Activity report on the project "*MIRROR: a Microplastic Raman Optical Rover to Understand Microplastics Variability Along Beaches of Matagorda Peninsula*"

PIs: Cornel Olariu, Christian Claudel and Carlos Baiz, The University of Texas at Austin

PhD students: - Gus Santaella, Joseph Shirley, Kobini Antony Rex

Postdoctoral scholar: -

Undergraduate students - - Aditya Matam, Shreya Arvind

Period: June 1st 2024 to September 30th 2024 – Work in the lab on the portable instrument development, rover instrumentation and calibration of the equipment.

During the June to September 2024 period, the project focused on (1) testing Near infrared (NIR) spectroscopy in the laboratory. The primary focus was to test the accuracy of, first recognize plastic material and secondly the type of the polymer; (2) design of the portable Rover with implementation of the NIR portable spectroscopy instrument.

The MIRROR project relies on the development of a robust method to recognize microplastics that is compact and can be implemented on a rover and used in the field environment rather than in the lab. To test and improve the method a series of laboratory tests are undertaken before field evaluation.

A study on using data augmentation to identify plastics (Shriley et al., 2024) was undertaken to test the capabilities of the near-infrared (NIR) spectrometer in identifying of the different type of microplastics. The NIR method was chosen because it can be transferred to a rover device, it has a compact size it can be made portable, is a robust method and has rapid acquisition times of 100 ms per sample.

A custom based NIR instrument (Figure 1) was tested on plastic materials collected from the residential areas of Austin (Polyethylene terephthalate (PET), high-density polyethylene (HDPE), low-densitypolyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS),nylon, polylactic acid (PLA), and rubber bands) or purchased (acrylonitrile butadiene styrene (ABS), polyvinylchloride (PVC), polystyrene (PS), and neoprene rubber sheets). The samples were validated using established spectroscopic analyses.

NIR spectra of plastics and environmental background materials were collected and were categorized as ABS, Nylon, PET, PE, PLA, PP, PS, PVC, Rubber, Plant-Based, and Water (Figure 2). Using the NIR spectra two larger training sets (48000x2) were generated in via data augmentation and combined with Gaussian noise at multiple signal-to-noise levels (Shrieley et al., 2024).

For algorithms classification the highest performing algorithms on the training set the cubic support-vector machine SVM (SVM3) and the wide neural network (WNN) were used. The

MATLAB 2023b classification learner software was used to train classification algorithms using the labeled training data set.

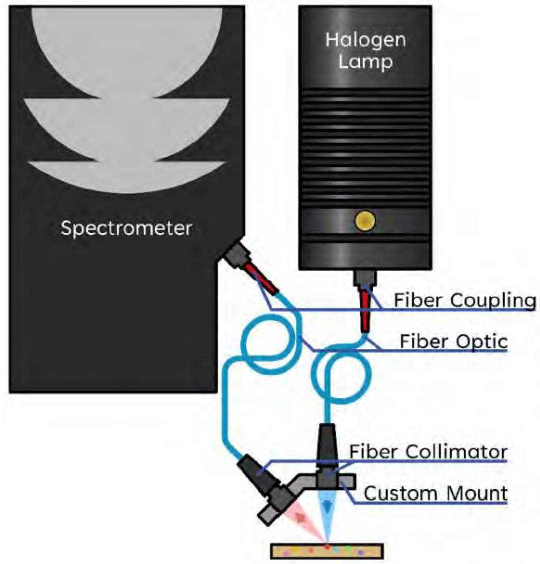


Figure 1. Schematic of the near infrared (NIR) instrument. A broadband light source is focused onto a sample and the remitted light is collected at a 45° angle between the illumination and collection sources. The collected light is sent to a spectrometer for measurement. (from Shrieley et al., 2024)

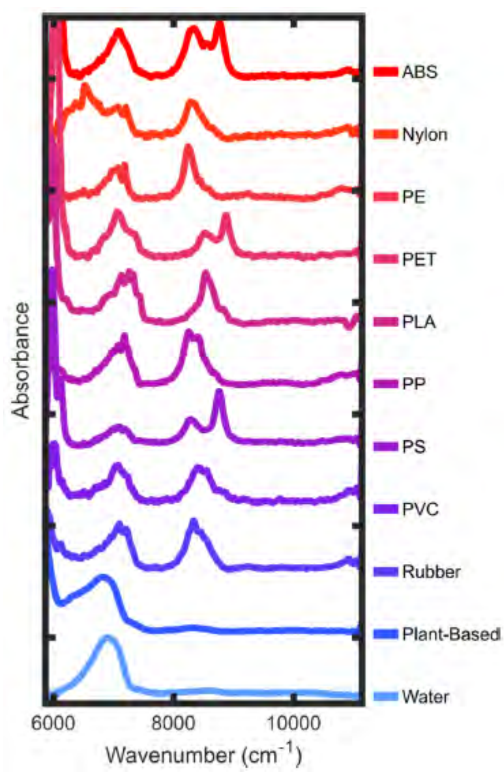


Figure 2. Averaged absorbance spectra of each category of material. Frequency in cm-1 is on the x-axis and absorbance is on the y-axis. The definition of each plastic is included in the Methods section of Shrieley et al. (2024).

