Safety risk assessment for a safe habitation on planet Mars

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ABSTRACT

This paper goal was to develop a safety risk assessment for a safe habitation on planet Mars by using weather data from REMS and flares data from the HESSI satellite. This was done after reviewing the societal complexity of designing such a solution. An Xgboost model was used to classify the risk following day with an accuracy of 76%. The information was then intuitively displayed in a tablet sized dashboard built using Vue and a Flask API running the models.

1 PROBLEM DESCRIPTION AND MOTIVATION

It is crucial to be aware of the risks associated with residing on Mars. The planet's surface is subject to hazardous weather, UV radiation, and solar flares because to its thin atmosphere and absence of a magnetic field. The radiation of mars can be up to 700 times higher than on the surface on earth(refer to figure 2) [1]. Inhabitants will need to take precautions including wearing protective clothes, keeping indoors during solar flares, and utilizing shielding materials in their habitats to reduce exposure to radiation [9]. Also, they could need to grow their own food and crops indoors, protected from radiation.

Since the Martian atmosphere is about 100 times thinner than that of Earth [4], it cannot effectively shield inhabitants from dangers outside. This indicates that Mars is vulnerable to enormous dust storms with wind speeds up to 100 km/h and last for months. Severe storms pose a threat to human life by seriously damaging infrastructure and machinery.

Additionally UV radiation exposure is a serious threat to Martian residents. The planet's surface is exposed to damaging radiation because of its thin atmosphere and absence of a protective ozone layer [7]. This is made worse with increased vulnerability to solar flares.

Societal Complexities

Designing with data involves using data-driven approaches to inform the design of products, services, and systems. While data can provide valuable insights and inform decision-making, there are several societal complexities that we must consider when designing with data (as shown in figure 1).

Firstly, we must look at the complexity of the environment which includes dust storms, extreme temperature range, UV exposure and solar flare radiation. Therefore what dangers should be shown and how should it be shown to improve awareness.

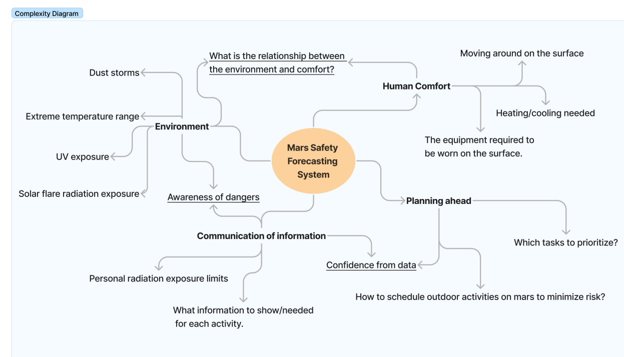

Figure 1: The diagram shows the web of human complexity for a safety classification system on mars.

Secondly, another consideration is how do inhabitants of mars plan ahead, and create schedules for their activities, knowing the high risk on the surface. This can be done through confidence by using data.

Thirdly, data can be complex and difficult to understand, particularly for those who are not data-literate. Therefore how do we communicate the necessary information while ensuring that the design is accessible and understandable for all users, and avoid relying on overly complex data visualizations.

Finally another complexity is the human comfort, which relates to the physical conditions of the environment such as the equipment that needs to be worn for radiation shielding but also the mental comfort.

Overall, designing with data requires careful consideration of the societal complexities involved. When designing the system, we were mindful of the potential implications of the system designs to ensure that the solution is understandable for all users.

2 RESEARCH POSITIONING

While there are existing works in weather forecasting for martian weather [6]. In this project the focus was made safety from both weather and radiation risks. Radiation on mars and space it one of the biggest challenges on going and staying on mars [2]. It is argued that in order to complete a mission on mars the radiation exposure limits for astronauts need

