Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
MICS Made in Italy Circolare e Sostenibile

Enhancing waste material recycling from space activities

Giuseppe Bonifazi[1], Idiano D'Adamo[2], Roberta Palmieri[1], Silvia Serranti[1]

[1]Department of Chemical Engineering, Materials and Environment,
Sapienza - University of Rome, 00184 Rome, Italy
[2] Department of Computer, Control and Management Engineering,
Sapienza - University of Rome, 00185 Rome, Italy

Keywords: Hyprspectral Imaging, Recycling, Characterization, Space waste materials.

Presenting author email: roberta.palmieri@uniroma1.it

Introduction

Worldwide space agencies are increasingly prioritizing the recycling of plastics and other materials in space as a central strategy to reduce waste, repurposing materials that would otherwise be discarded (Hall, 2021; Ailor, 2022; Makaya, et al., 2023). Material identification and classification are essential for ensuring effective recycling processes and determining the appropriate production equipment to use. The proposed study explores the potential of using a cost-effective strategy based on HyperSpectral Imaging (HSI) to classify space waste products. Specifically, it investigates the use of HSI sensors operating in the Near InfraRed (NIR) range to identify materials for sorting and classification. The results show promising prospects for further research, indicating that the HSI approach can effectively identify and classify different material categories. This research is part of the "Hyperspectral based sensing architectures for resource circularity" project under Spoke 5 of the Extended Partnership "MADE IN ITALY CIRCOLARE E SOSTENIBILE" (MICS) within the Italian PNRR, focusing on closed-loop, sustainable, inclusive factories and processes.

Material and Methods

Analyses were performed on a set of samples which included components related to the most popular material categories in space applications as foam, polymers, and technical textiles that at the end of their useful lives, they may become space waste. The hyperspectral images were acquired adopting the NIR Spectral Camera™ (Specim, Finland) equipped with an ImSpector N17E™ (SPECIM Ltd, Finland) imaging spectrograph working in the spectral NIR field (1000-1700 nm).

Results and Discussion

Raw spectral data were preprocessed using different algorithms: Principal Component Analysis (PCA) was performed to evaluate the differences between spectral fingerprints and Partial Least Squares Discriminant Analyses (PLS-DA) was used to perform classifications. A cascade detection approach was applied to recognize textiles from plastics in a first step, and the different textile categories and plastic categories in the following one (Figure 1). Raw spectral data (Figure 2) were pre-processed to enhance sample differences and to reduce instrument noise, scattering and other physical phenomena. In Figure 3, an example of the obtained predicted images is shown.

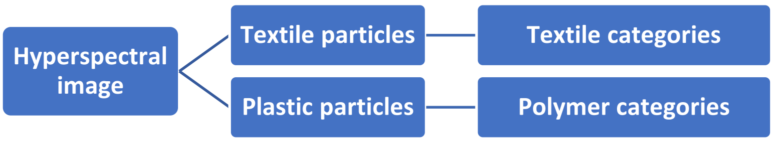
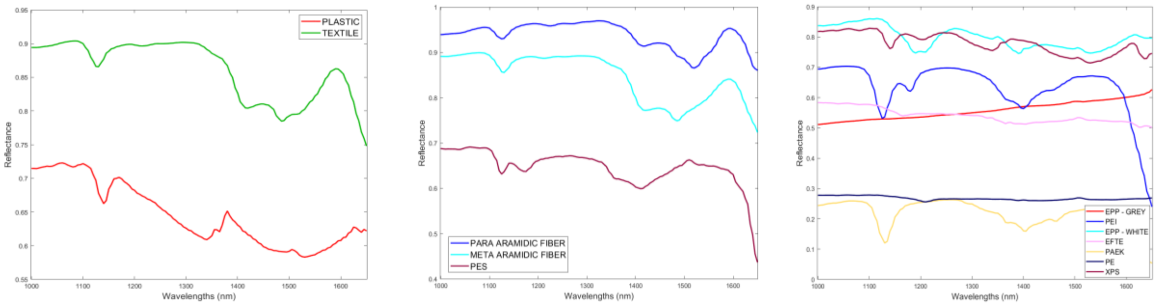


Figure 1. Flow chart of implemented cascade detection classification.

