Development of highly mobile planetary rovers: from hardware optimisation to embedded software

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I. INTRODUCTION

A mobile robotic platform aims at offering the capability to move a valuable payload safely and reliably. The known and characterised elements of the rover are mechanically attached to it and to achieve its goal, the platform has to interact with an unknown actor, which is the environment. This effect is even more apparent in the case of applications in rough-terrain. We address these challenges using two main directions: first the optimisation of the hardware platforms and secondly the optimisation of the embedded software.

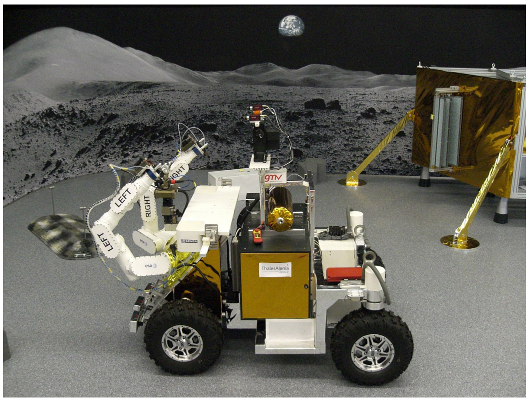

Fig. 1. The EGP Rover during the test phase

II. HARDWARE PLATFORMS

The Autonomous Systems Lab at the Swiss Institute of Technology of Zürich (ETH Zürich) is involved in several projects with the European Space Agency, with the aim of developing and evaluating robotic platforms for space exploration. This section reports two recent developments in the field of rover design.

A. Eurobot Ground Prototype

The EGP-Rover (fig. 1) is a mobile platform sized $1.5m \times 1m$, aiming to assist astronauts in the construction and maintenance of a lunar or Martian base station. To this end, the rover is intended to carry the Eurobot prototype: two highly mobile robotic arms, setup in a human-like configuration. This platform, considered as an on-Earth technology demonstrator, weighs 880 Kg and has a payload capability of 400 Kg. By using space qualified components, weight would be reduced at least by a factor of 1.5.

The research and developments presented in this paper would not have been possible without the support of the European Space Agency through the ExoMars and Eurobot projects

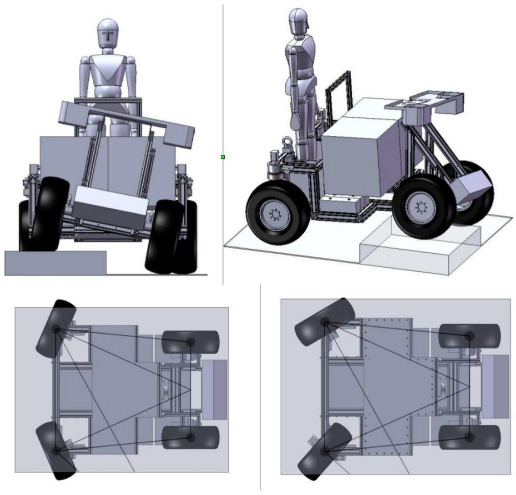

Fig. 2. The EGP Rover mechanical design

Several solutions were considered to achieve the required high manoeuvrability, and in particular the ability to rotate on the spot. For the sake of reduced mechanical complexity, a 4-wheel rover was designed with only two steerable wheels.

It was furthermore decided to align the rotation point with the centre of the Eurobot arm support. For this reason, the final rover design resulted in the two rear wheels being independently steerable from 0 to 90 degrees. The rover can then either drive on tight curves or rotate on the spot. Finally, the EGP-Rover was also designed to remain stable on rough outdoor terrain. To this end, a passive rotation axis was included between the front and the rear part of the rover, as illustrated in fig. 2.

B. ExoMars Breadboard Testing

The second breadboard (fig. 3) of the phase B of the ESA ExoMars program has now entered the functional and performance evaluation process. The ASL is responsible for conducting the test plan and developing the software to operate the breadboard: control algorithms, forward kinematic algorithms and human-machine interface.

