MAGIC: Martian Analysis for Geological and Intelligent Classification. E. C. Belhadfa[1] and M. Fujita[2], [1]University of Toronto, Faculty of Engineering and Applied Sciences, emma.belhadfa@mail.utoronto.ca
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Introduction: Increasing interest in humanity's travel to Mars opens up engaging opportunities for scientific discovery in the fields of geophysics and geology. With the hopes of soon having boots on Mars, we must first begin by deepening our understanding of the planet's geophysical history, possible resources, and potential scientific opportunities. However, in order to accomplish these objectives, improved data processing tools with the ability to accurately and quickly classify key minerals are necessary. MAGIC, the Martian Analysis for Geological and Intelligent Classification, provides a simple, interactive solution that permits scientists and mission planners alike to leverage databases that have already captured Martian information. The primary goal is to deliver a user-friendly tool for all stakeholders, from students to subject matter experts.

Motivation: Understanding of Mars' geophysical past and potential for future exploration hinges on sample collections, in-situ measurements, and imaging observations. Decades of such data exist in databases (such as MSL Notebook and Perseverance) which can be often overwhelming to navigate. Certain tools, such as the AEGIS system (Li et al, 2020) installed on NASA's Curiosity rover, successfully target and identify different rock types autonomously. However, there is an unmet need for usable classification systems for Earth-based research. MAGIC aims to leverage a simple graphic user interface (GUI) to easily classify data into specific mineral and rock types using information from existing databases.

Scientific Objectives:

Water on Mars: Billions of years ago, it is believed that Mars' denser atmosphere provided the planet with the possibility of liquid water existing on the surface. However, this hypothesis remains an open question; one that could potentially impact our understanding of past life on other planets as well as useable resources for future human exploration. A better evaluation tool of Mars' sedimentary history, which may indicate groundwater upwelling, could confirm this hypothesis. Further, the existence of hydrated or hydroxylated minerals, including gypsum, kieserite, and phyllosilicates, could also serve as confirmation of such a theory. An improved identification system, such as the proposed MAGIC, could permit for the efficient and accurate classification of rock and mineral findings from the imaging databases.

Resource Characterization: In order to support extended human missions to Mars, the utilization of planetary resources is essential. Such resources could include ice-water depositions and oxygenated minerals.

Mission Determination: Better understanding of potential sites of interest, whether it be for geophysical history or for resource investigation, can provide mission specialists with the insight required to select appropriate landing sites for robotic and human exploration alike.

Design Concept: With the goal of addressing the scientific objectives above, MAGIC makes use of an image classification model, trained to recognize and categorize different groups of rocks with a coupled GUI to provide a user-friendly interface from which scientists can rapidly extract classified data. A preliminary design for MAGIC is shown in Figures 1 and 2.

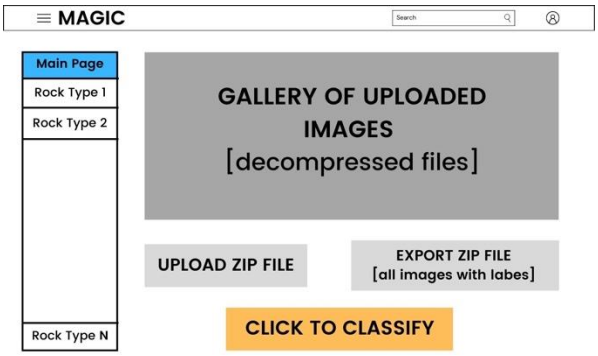

Figure 1: MAGIC main page

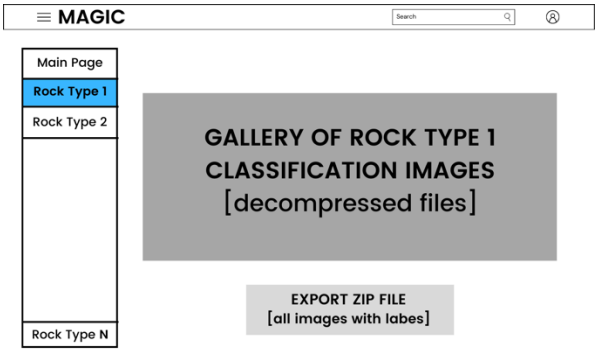

Figure 2: MAGIC rock specific page

As can be seen in Figures 1 and 2, the input format accepted by the application is a compressed zip file containing all images that one wishes to classify. These input images can be visualized in a gallery within the main page, to confirm the user has uploaded the correct files. When prompted, the application will perform the classification on the input data using the pretrained classification model integrated in the application. The GUI also supports exportation of data in two ways to enable users to work with labeled data; from the main

page, and from rock specific pages (see Figure 2). In the case of exportation done from the main page, the application will export all of the images from the input dataset, now with their predicted labels. If exportation is done from a rock-specific page, the app will export all of the images that have been classified into that specific rock type. Furthermore, the GUI includes visualization functionalities on each rock specific page, to increase the ease of use of the application.

Technical Specifications: Table 1 presents initial technical specifications for MAGIC.

Table 1 : Initial technical specifications for MAGIC

Specification	**Metric**
Data Features	Importation of data
	Classification of data
	Exploration of classified data
	Visualization of imported data
	Visualization of classified data
User Interface	Usability
	Open source accessibility

Mission Concepts: The proposed mission concept for MAGIC use is the following.

Ground Station Data Classification. In this concept, the user interface does not act as a payload, but rather as an assistant to any user who wishes to classify a dataset of rocks from Mars. The application would accept a compressed zip file input containing all of the image files the user wishes to classify for their purpose. MAGIC would then decompress the zip file and predict labels for each image in the folder when prompted, classifying each into their respective classes. If the user then wishes to export this classified data for future use, they would be able to export the labeled files in either of the two ways mentioned in the design concept. Both categories of exports would be done such that the user ends up with a compressed zip file of labeled files that facilitates their particular purpose. This process of uploading the input dataset to classify, as well as retrieving the desired output from the application is simplified by MAGIC's user interface, which has clear indications of where to upload and export files. The user would also be able to visualize the uploaded input to confirm they have uploaded the dataset they wish to study, and will enable visualization of classified data, to allow the user to evaluate whether the classification was done as they expected.

Closing Remarks: MAGIC provides a simple and intuitive solution to improve the efficiency and accuracy of geological classifications based on Martian imaging. The tool utilizes existing databases to rapidly identify mineral types, allowing for improved mission planning for future sorties and simplify geophysical research.

References:

Li, J., Zhang, L., Wu, Z. *et al.* Autonomous Martian rock image classification based on transfer deep learning methods. *Earth Sci Inform* 13, 951–963 (2020). https://doi.org/10.1007/s12145-019-00433-9

Nazari-Sharabian, M., Aghababaei, M., Karakouzian, M., & Karami, M. (2020). Water on Mars—a literature review. *Galaxies*, *8*(2), 40. https://doi.org/10.3390/galaxies8020040