USING DECONVOLUTION AND MACHINE LEARNING TO IMPROVE MSL CURIOSITY IMAGES: APPLICATION TO CHEMCAM/RMI AND MAHLI. S. Le Mouélic[1], O. Gasnault[2], K. Herkenhoff[3], W. Rapin[4], K. S. Edgett[5], R. A. Yingst[6], N. Mangold[1], G. Caravaca[1], P. Pinet[2], R.C. Wiens[7], S. Maurice[2]. [1]Laboratoire de Planétologie et Géodynamique, CNRS UMR6112, Univ. Nantes, France. [2]IRAP, Toulouse, France, [3]USGS, Flagstaff, USA. [4]Caltech, USA. [5]Malin Space Science Systems, San Diego, CA, USA. [6]Planetary Science Institute Tucson, AZ. , [7]LANL, Los Alamos, USA. [stephane.lemouelic(at)univ-nantes.fr]

Introduction: We investigate the performance of the recently released image processing software suite "Topaz Gigapixel" on martian images from the Mars Science Laboratory "Curiosity" rover. The objective is to evaluate the possibility to visually enhance the apparent resolution of acquired images, using cutting-edge image processing algorithms, in order to improve the mapping and interpretation of small scale features such as layers, laminations, cross-bedding, grains, veins, nodules...

The Topaz Gigapixel algorithm: Gigapixel is a commercial software suite from Topaz labs, which performs several image processing steps to improve the sharpness of any image. The software oversamples the image by a factor of up to 6. The user can only control the level of blur correction and the level of noise correction, both being achieved using proprietary algorithms. The blur correction is based on deconvolution. A contribution of articial intelligence (AI) is also introduced to automatically emphasize features recognized by the algorithm, using a training database of several million images. The results on terrestrial examples are generally sharper than the ones obtained using more conventional image processing software packages.

Test of the Gigapixel algorithm on ChemCam RMI images: We have tested the software on several long distance mosaics of the ChemCam Remote Microscopic Imager [1, 2]. RMI has a very small depth of field, which can result in some cases in slightly blurred areas in some part of the mosaics, depending on the geometry of the observed outcrops. The telescope was also mostly designed to document the markings left on rocks by ChemCam's laser at only few meters away from the rover during LIBS investigations. Whereas it was not optimized for this purpose, ChemCam's RMI proved to be a valuable reconnaissance tool to observe targets up to several kilometers away [3, 4].

Fig.1 shows an example of the Topaz Gigapixel output on a subset (white square) of an RMI mosaic taken on Sol 2386, when Curiosity was remotely investigating layers at the base of Mount Sharp located 1.9 km from the rover. The blur and noise correction level has been set to high and the oversampling to x4. We see in the bottom image that a very significant gain in sharpness, without any obvious artifacts, has been achieved. In a few test cases, when the original image was too blurred and/or too noisy, obvious artifacts appeared in the resulting image. This is due to the influence of the machine-learning component, which is trained on terrestrial images. A post-processing visual inspection and comparison with the original image is therefore always mandatory to evaluate the relevance of the result and the strength of the correction to be applied.

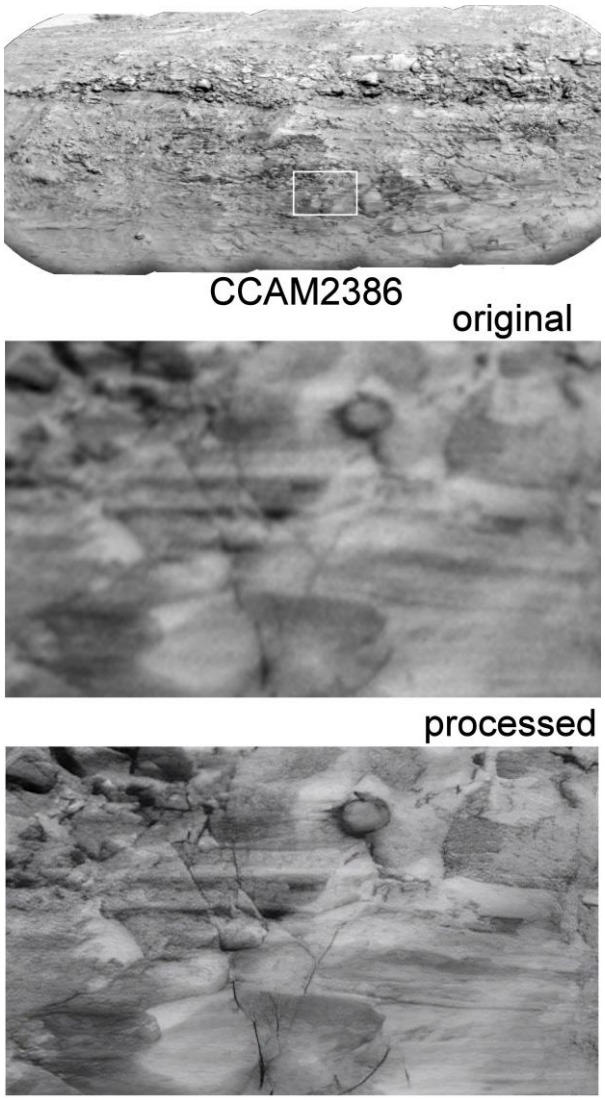

Fig 1: Example of Gigapixel output on a subset of a ChemCam RMI mosaic taken Sol 2386. The output (bottom image) has been obtained with an oversampling x4 and high blur and noise corrections.