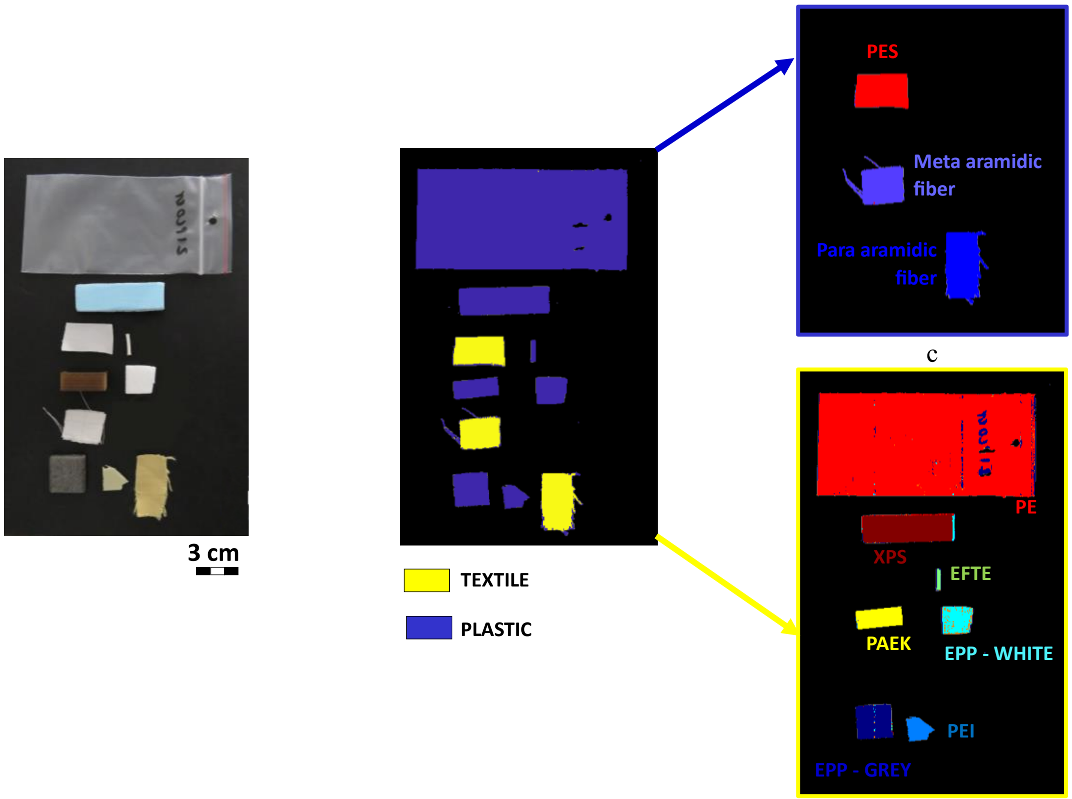
Conclusion

The obtained results show as the presented approach can be profitably utilized to identify, recognize, and classify the different space material categories. These findings lay the groundwork for further studies aimed at implementing a comprehensive material recognition system tailored for recycling purposes in unique environments such as space. Future research activities will be focused on refining and deploying effective material recognition procedures suited for space-based recycling initiatives.



a b c

Figure 2. Raw spectra related to textile and plastic classes (a), textile category (b) and polymer category types (c).



a b c

Figure 3. PLS-DA predicted images: digital image (a), textile vs plastic predicted image (b), textile category predicted image (b) and polymer category predicted image (c).

Acknowledgements

This study was carried out within the MICS (Made in Italy—Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)—MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3—D.D. 1551.11-10-2022, PE00000004) PE 11 (CUP B53C22004130001).

References

Ailor, W. (2022), 'Protecting the Leo Environment', Journal of Space Safety Engineering.

Hall, P. B. (2021), Recycling in-Space Plastic Waste for Deep-Space Additive Manufacturing: Capability Assessment and Technology Development, Part-Ii1, Marshall Space Flight Center Faculty Fellowship Program, pp. 94.

Makaya, A., L. Pambaguian, T. Ghidini, T. Rohr, U. Lafont and A. Meurisse. (2023), 'Towards out of Earth Manufacturing: Overview of the Esa Materials and Processes Activities on Manufacturing in Space', CEAS Space Journal Vol. 15, No. 1, pp. 69-75.