0.1 Panoramic 3d vision on the ExoMars Rover

G. Paar (1), A.D. Griffiths (2), D.P. Barnes (3), A.J. Coates (2), R. Jaumann (4), J. Oberst (4), Y.Gao (5), A. Ellery (5), R. Li (6)

(1) Institute of Digital Image Processing, JOANNEUM RESEARCH, Wastiangasse 6, A 8010 Graz, Austria, (gerhard.paar@joanneum.at) (2) Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, RH5 6NT, UK (adg/ajc@mssl.ucl.ac.uk) (3) Department of Computer Science, University of Wales, Aberystwyth, SY23 3DB, UK (dpb@aber.ac.uk) (4) German Aerospace Center, Institute of Planetary Research, Rutherfordstr. 2, D-12489 Berlin, Germany (juergen.oberst/ralf.jaumann@dlr.de) (5) Surrey Space Centre, University of Surrey, Guildford, GU2 7XH, UK (Yang.Gao/ Alex.Ellery@surrey.ac.uk) (6) Mapping and GIS Laboratory, CEEGS, The Ohio State University, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210-1275 (li.282@osu.edu)

The Pasteur payload on the ESA ExoMars Rover 2011/2013 is designed to search for evidence of extant or extinct life either on or up to $\sim$2 m below the surface of Mars. The rover will be equipped by a panoramic imaging system to be developed by a UK, German, Austrian, Swiss, Italian and French team for visual characterization of the rover's surroundings and (in conjunction with an infrared imaging spectrometer) remote detection of potential sample sites.

The Panoramic Camera system consists of a wide angle multispectral stereo pair with 65˚ field-of-view (WAC; 1.1 mrad/pixel) and a high resolution monoscopic camera (HRC; current design having 59.7 μrad/pixel with 3.5˚ field-of-view) .

Its scientific goals and operational requirements can be summarized as follows:

- Determination of objects to be investigated in situ by other instruments for operations planning
- Backup and Support for the rover visual navigation system (path planning, determination of subsequent rover positions and orientation/tilt within the 3d environment), and localization of the landing site (by stellar navigation or by combination of orbiter and ground panoramic images)
- Geological characterization (using narrow band geology filters) and cartography of the local environments (local Digital Terrain Model or DTM).
- Study of atmospheric properties and variable phenomena near the Martian surface (e.g. aerosol opacity, water vapour column density, clouds, dust devils, meteors, surface frosts,)

- Geodetic studies (observations of Sun, bright stars, Phobos/Deimos).

The performance of 3d data processing is a key element of mission planning and scientific data analysis. The 3d Vision Team within the Panoramic Camera development Consortium reports on the current status of development, consisting of the following items:

- **Hardware Layout & Engineering:** The geometric setup of the system (location on the mast & viewing angles, mutual mounting between WAC and HRC) needs to be optimized w.r.t. fields of view, ranging capability (distance measurement capability), data rate, necessity of calibration targets, hardware & data interfaces to other subsystems (e.g. navigation) as well as accuracy impacts of sensor design and compression ratio.

- **Geometric Calibration:** The geometric properties of the individual cameras including various spectral filters, their mutual relations and the dynamic geometrical relation between rover frame and cameras – with the mast in between – are precisely described by a calibration process. During surface operations these relations will be continuously checked and updated by photogrammetric means, environmental influences such as temperature, pressure and the Mars gravity will be taken into account.

- **Surface Mapping**: Stereo imaging using the WAC stereo pair is used for the 3d reconstruction of the rover vicinity to identify, locate and characterize potentially interesting spots (3-10 for an experimental cycle to be performed within approx. 10-30 sols). The HRC is used for high resolution imagery of these regions of interest to be overlaid on the 3d reconstruction and potentially refined by shape-from-shading techniques. A quick processing result is crucial for time critical operations planning, therefore emphasis is laid on the automatic behaviour and intrinsic error detection mechanisms. The mapping results will be continuously fused, updated and synchronized with the map used by the navigation system. The surface representation needs to take into account the different resolutions of HRC and WAC as well as uncommon or even unexpected image acquisition modes such as long range, wide baseline stereo from different rover positions or escape strategies in the case of loss of one of the stereo camera heads.

- **Panorama Mosaicking:** The production of a high resolution stereoscopic panorama nowadays is state – of – art in computer vision. However, certain

challenges such as the need for access to accurate spherical coordinates, maintenance of radiometric & spectral response in various spectral bands, fusion between HRC and WAC, super resolution, and again the requirement of quick yet robust processing will add some complexity to the ground processing system.

- **Visualization for Operations Planning:** Efficient operations planning is directly related to an ergonomic and well performing visualization. It is intended to adapt existing tools to an integrated visualization solution for the purpose of scientific site characterization, view planning and reachability mapping/instrument placement of pointing sensors (including the panoramic imaging system itself), and selection of regions of interest.

The main interfaces between the individual components as well as the first version of a user requirement document are currently under definition. Beside the support for sensor layout and calibration the 3d vision system will consist of 2-3 main modules to be used during ground processing & utilization of the ExoMars Rover panoramic imaging system.