A simple embedded stereoscopic vision system for an autonomous rover

GIANCARLO GENTA, MARCELLO CHIABERGE, NICOLA AMATI, MAURO PADOVANI, CLAUDIO SANSOE, PAOLO ROLANDO

Mechatronics Laboratory, Department of Mechanics, Department of Electronics, Politecnico di Torino, Corso Duca degli Abruzzi, 24 10129, Torino, Italy

ABSTRACT A number of demonstrators of a legged microrover for planetary exploration, also suitable for terrestrial applications, mainly for operation in hazardous environments, were developed by the authors. The version 6.2, which was widely experimented both in laboratory and in outdoors ‘Mars analogue’ environments, operates autonomously using ‘touch sensors’. The performances of the vehicle can be increased if teleoperated for trajectory planning and obstacle prediction. An improvement of the autonomy goes in the same direction. The present paper describes the on-board vision system, developed with the aim of increasing the autonomy of the machine.

1 INTRODUCTION

Rovers operating autonomously at long distance from the human driver must be supported by robust control and navigation systems. The motion of Walkie 6 [1-5], (Figure 1), a twin rigid frames walking micro rover, developed at the Mechatronics Laboratory of the Politecnico di Torino, in cooperation with Alenia Spazio, is controlled by a finite state automata allowing to perform autonomous walking on rough terrains. The existing low-level controller is limited by the lack of supporting tools for autonomous operation in unstructured environments. The present paper describes the stereoscopic vision system, installed on board, and the navigation simulator to be used by the human operator to plan in advance a strategy suited to the terrain to be crossed.
The hardware and the control algorithm of the stereoscopic vision system were developed to be integrated with the hardware electronics to simplify the communication and to reduce the power required for computation. Experimental tests showed that the conformation of the obstacles close to the vehicle and their distance could be defined with a sufficient accuracy and at a low computational cost. Such information is computed in real time by the algorithm and is used by the onboard control system to define the correct trajectory that the rover must follow to reach the goal within the shortest time and with minimum energy consumption. The images of the micro cameras, which are sent by radio link to the human operator, are used to reproduce the environment in which the vehicle is operating to study in advance the appropriate navigation strategy. Such a strategy can be implemented on board by radio link as the new electronic hardware (which is under construction as version 6.3) uses programmable logic devices (FPGA). Specific software (commercially available) reproduces and updates the virtual environment on the base of visual information. Information of the vision system represent an important input for the simulator of the rover widely described in [6] and used in the second part of the present paper to study advantages and drawbacks of several control and navigation strategies. Experimental validation of the model is presented in [6] when the vehicle works on flat surfaces while the comparison of numerical and experimental results of the rover walking on rough terrain are described in the present article. The simulator, developed using MATLAB/SIMULINK software, was validated experimentally using the version 6.2 of the prototype.

2 VISION SYSTEM

The aim of the stereoscopic vision system here below described is to equip Walkie 6 with a tool able to provide both scientific images and information for the onboard control system and for the human driver operating at the control station. The first kind of images are simply processed, compressed and downloaded to the control centre through the telemetry communication channel available on the rover. The second kind of images are directly
This information is used to modify the trajectory of the rover on the terrain in order to optimize velocity, movements and save energy. If the navigation system fails to avoid an obstacle, the rover has a low level obstacle avoidance system that use “contact” information to change direction when in front of a dangerous obstacle (stone, hole or a dangerous slope). The stereoscopic configuration (Figure 2a and b) of the vision system helps to find distance information: it is composed of two CMOS cameras (PB300), a control logic implemented on a FPGA device (for camera handling and configuration) and a DSP processor (for image management analysis and compression). The vision system algorithm is based on the similarity of the two images acquired, due to a distance between the two PB300 sensors of only 10 cm. This similarity is used to optimise the compression and for distance extraction of visible and close obstacles. Using this kind of images, the distance of the obstacle (Figure 3), a big stone in this case, is proportional to the inverse of the difference of the two positions (clearly visible in the two images). With the
same procedure it is also easy to compress the images before transmission: the left image and, instead of the right image, the optimised difference between the two is transmitted.

The vision system is actually provided with a console running under Windows OS (Figure 5) where the operator can manage all the different settings, download the images and extract distance information. In the next version the system will be totally integrated with the new electronic subsystem and will provide navigation information directly to the control platform.

The new Walkie 6.3 electronic subsystem is completely different from the previous versions based on a µP controlling the strategy, the movements and the communication links of the rover. The new architecture is structured in ‘layers’ to allow ‘users’ to customize the functions of the rover.

The ‘action’ layer (low level interface between sensors and motors) is based on a programmable logic device (USER PLD) that implements a finite state automata controlled by several parameters. Those parameters are handled by the on-board microprocessors (80C51, space application certified) that is the ‘supervisor’ of the entire electronic subsystem. The finite state automata (FSA) is an example of a possible rover controller: user can easily modify the FSA or completely change the control architecture (the USER PLD is completely available).

Another PLD device is responsible of the ‘service’ layer. All the on-board ‘services’ are available to the user: communication links (bidirectional for commands and telemetry), accelerometers data handling and vision system (actually implemented as a separated
resource: will be integrated in the next version). All these ‘services’ are considered ‘fixed’, not changeable by the user: next versions of the electronic subsystem will implement more service parts to offer more flexibility to the user ([7]). The implemented structure allows the user to store different ‘user control strategies’ in the onboard configuration device (handled by the 80C51) and download on the USER PLD only when necessary: this feature improves fault tolerance and flexibility of the electronic subsystem and allows the user to “virtualize” the control electronics (a maximum of eight possible configuration is allowed).

Conclusions
The addition of a simple vision system able to recognize the obstacles and to measure their distance before the rover actually touches them is a worth addition to the demonstrators of the WALKIE 6 line. The hardware and software, which has been built and tested, proved to be effective enough to improve the performances of the machine. This, together with the increase of the memory storage capabilities built in the electronics developed for the 6.3 version, which allows to store different control strategies to be implemented and used when needed, will increase the rover velocity while decreasing the energy consumption.

The simulator built and validated on the 6.2 version of the rover proved to be effective in testing control strategies and optimising the parameters of the system. The same simulator, however, has also another use: when operating at interplanetary distances, it can give the human operator/supervisor a real-time (and predictive) knowledge of the current situation of the rover. It can therefore be useful for fault detection.

Only experimental tests, which include the relevant control delay, will show whether this combination of autonomy and human control is able to overcome the difficulties due to the operation on severe environments with large distances and therefore long time delay.

References