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Rock recognition onboard the Modernity 3+ Mars rover using Python with Tensorflow and Keras libraries

Introduction

The presented invention was created by one of the students with intention to be used at the University Rover Challenge in the USA in June 2023 during the Science Mission competition. The project assumes using AI for recognizing rock types from the photos taken by the Modernity 3+ rover with its onboard cameras.

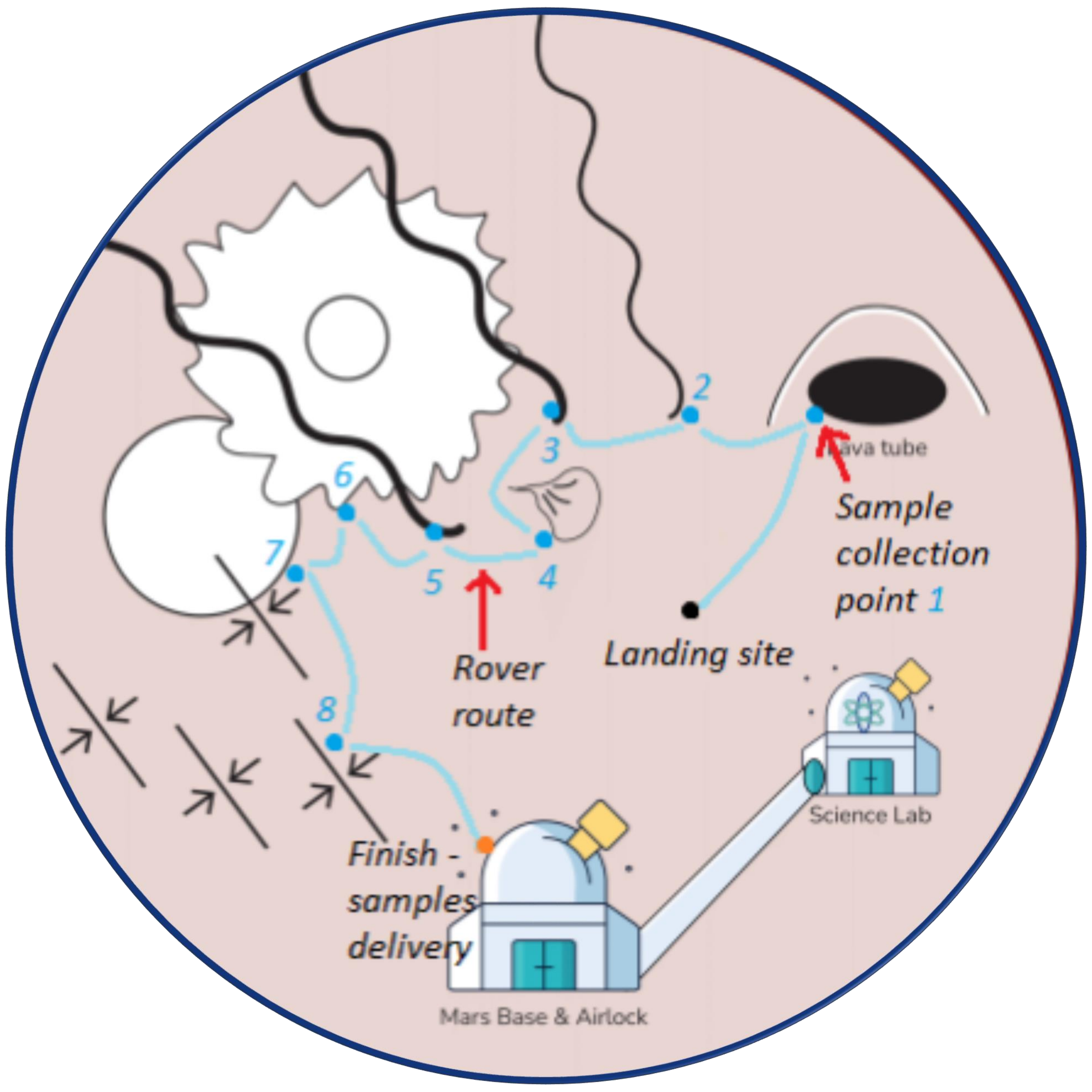
Motivation

During the mission, the rover is controlled remotely and the team is responsible for detecting extant or extinct traces of life in the examined samples of rocks and soils. As it is forbidden to bring any rock samples back to the base, the whole analysis must be conducted onboard the rover. Rocks are difficult to pick up or rotate, therefore the easiest and most reliable method of examining them is photographing using the rover's external cameras along with defining possible life conditions, basing on the team's own knowledge.

In order to define the possibility of life existence, the team has to detect a rock type correctly. There are over forty rocks and minerals detected by far on Mars, such as igneous rocks (basalt), volcanic or intrusive rocks relatively low in silicon and high in iron and magnesium. These chemical elements are known for different color characteristics and stripes patterns. Therefore, they turned out to be a perfect reason for creating a Python neural network for rock recognition.

AI model

The model was created using the Tensorflow and Keras. The dataset used for teaching the AI contained over 4,000 photos divided into 7 main classes: Basalt, Coal, Granite, Limestone, Marble, Quartzite and Sandstone. It was necessary to find a satisfying balance between accuracy and teaching time because of reduced machine power available on-site in the USA.



One of the possible rover's routes

```
1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 47ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 37ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 38ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 36ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 41ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 39ms/step
Image: 66
Predicted class: Chert

1/1 [==============================] - ETA: 0s
1/1 [==============================] - 0s 45ms/step
Image: 66
Predicted class: Chert
```

The program's output

Example photos taken with the rover's onboard cameras

The learning process reached >90% of accuracy within 40 epochs. Dataset was divided into portions counting 32 images each. The sequential model of the neural network was used to create a convolutional 2D model layer by layer. Each of 4 layers uses rectified linear unit as an activation function and contains an increasing number of kernels, from 32 to 256. This parameter indicates how many different features the layer is able to learn. Each kernel is of size 3x3. Finally, the network is flattened into a one-dimentional vector. The model is saved after each learning epoch with updated weights. After training was finished, each competition image was tested 10 times to avoid incorrect labelling.

The tool overall turned out to be a huge advantage during the Science Mission as it helped the team indicate a group of potential rocks while identifying the photos (taking into consideration the false positive or false negative occurances – after all, the knowledge of team members is prioritized), as well as it allowed to improve the score from the judges for unconventional approach.

References

https://mars.nasa.gov/MPF/science/mineralogy.html
https://www.kaggle.com/datasets/salmaneunus/rock-classification
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