CASP-GO 3D IMAGING SOFTWARE FOR PROCESSING PLANETARY MULTI-ANGLE DATA INTO 3D IMAGES FROM LAPTOPS TO CLOUD COMPUTERS.

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Introduction: Within the EU-FP7 iMars project (http://www.i-mars.eu), a fully automated multi-resolution Digital Terrain Model (DTM) processing chain has been developed, called Co-registration ASP-Gotcha Optimised (CASP-GO), based on the open source NASA Ames Stereo Pipeline (ASP) [1], Mutual Shape Adapted Scale Invariant Feature Transform (MSA-SIFT) based multi-resolution image co-registration [2], and the Gotcha [3] sub-pixel refinement method. The implemented system [4] guarantees global geo-referencing compliance with respect to High Resolution Stereo Camera imaging (HRSC), and hence to the Mars Orbiter Laser Altimeter (MOLA), providing refined stereo matching completeness and high accuracy based on the open source ASP platform.

Methods: Aside from the ASP core pre-processing, initial matching, subpixel matching, camera triangulation, and DTM generation, five additional workflows are introduced to further improve the DTM completeness and quality. Figure 1 shows that these include (a) a fast Maximum likelihood sub-pixel refinement method to build a float initial disparity map; (b) an optimized outlier rejection and erosion scheme to define and eliminate mis-matches; (c) an Adaptive Least Squares Correlation (ALSC) and region growing (Gotcha) based refinement and densification method to refine the disparity value and try to match un-matched and mis-matched area; (d) co-kriging grid-point interpolation to generate DTMs as well as height uncertainties for each interpolated DTM point; and (e) OrthoRectified Image (ORI) co-registration with respect to a given base dataset (in our case level-4 HRSC products).

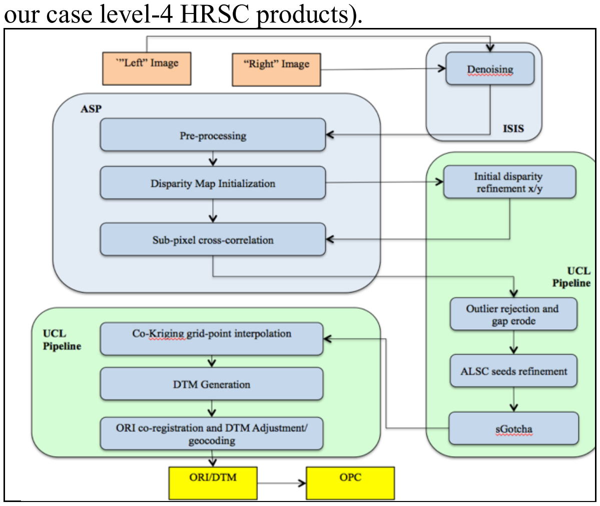

Figure 1. CASP-GO flowchart [4] ASP (blue) & new (green)

Products: The CASP-GO processing chain has been applied to generate ~5,300 NASA Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) stereo-derived 3D imaging products using the MSSL-Imaging processing cluster and the Microsoft Azure® cloud computing platform [6]. These DTMs cover ~18% of the Martian surface at 18 m/pixel compared to the current HRSC DTM coverage of around 50% with grid-spacing from 50 m/pixel to 150 m/pixel. The resultant multi-resolution co-registered 3D models will allow a much more comprehensive interpretation of the Martian surface, and are available to browse by the international community of planetary geo-scientists through an interactive webGIS system (http://www.i-mars.eu) developed at the Free University Berlin [5] available at UCL-MSS and through the ESA Guest Storage Facility [6]. Some tens of HiRISE stereo products have also been processed and compared against products from other systems. An example of CTX products from ASP and CASP-GO is shown in Figure 2 along with an example of co-registered HRSC-CTX and HiRISE derived DTMs in Figure 3, viewed within Fledermaus®

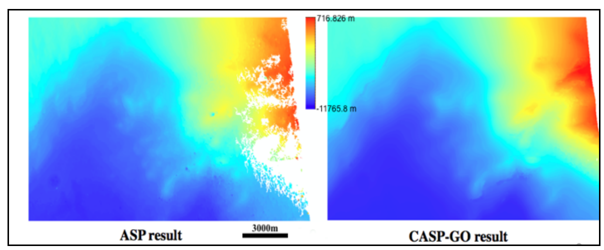

Figure 2. Comparison of CTX DTM products showing the impact of using Gotcha to fill in the gaps as well as the slight reduction in fine-scale detail from smoothing.

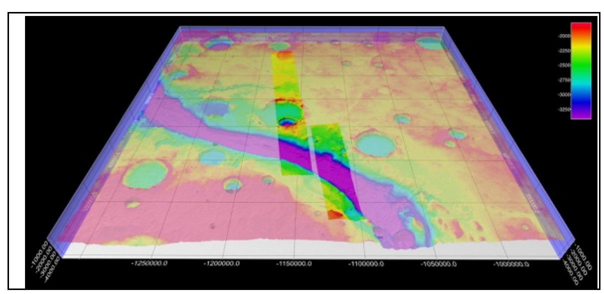

Figure 3. Perspective view of HRSC + CTX + HiRISE (2 strips) DTM products.

Quality: Visual evaluations were performed by several volunteers of the processed CTX DTMs as to their quality in 5 different groups as well as an assessment whether striping due to jitter was present (1-2m differences). The vast majority of DTMs are in the first 3 classes with only 6% in the poor quality class [6]. An evaluation of this quality is further performed using automated machine learning methods [6].

Known issues: The CASP-GO pipeline has been demonstrated to produce optimal results for CTX images when compared with several inhouse or commercial DTM pipelines, such as SOCET-SET. However, there are known issues including: lack of a current dejittering procedure, no options for an adaptive kernel size, different tiling artefacts from different matching stages which cannot yet be fully removed, and the computation time of the Gotcha process is quite high.

Software: The CASP-GO system has been tested on the latest Mac OS, RHEL and Ubuntu systems and will be available as opensource through the ASP and MSSL_Imaging's Github page. A GPU version is currently under development to address the Gotcha bottleneck. A harness to allow use of cloud computing platforms such as Microsoft Azure® and Amazon® Web Services is also available.

Future work: Further development work is planned including (a) assessment of input image quality to screen out unsuitable input scenes; (b) optimal setting of parameters to reduce gaps; (c) further detection and elimination of artefacts. The iMars base products can be used by the ESA ExoMars Trace Gas Orbiter 2016 and subsequent ESA missions for navigation and orientation and can be employed to provide the necessary inputs for engineering operations for the ESA ExoMars 2020 rover and for any Mars Sample Return missions in the 2020s. Experiments have been performed with CaSSIS DTM production and will be made available through future updates at the Github page. HRSC products can also be derived using ASP and this functionality will be integrated into CASP-GO to allow the unprocessed orbital strips (≈50% of the surface) and large area mosaics to be created at multi-resolutions.

References: [1] Beyer R. et al. (2018), *ESS*, 5 (9), 537-548. [2] Tao Y. et al. (2016), *Icarus*, 280, 139-157. [3] Shin, D. and Muller J-P. (2012). *Pattern Recognition*, 45(10), 3795-3809. [4] Tao Y. et al. (2018), PSS, 154, 30–58. [5] Walter S. et al. (2018), *ESS*, 5 (7), 308-323. [6] Muller, J-P., et al. (2019*) this workshop.*

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