conditions	0.95	0.95	**0.95**
Darkness → Ambient	0.94	0.92	**0.93**
Average	**89.0**	**88.7**	**88.9**

Plastic classification accuracy in different experimental conditions.
Model data -> Predicted

PENGUIN: In the wild

Result: AUV navigation is not disrupted. Human operators are required.

PENGUIN front view

PENGUIN: Ongoing work

- Other cases
  - Water turbidity
  - Water flow (stability with other sensors, e.g., accelerometer)

- Other uses for green light and other light spectrum, e.g., red
  - Supporting simultaneous communication and sensing is possible

- Cooperation between UAVs
  - Augmenting processing resources even further underwater, e.g., like a Naptick datacenter

Summary and conclusions

- **New system:** We present PENGUIN, a novel AUV system and architecture for underwater plastics pollution monitoring
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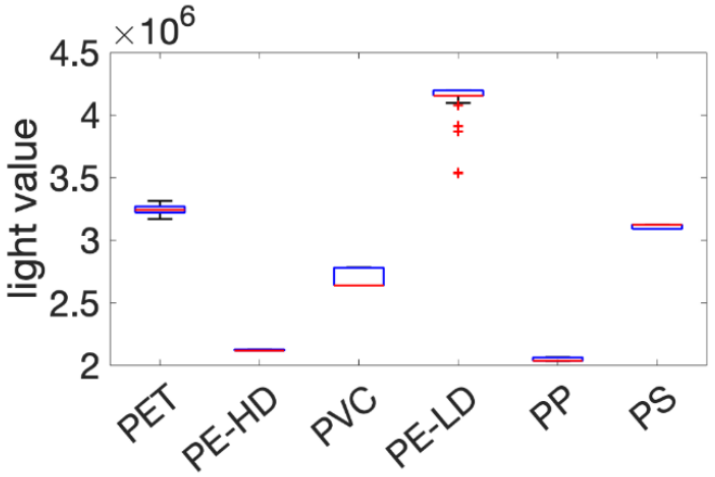
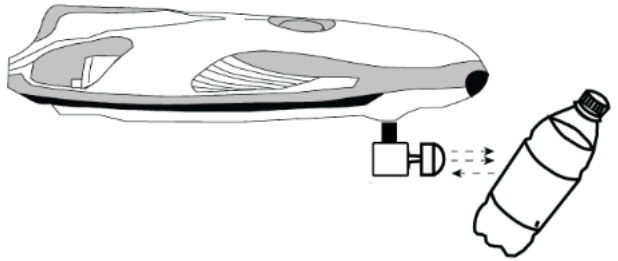


Questions?



Thank you! (Do not hesitate to reach us via e-mail)

Huber Flores (huber.flores@ut.ee)
Agustin Zuniga (agustin.zuniga@helsinki.fi)
Naser Hossein Motlagh (naser.motlagh@helsinki.fi)
Mohan Liyanage (mohan.liyanage@ut.ee)
Monica Passananti (monica.passananti@unito.it)
Sasu Tarkoma (sasu.tarkoma@helsinki.fi)
Moustafa Youssef (moustafa@alexu.edu.eg)
Petteri Nurmi (petteri.nurmi@helsinki.fi)