In comparison to the previous breadboard, this platform is equipped with 36 active degrees of freedom plus 3 passive

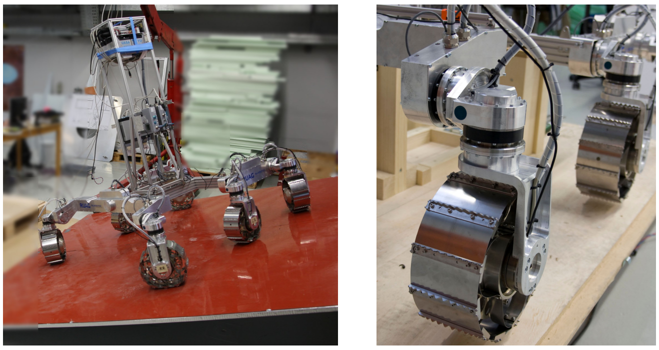

Fig. 3. The ExoMars breadboard during testing. The high position of the batteries is necessary to obtain the expected centre of gravity of the flight model. On the right, close-up on the wheel and its 3 degrees of freedom.

joints at the boggies. Each of the 6 wheels (fig. 3) is steerable and the leg linking the boggie to the wheel is also controllable so as to have the possibility to use a wheel-walking mode.

III. Embedded Software

A. Low-level control

An optimised hardware is a necessity for an autonomous rover, but unfortunately it is unfortunately not sufficient. The control software can be separated into two main parts: the low-level control responsible for the generation of synchronised motor commands and the high-level control dealing with planning optimised trajectories.

The Autonomous Systems Lab is currently involved in the prototyping of the control modes for the ExoMars platform. This consists in generating synchronised motor control to achieve generic Ackermann motion, rotations on the spot, lateral motions (crab mode) or even wheel walking.

In order to improve the navigation performances, we have developed a advanced control system that intends to optimise the distribution of torque on the rover wheels based on the measured load on each wheel. The advantage of such controller is that it minimises the required friction coefficient on each wheel. The disadvantage is the increased system complexity to measure not only the force but also the contact point of each wheel. Detail results will be submitted to IROS'10 [1]. Preliminary work can be found in [2].

B. High-level control

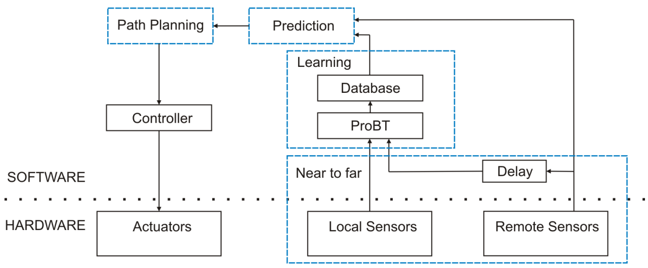

Fig. 4. RTILE architecture

At a higher level, we are interested in designing a rover with the capability to learn from its experience while it operates in a mission. The accumulated knowledge could then be used to improve the rover behaviour. Thus the idea is to make the best out of an operating platform by giving it the capability to link remote data and local data. Remote data describes the environment at a distance and is provided by sensors such as cameras. Local data expresses the rover-terrain interaction model which refers to a metric characterising some aspects of the rover behaviour. The RTI model can be related to sensors such as an Inertial Measurement Unit (IMU) or other proprioceptive sensors. Learning the correspondence between local data (information that is near) and remote data (information that is far) allows anticipating the rover-terrain interaction characteristics ahead of robot position. This information can be used to influence the rover behaviour by changing its path.

Fig. 5. An example of RTI prediction from remote appearance. The marks in the grass illustrate the influence on RTILE on the trajectory chosen by the rover.

The resulting approach, named RTILE for Remote Terrain Interaction Learnt from Experience, can be summarised in fig. 4. An example of terrain classification can be shown in fig. 5, where terrain with a green overlay has been identified as generating less vibrations. More details about the approach can be found in [3].

IV. Conclusion

This paper rapidly introduces the planetary rover research at the Autonomous Systems Lab from ETH Zürich. Our approach is to combine optimised hardware design and intelligent perception and navigation software to improve the overall navigation capabilities of these robotic platforms.

References

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