Test of the algorithm on MAHLI images: We have also tested the algorithm on several images from the MAHLI camera mounted on the robotic arm [5]. The results on rover hardware were generally very impressive. This is probably due to the fact that the rover hardware resembles several artificial features in the learning database, therefore benefiting from the AI processing. Fig. 2 shows the output obtained on a small (one-fifth) subset of the MAHLI image 1184MH0001630000402969R00 taken on sol 1184 during the Bagnold dune campaign over a sand sheet, only few centimeters above the sand.

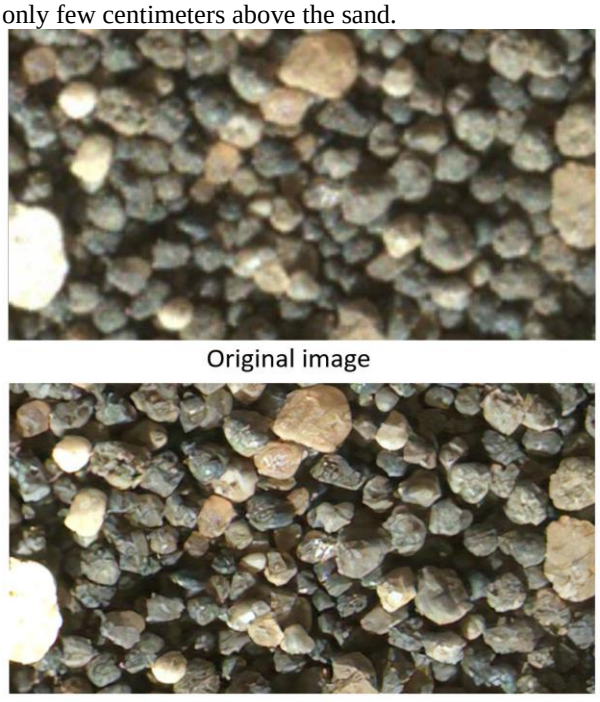

Fig. 2 : result of the Gigapixel algorithm on a MAHLI image of sand grains

Fig 2 (top) is the original MAHLI subset image used as input. Fig. 2 (bottom) is the image obtained with an oversampling of 4 and a high level of noise and blur correction in Topaz Gigapixel. The sharpness of the individual sand grains has been significantly improved, without any obvious artifact. Such a result could be useful in detecting very fine grains. Figs. 3 and 4 show another example on a subset (one third) of the MAHLI image 0946MH0004870010303821C00_DRCL acquired on a vein network near the Garden City site. Again, impressive performance is obtained with a high level of noise and blur correction and an oversampling factor of 4.

Conclusion and future work: From our tests, it appears that Topaz Gigapixel is performing extremely well under certain conditions to improve the sharpness of Curiosity RMI and MAHLI images. The result still depends on the quality of the original image. One drawback of this software is the fact that the AI is trained on a set of terrestrial images, which could potentially introduce artifacts appearing in originally blurred and noisy areas. A new training data set using martian images only would probably result in even better performances of the algorithm in our field of research. In any case, great care must be taken when interpreting features below optical resolution, and the result of the processing should always be compared with the original image to evaluate the relevance of the correction and the absence of artifacts. This mandatory step hampers the integration of the algorithm into the standard calibration pipelines at this stage.

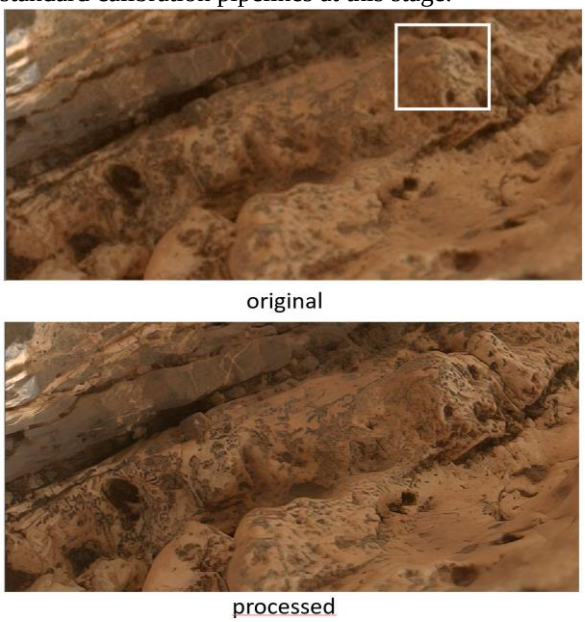

Fig. 3 : result of the Gigapixel algorithm on a subset of a MAHLI image of veins.

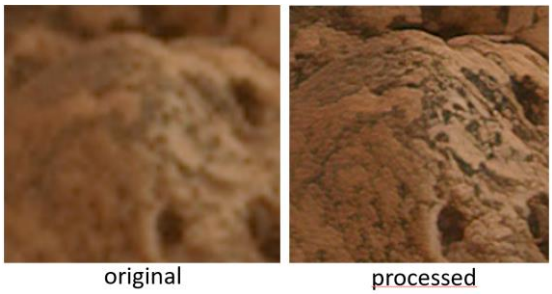

Fig 4 : zoom on the white rectangle of Fig. 3

Acknowledgments

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