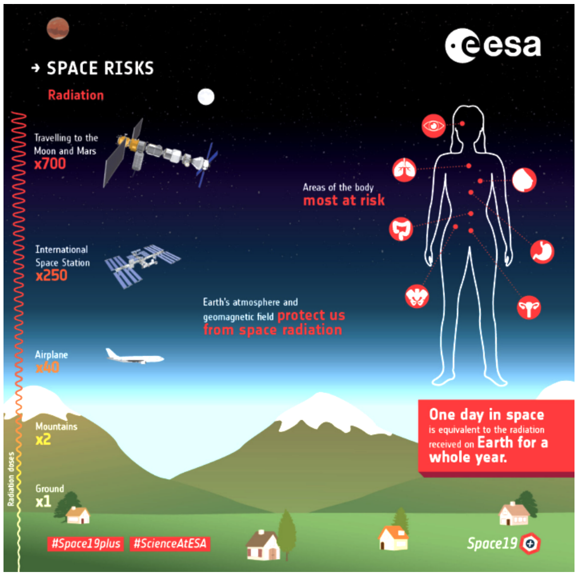

Figure 2: The scale of radiation from earth, space and Mars. The image show the potential health risk from radiation on the human body. Taken from the European Space Agency. [1]

to increase [10]. The personal dosage limit is different for multiple individuals, as radiation affects people differently

Sources of radiation. The sun emits various types of radiation, including ultraviolet (UV) radiation and solar flares, which can pose a significant threat to human health on Mars (as shown in figure 2) [1].

UV radiation is a form of electromagnetic radiation with a shorter wavelength than visible light. On Earth, our atmosphere and ozone layer provide significant protection against UV radiation, but Mars' thin atmosphere and lack of an ozone layer means that the surface is exposed to harmful levels of UV radiation. Prolonged exposure to UV radiation can cause skin cancer, cataracts, and other health issues.

Solar flares are sudden, powerful bursts of solar energy. High radiation levels from these flares, including X-rays and gamma rays, can pass through the tenuous Martian atmosphere and reach the planet's surface. The high radiation levels from solar flares can pose a serious threat to both electronic devices and human health.

To mitigate the risks of UV radiation and solar flares, inhabitants will need to implement strict radiation protection measures. These measures may include designing habitats that are shielded from radiation, using protective clothing that blocks UV radiation, and avoiding exposure to high-risk areas during solar flares. This motivated the project, to create a solution on which future safety risks can be monitored on a tablet and receive updates whenever the risks change to ensure their health and well-being.

3 METHODOLOGY

The following section describes the method used to develop the system.

The data collection, processing and modelling

The data sources. The project used two data sources called HESSI and REMS. The following subsection describes what the data is and how it was processed as used for the classification model.

The HESSI (High Energy Solar Spectroscopic Imager) satellite was a NASA mission launched in 2002 to study the dynamics of solar flares and their impact on Earth's environment. The satellite carried a suite of instruments designed to measure X-rays and gamma rays emitted during solar flares [3].

HESSI satellite data provided unprecedented insights into the mechanisms of solar flares and helped scientists understand the processes that generate high-energy particles and radiation during these events [3]. The satellite's ability to capture high-resolution images of solar flares in multiple energy bands allowed scientists to study the dynamics of these events in great detail.

The HESSI satellite was also instrumental in helping scientists develop new models and theories about solar flares and their impact on space weather and radiation levels.

The REMS (Rover Environmental Monitoring Station) was a scientific instrument suite on NASA's Mars Science Laboratory (MSL) rover, Curiosity, which landed on Mars in 2012 [5]. The REMS instrument suite was designed to measure various environmental parameters, including temperature, humidity, wind speed and direction, air pressure, and UV radiation levels on the Martian surface.

The REMS rover data has also provided valuable information about the Martian climate and weather patterns. The data obtained by the rover has revealed seasonal variations in atmospheric conditions, including fluctuations in temperature, humidity, and air pressure. This information is essential for future missions to Mars, as it will help scientists better understand the challenges of living and working on the planet.

The models and processing. In this project, three seperate models were made, two for predicting the maximum and minimum temperature based on weather data, and a classification model use to provide a safety risk assesment.

The temperature forecasting model used the time series forecasting tool Prophet, developed by Facebook's Core Data Science team [11]. It is a statistical model that is used to make predictions based on historical data, where the time variable plays an essential role.

