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Examination of recent Martian rovers data for supporting the planetary terrain trafficability assessment techniques and algorithms development

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Abstract

This abstract summarizes the preliminary analyses related to the development of the effective and reliable hardware and software solutions for the Martian terrain traversability assessment implemented as a part of the rover base functionalities. The presented example is the effect of long discussions and analyses made during preparation of the data fusion software for FASTER project. Set of existing visual and spectroscopic data is examined as a reference source data for defining the typical variability of the Martian soil in terms of traversability by the rover. Presented preliminary analysis can be a base for enhanced fusion strategy of soil sensors measurement and basis for reliable path planning process implemented into the rover software.

1. Introduction

Traversability of planetary surfaces was an issue for the engineering investigations proceeding development of planetary robots. Starting from the first Moon Lunokhod rover missions, some of the geotechnical parameters were measured [1]. Unfortunately, the data collected during the missions were not used for planning the rover activities at all. Most recent missions, like MERs or MSL rovers on the Martian surface, do not use the terrain trafficability direct measurements for support the planning of the movement path, but rather use the human analyses of received imagery from the cameras mounted on the rovers. Such support gives not perfect assessment of the terrain traversability, as it was demonstrated by MER Spirit and Opportunity 'caught' in the sand-trap few times during the mission. Recent FASTER project, realized as a EU FP7 project, covers the problem of direct assessment of the terrain trafficability with use of set of sensors mounted on the pair of the rovers (Main rover and Scout rover, the reconnaissance small platform supporting the primary mission robot).

Fig. 1: Mars Exploration Rovers - terrain changes due to rover mobility

1. Data sources

There is few sources of data, that can support assessment process of the Martian surface traversability. Among thousands of the images acquired during the MERs and MSL rovers activity on the Martian surface, mast-mounted cameras, multispectral cameras and engineerical cameras can be used to obtain the valuable data of the planetary geomorphic forms and features. Additionally, IR-spectrometers measurements of Mini-TES (both MERs and MSL) give the unusual opportunity of the examining the surface material variability. Additional pure-engineering data from the motors and actuators, although not easy to obtain, can serve as a perfect source of data directly referred to the mechanism (eg. robotic arm, wheel, etc.) to regolith interactions [2] and to the geotechnical properties of the regolith.

Instrument	Data cover	usefulness
MER Pancam	high	high
MER Navcam	high	medium
MER Hazcam	high 3	medium
MER Microcam	medium	high
MER MiniTES	medium	high
MSL Mastcam	high	high
MSL Navcam	high	medium
MSL Hazcam	high	medium
MSL MAHLI	medium	high
MSL Chemcam	medium	high

Fig. 2: datasets for rover traversability assessment

During the development of the FASTER project hardware and software, the presented aspect of the analyses of existing rover-related sources of data was not used. However, the Data Fusion team in Astri Polska company, the member of FASTER consortium, realized the need of the wide analysis of the real properties of the Martian surface and existing there traversability to prepare a backup, open algorithm for effective data fusion of soil sensors' measurements. Although, this wide analyses were not fully supported by the Consortium, the problem was widely discussed, preliminary studies were made, and the final data fusion software is ready for statistical and real properties-related algorithms implementation. This should enable the subsequent extension of the existing FASTER software for more and more reliable data processing and quality of final terrain trafficability assessment.

3. Analyses methods

In the preliminary work, the set of data, including Panoramic Camera (for MERs) or Mast Camera (for MSL) and microscopic cameras (MER and MSL) were used to determine the basic parameters of the soils (sediments, geomorphic forms, changes in spectroscopic parameters through the form, grain size and shape, answer of the soil on the contact with the rover wheels. Such basic observations made with use of public data can lead to simple, but important assumptions and can be a basis for further soil traversability assessment.

During the analyses, special care were placed on definition of variability of soil geotechnical conditions and typical behaviour in the boundary area between different kind of forms (sediments) – this aspect is very important for final definition of data fusion algorithm [3] development – determination of boundaries between scattered points of measurements can be crucial for final traversability map prepared for the path planning software (e.g. Path Planner for FASTER), and finally for a safe and efficient rover movement planning process.