The classification performance of the algorithms show that the cubic support vector machine (SVM3) models and wide neural network (WNN) models retain a high degree of accuracy when transferring from the training to the testing. The classification algorithms test on measured samples shows the SVM3+BG (background) are 86.4% accurate (Figure 3).

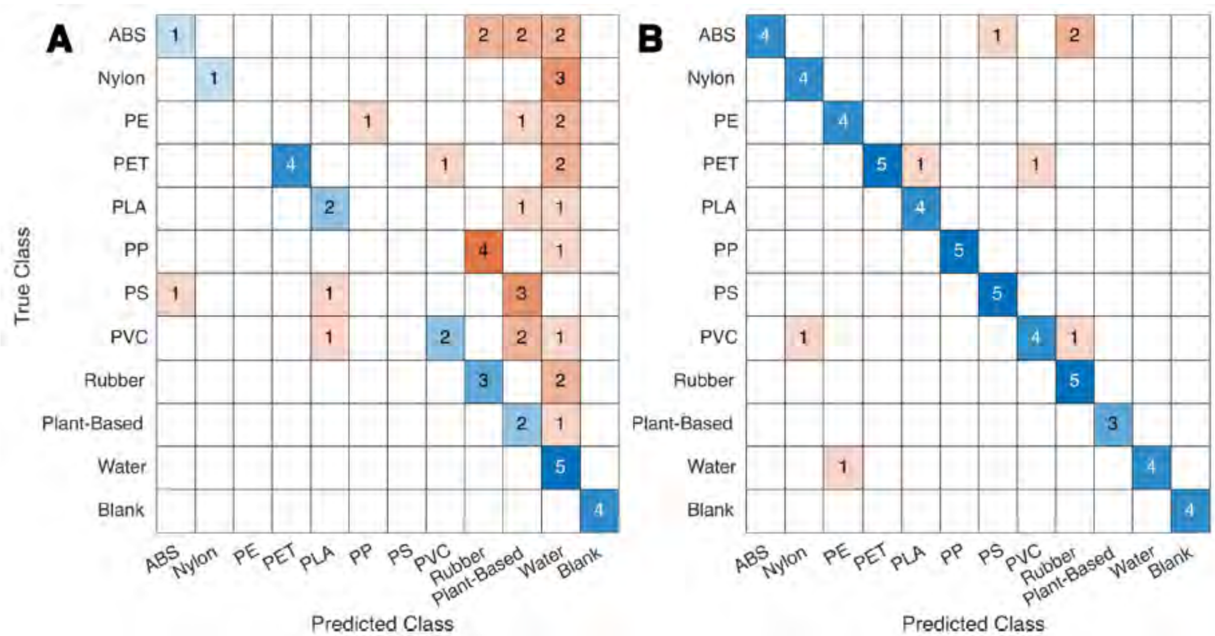


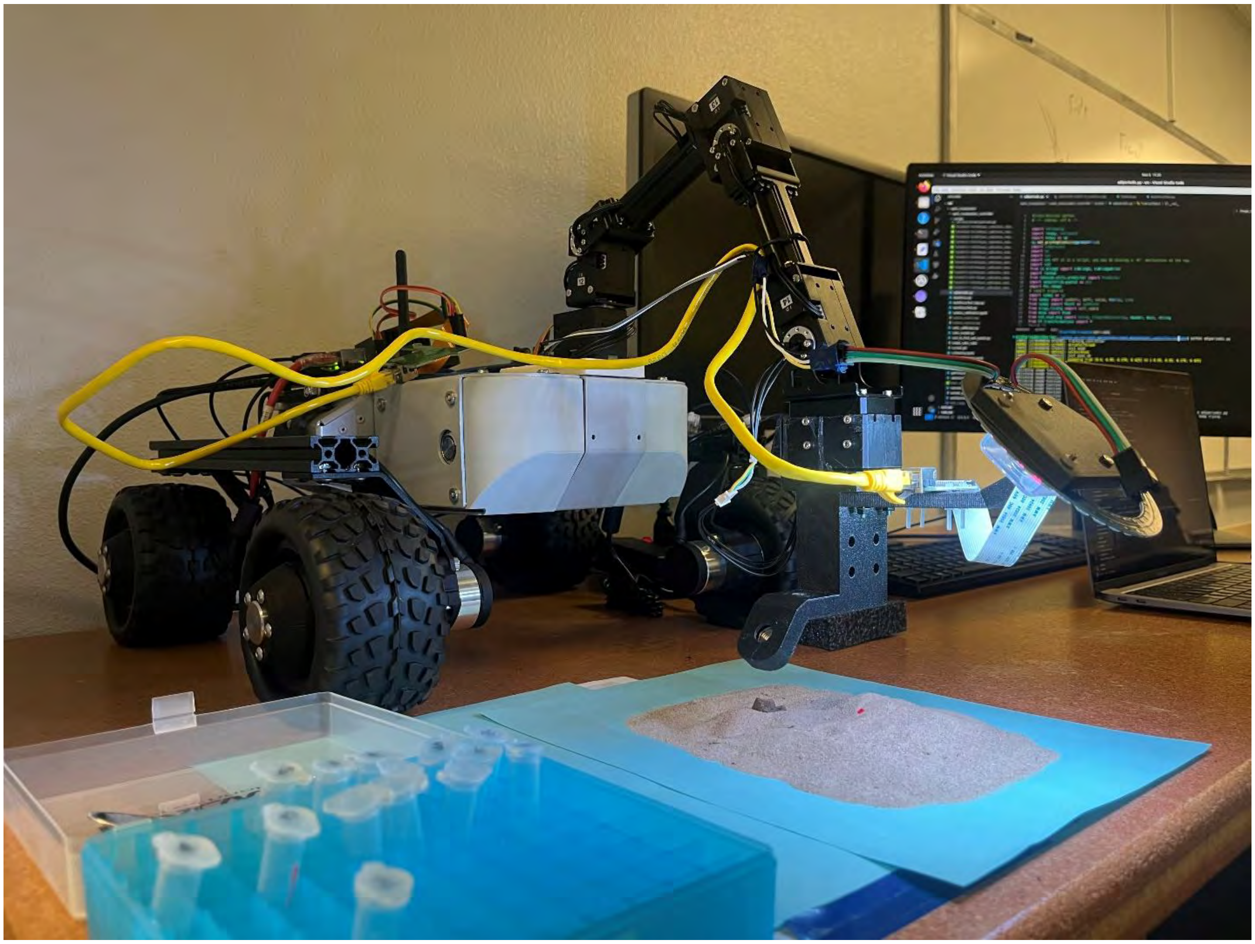
Figure 3. Confusion matrix of the SVM3 model (A), and the SVM3+BG model (B) on the authentic testing set. Predicted class is on the x-axis and true class is on the y-axis. False positives are off diagonal elements in a column, false negatives are off diagonal elements in a row. (from Shrieley et al., 2024).

The study demonstrated that augmentation of a limited spectral basis set with contaminant spectra significantly improves machine learning performance on real-world data classification, going from 40.7% accuracy to 86.4%. However, the method can be further improved by using a wider spectral range, reducing the spot size or using longer acquisition times. All of these will be further tested in the lab.

Rover designed focused on the integration of the robotic arm to the rover, and the analysis of the kinematics of the robotics arm. During the reporting period, the team focused on the problem of joint coordinate control for each of the joint of the robotics arm, in function of the desired position of the target virtual point (which corresponds to the focus zone of the near IR spectrometer). Since the joint was modified from its original design to accommodate the camera and near IR spectrometer, the team had to reprogram the inverse kinematics algorithm to match the new design.

The below image represents a detailed view of the tip of the robot arm, which contains a camera, an illumination ring, and the mounts required for the infrared spectrometer

Further work will focus on verifying that the coordinates of the virtual point in the world reference frame match the commands in all situations. Once this step has been achieved, the objective will be to control the robotic arm to place the virtual target point exactly on the coordinates of the identified microplastic piece. This will require the detection of candidate microplastics pieces using optical methods, the estimation of the microplastics piece locations in world frame coordinates using multiple images taken from different viewpoints, and the use of inverse kinematics to control the joint positions of the robotic arm.



REFERENCES

Shirley, J.C., Rex, K.A., Iqbal, H., Claudel, C.G., and Baiz, C.R., 2024, Microplastics in the Rough: Using Data Augmentation to Identify Plastics Contaminated by Water and Plant Matter, Submitted to RSC Sustainability