The Prophet algorithm is based on a decomposable time series model with three key components: trend, seasonality, and holidays. The trend component models the overall direction of the time series, while the seasonality component captures periodic fluctuations in the data, such as daily, weekly, or yearly patterns.

Prophet uses a Bayesian approach to model fitting, which allows it to handle uncertainty in the data and provide probabilistic forecasts that capture the range of possible outcomes. It provided a simple and intuitive interface that allows us to specify the time series data and the forecast horizon.

The goal was to combine the solar flares data from HESSI with the weather data from REMS based on the date. However, in the flares dataset the data contained multiple flares in a day, hence it was decided to aggregate the data per day, and obtain a two new columns which count the number of flares within that day and weather the average of the flares happened during the day. This mattered as the human inhabitants would be facing the sun during solar flares.

Creating the labels

A rule based system was created to generate labels that will be used as targets for the model. The decision is made based of the following variables: the minimum ground temperature, the amount of ultra-violet radiation (measured from REMS), the amount of flares and whether the the flares happened during the day. Using this rule system each day from the training data was given the following classification labels (ordered from least safe to safest): Indoor activities only, short outdoor exposure, moderate outdoor exposure, stable outdoor exposure.

After creating the classification labels, a classification model using Xgboost [8] was used to classify the safety risk of the following day, by using as input both the weather and processed solar flare data of the past 7 days. The 7-day trailing data was fine tuning using grid search, a common hyper-parameter optimisation method. The model achieved a classification accuracy of 76%.

The system architecture

The system was designed in a circular fashion, meaning that new data measured from the sensors and satellites get passed forward until it is processed, from which future classification are made and displayed to the user in a dashboard as shown in figure 3. The model runs on a Flask API which retrieves the data of the previous days from the database, create the classifications for the next 7 days and return the result to the dashboard.

Designing the dashboard Motivation to create a system that uses real available data to classify the risk level of the upcoming week. The dashboard was designed to be used on a tablet. The user interface features a straightforward design which focus on the personal exposure limits, the current weather status, and a forecast with the classification of the safety risk. The safety risk classifications were color coded with a diverging color scheme in order to be more intuitive as show in figure 6.

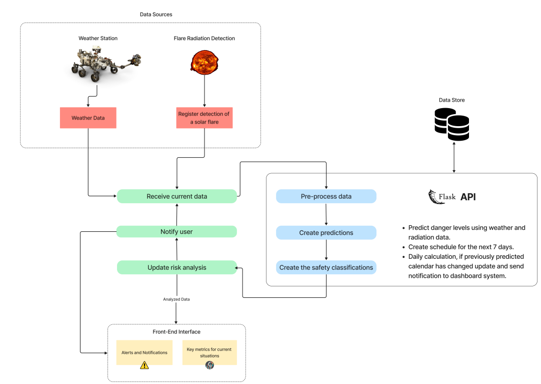

Figure 3: The proposed design of the system. The data is taken from the weather station and solar radiation satellites, pre-processed for the models, the safety classifications for the next week is made and sent to the dashboard for analysis by the astronauts.

	precision	recall	f1-score	support
high	0.64	0.03	0.07	201
low	0.00	0.00	0.00	10
moderate	0.76	0.99	0.86	653
very_high	0.00	0.00	0.00	0
accuracy			0.76	864
macro avg	0.35	0.26	0.23	864
weighted avg	0.72	0.76	0.67	864

Figure 4: The accuracy summary of the classification model. It was noted that the model doesn't not perform well for all classes.

4 RESULTS

In this study, we developed a multi-class classification model to classify the safety risk into four different types. We evaluated the performance of our model using various metrics, including accuracy, precision, recall, and F1-score, for each classified type as shown figure 4. It was noted that the model achieved a 76%. accuracy score however this might not provide a realistic result as the classes (obtained from the rule-based system) are not well balance, as shown in figure 5.