The methodology of analysis is simple: in the first phase we're trying to choose a imagery with the visible variability of the surface sediments and geomorphic features (e.g. ripples, small dunes or ghost-deposits connected to exposed boulders, escarpments). The dimensions of the forms, spacing between them, in relation to the existing and future rover designs are analysed to obtain the assessment of the importance of such features for the rover mobility. Spectroscopic data are used for final check of the spectral differences observed on the form to assess the activity of the form (e.g. we're observing the slopes of the small dunes or ripple to assess the sorting properties of the material and thus the activity of the form). So generally, we're collecting various kind of data for the observed geomorphic forms and do the most basic assessment of the traversability based on the genesis and properties of the observed forms/sediments. In the second phase, the boundaries region between the various forms/sediments is analysed and the typical (or better assumed) 'behaviour' in the transition zone is defined. The transition zone is measured and analysed in relation of the instrument detection area and wheels' footprint. In the third phase, the typical behaviour of the rover during crossing of the transition zone is analysed in terms of subsystem work and whole rover operations and safety. Forth phase is focused on preparation of the similar surface conditions in the virtual environment (e.g. Gazebo) for later tests. In the case of Gazebo, there is no direct possibility to differentiate the properties of the surface, the additional procedure was written for FASTER data fusion tests to enable such tests. Fifth phase cover tests of the data fusion tests in the virtual environment and some tests of the separate soil sensors too. The last, sixth phase is focused on the upgrading the algorithms and procedures (both measure procedures and rover operational procedures) for best fit to the obtained results of the tests.

Until now, we made a preliminary analyses up to the second phase. Additionally software for phase four is ready for use. The next steps will be done after completion of the integrated tests of the FASTER project system until end of the year 2014.

4. First results

After examination of full imagery content for MERs and MSL Pancam/Mastcam cameras and some of other data, 5 sets of data were selected for the preliminary analyses. Up to date, only first two phases of the analyses were performed. Part of these results are shortly described below.

MSL Curiosity, sol 527

Overall analysis of the image from sol 527 can be a good example of the information collected from the existing dataset for definition of the geotechnical parameters for future missions. One of the issues specified during FASTER project data fusion subsystem development is the problem of correct definition of the inflation of the buffer zones in which point measurement can be 'valid' – the problem of 'inflation' of the point measurement to the specified buffer size, to fulfil the base traversability map for path planning purposes.

Fig. 3: MSL Curiosity, sol 527, variable traversability related to terrain forms and sediments

In the case of analyzed imagery, we can find a patch of sand, aeolian genesis, forming a small dune-like or big, separated ripple-like positive form of the terrain. Additionally, two groups of sharped rocks are clearly visible on the image and additional scarp, steep slope, partly covered by small boulders and windblown sand is visible behind the dune. There are at least three aspects of analysis the terrain traversability in such case: first, the terrain morphology affects hardly the potential safe and effective paths, second – important obstacles are visible, third – the soil need to be analysed in terms of the traversability due to various geotechnical properties.

In the first phase we can produce the map of the terrain and divide it into separate regions based on the visual analysis and predicted traversability based on the genesis of the sediments. The geometrical relations between forms can be analyzed now (e.g. space available for rover movements in the observed area or height differences between the forms) as well as genesis of the forms can be defined. It helps in analysis of the geotechnical properties (eg. dune as observed on the image should have generally uniform, well-sorted, sand-sized internal material, so in terms of geotechnics we can expect low bearing capacity and high sinkage and slippage rates. Now, we can use a spectrometer to check the recent activity of the dune analyzing the variability of acquired spectra through the slopes. When the typical variability is observed, we can expect the sediment properties as described above, if not – we can expect the silt-sized cover of dust decanted from the atmosphere and relatively high initial sinkage, but limited (as described later). There is also another possibility, when the duricrust is formed on the form – in such case it will be completely masked by the dust cover.

In the second phase, we can realize, the transition from the rock-covered surface to the dune surface should be easy to detect in normal conditions. But, when we find no relatively good visible boundary in our soil sensing measurements, and the soil will looks like before in terms of the geotechnical properties, we can expect the duricrust there.

Summarizing this case: even on the first or second phase of analysis of the available data we can find interesting information and assumptions related to the traversability of Martian surface. Good assessment realized by onboard software, when such cases will be checked during tests, will give as higher confidence of our assessment results.