In summary, our multi-class classification model achieved good performance in classifying four different types of risk, with an overall accuracy of 0.76 %, however further work

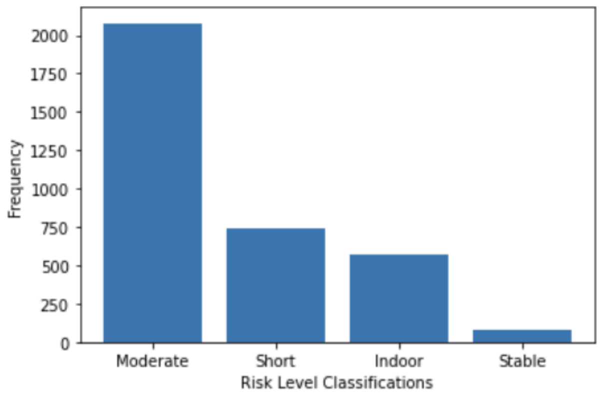

Figure 5: The class balance for the data. The class stable has significantly lower examples than the rest.

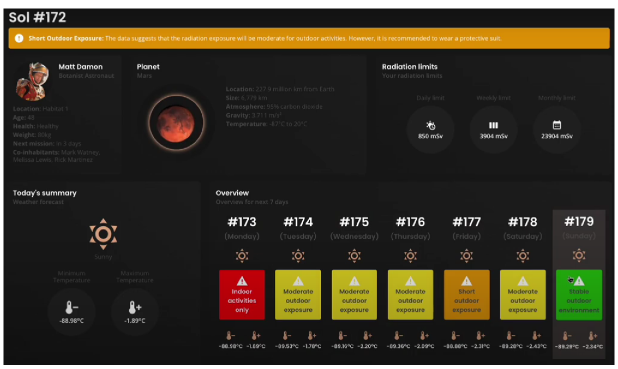

Figure 6: The personalised dashboard for showing the classified risks for the following week. The dashboard includes the personal radiation limits.

needs to be done to improve the class balance for the results to be more reliable.

5 DISCUSSION

The following section will discuss the outcomes, impacts and limitations of the project.

Relevance and Impact

The radiation danger classification system created for Mars is an important accomplishment because it accurately describes the potential risks faced by the planet's inhabitants in the future. The system is capable of making precise predictions about the level of radiation and weather danger by incorporating data from numerous space missions. This knowledge is essential for enabling the reduction of unnecessary radiation exposure and ensuring the safety of people on the planet.

This system has a significant impact because it improves our capacity for Mars mission planning and preparation. We can take the necessary precautions to guarantee the safety of people and the equipment that is sent to the planet if we have accurate information on the risks associated with radiation.Furthermore, the system is even more trustworthy and gives users more confidence in its predictions because it uses actual data from earlier space missions.

This system can be used in a variety of ways with more optimization and fine-tuning, including designing protective equipment and structures for upcoming Mars missions as well as choosing the best landing sites and times to send missions to the planet. This system has a wide range of potential uses, and it represents a significant advancement in our ability to safely explore and inhabit the Red Planet.

Limitations

A limitation of this project is that the solar flare data-set was collected by a mission, however the satellite is no longer active, hence no new data can be added to the current system. Another limitation that is important to note are potential biases when creating the rules used to create the labels for the models. The way the points are given can significantly affect how the classifications are given. Finally due to the low temporal resolution of the weather data (one data point per day), the flares data-set (which had multiple data points per day) needed to be aggregated per day which may have negatively impacted the performance of the classification model.

Future work

The current system was designed for future classification of safety risk. Despite this it would be also beneficial to have exposure tracking on past exposure based on data collected from smart watches. Based on the location, the smartwatch could measure the time periods in which the inhabitant was exposed. Furthermore, analytics can be computed of actual radiation exposure over that period.

Another thing that could improve the system would be a usability study in a high stress scenario. The benefit would be that the user interface can be optimised to show only the relevant information needed at the time of use.

6 CONCLUSION

We have effectively created a system that may be used to provide future inhabitants of mars with future classification of safety risk in order to mitigate the potential harmful effects of radiation on their bodies. Our method classified the risk into 4 classifications and achieved an accuracy score of 76 %. We also integrated this information into a dashboard intended to be used on tablet in a straightforward manner in order to provide awareness of the potential future risks.

Our solution has the ability to enable future inhabitants of mars to asses the risk and facilitate the creation of an activity schedule using a data-driven solution.

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