MSL Curiosity, sol 530

Typical behavior of the Martian soil with high content of the silt-sized material – the material seems to be compressive, but only to the limit related to the maximum density state of the granules. In some kinds of simple traversability algorithms, such terrain will be assessed as 'NOGO' due to high rate of sinkage of the wheel (or leg-wheel, like for FASTER project Scout Rover). Definitely, the rate of sinkage, and also slippage, in the first moments after arriving here, is high, but after heavy compression of the sediment due to wheel footprint, the soil looks to be compressed and of relatively high bearing capacity. Such behavior, not resolved in a simple sinkage algorithms, will disable the path planning through such area. It's OK, when the possibility of diversion is actual, but in the case of terrain described before (the same sediment observed though sol 527), lack of possible forward movement due to soil sensing results and data fusion algorithm (in the most simple form it is just 'one out – all out' mechanism)

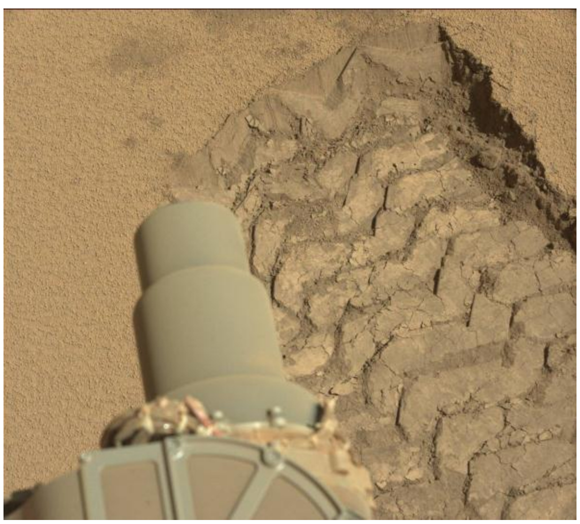

Fig. 4: MSL Curiosity, sol 530, rover wheel footprint presenting the behaviour of the sediment under pressure

For the previous studies, selected sols of MERs visual data and some Mini-TES spectral measurements were analyzed in terms of assessment of surface properties important for Martian rover mobility. First of all, the variability of observed soil and sedimentological features were analyzed, and then, in the second phase of analyses, the geometrical constrains of the soil variability were observed. For previous studies, MER dataset covering small dune-shaped sand patch was tested in terms of the activity of the material – visual information gives no answer for the question about the actual status of the form, but subsequent Mini-TES analysis showed, there is a typical sequence of mixing between well-sorted front slope material and the surface material in the bottom part of the slope and clear and steady spectral answer in the upper slope part without any surface influences. Such simple and effective analyses showed the potential activity of the dune. Returning to the MSL sol 530, the wheel track in the soft material is observed. Visual analysis shows the high content of the silt-sized material between the larger grains and low traversability through this area. In the upper right corner of the image you can observe set of dots – it's the same type of spectral analyses, made by ChemCam, like described earlier. From the point of view of potential impact of such uniform soil surface on the traversability assessment, we can find, the algorithm should simply check for the

5. Implementation

Results presented above gave the unique possibility to assess the typical 'behaviour' of the surface soil in the contact with the moving rover. The assessment of the variability of the soil patches can play a very important role in definition of the ranges of buffer zones in which the point measurements data are inflated to obtain the full coverage of building map – final traversability map used by path planning software on-board the rover without gaps in data will be the base for movement path calculations.

Sensors typically used for geotechnical assessment for planetary rovers uses various principles of measurements, starting from typical Wheeled Bevameter design (known from Lunokhod), through static test devices (eg. cone pushed into a soil), dynamic cone or cylinder tests (e.g. Dynamic Penetrometer device used in FASTER) to various visual devices (observation of wheel sinkage and slippage, remote sensing of rover vicinity etc.).

From the software point of view, the open architecture for data fusion and common and simplified interfaces between soil sensors will be crucial for easy implementation of advanced statistical algorithms supporting data fusion process.

6. Future analyses

There is still a vital need to analyze existing datasets and define typical variability and assumed properties of the soil patches observed on the surface of the Mars. This work will enable definition of the correct sizes of buffer zones for any of the used sensor and type of inflation method of the buffer from the pixel measurement. Additionally, important part of work will be related to the fusion of different sensor measurements with dependency of the overall context of the rover sedimentological vicinity.

7. Summary and Conclusions

Presented abstract of preliminary analyses show the potential of using both actual and historical dataset from Martian rover mission to obtain a basic parameters, variability and terrain-rover interaction observations, that can be used for traversability assessment enhance and algorithm building for next missions. MER and MSL data, analysed commonly, can give the important input to algorithms of soil measurement data fusion for terrain traversability. The presented FASTER Project context can explain basically the actual state of development of system supporting the movement operations of the proposed future Martian mission rovers.

The preliminary results showed here will be a part of the wide analysis of data fusion-related algorithm strategy for FASTER Project, and will be presented in details at the final workshop in October 2014 in Airbus Defence and Space MarsYard facility, Stevenage, UK.

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