

LIBS AND PIXL PREDICTION ACCURACIES FOR NI, MN, S, AND MAJOR ELEMENTS: A COMPARATIVE STUDY USING THE SAME STANDARDS. C. R. Ytsma¹, J. Harowitz², and M. D. Dyar¹

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Introduction: Calibration models for detection and accurate quantification of elements on Mars are necessary to understand the composition of its surface. *Mars 2020* will carry Planetary Instrument for X-ray Lithochemistry (PIXL), an x-ray fluorescence (XRF) instrument, and a laser-induced breakdown spectroscopy (LIBS) instrument as part of the SuperCam instrument for geochemical analyses. No comparison of prediction accuracies between these two techniques using identical standards has been undertaken to date, making it difficult to compare results from the two methods.

Another issue with Mars geochemical accuracies is that most calibration models are made using terrestrial geologic standards with concentrations that may be significantly lower than those of, especially, Ni, Mn, and S in Martian soils [1], where these elements may be enriched by contributions from meteorites and volcanic gasses. Accordingly, this study uses standards created from several different rock types doped with up to 1 wt% (10,000 ppm) of these elements to create appropriate calibration models.

Background: With XRF, samples are bombarded with high-energy X-rays, resulting in ejection of inner shell electrons. The resultant holes in the inner-shell orbitals are filled by electrons from outer shells, in the process ejecting a photon with energy diagnostic of each individual element. In contrast, LIBS uses energy from a laser pulse to excite electrons into higher energy orbitals. When electrons return to their ground state, they release photons detected by spectrometers from the UV to the NIR. These transitions occur at longer wavelengths and lower energies than those measured in XRF, due to differences in the energy of the two excitation sources (plasma heat and x-rays, respectively). So these two techniques are highly complementary, and each has its strengths and weaknesses.

Methods: Doped samples consisted of 7 matrices with different bulk compositions, including three basalts, one granite, one rhyolitic volcanic glass, sea sand, and a 50:50 mixture of diopside and forsteritic olivine. Standard preparation and analyses are described in [2]. These powders were pressed into pellets and a subset of the 84 samples was analyzed under Mars conditions with the Mount Holyoke College ChemLIBS-analog instrument as well as the Stony Brook University PIXL-analog instrument in air.

Spectral Preprocessing: XRF spectra from three pellet locations were summed over a total dwell time of one or two hours using data from two spectrometers.

X-axis resampling and baseline calculations for later removal were performed by PIQUANT, a software created specifically to analyze PIXL spectra [3–4]. To remedy temporal count differences, the spectra were normalized by the emission counts at 2.697 keV, which derive from Rh-anode L-emission lines in the PIXL X-ray tube.

LIBS spectra were averages of 36 individual shots taken on 6 locations across the pellets' surfaces. Spectra were preprocessed using the same method as the ChemLIBS *Curiosity* team and normalized by the total intensity of each of the three spectrometers [5]. The baselines were removed using the Kajfosz-Kwiatkiewicz method (bottom width of 50 and top width of zero) [6].

Modeling and Analysis: Both datasets were uploaded to a web tool that utilizes the SciKit-learn library and allows for convenient multivariate analysis with partial-least squares (PLS) and the least absolute shrinkage and selection operator (lasso) regression methods [7]. Calibration models for the dopants (Ni, Mn, S) and the major oxides (SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, P₂O₅) were made using both the entire available spectral range (0–40 keV for PIXL and ~240–850 nm for ChemLIBS) as well as limited regions of the spectra that contain emission peaks specific to the element of interest (**Table 1**). XRF regions used each element's k- α fluorescence peak, while LIBS focused on regions with the most intense peaks or clusters of peaks found with the NIST LIBS spectral database [8]. PIXL calibrations for Na and Mg were not possible because their XRF emissions are not measurable in air.

Table 1. Limited ranges used by calibration models.

Element	XRF (keV)	LIBS (nm)
Ni	7.25–7.70	298–315
Mn	5.72–6.07	255–265, 290–300
S	2.2–2.42	no peaks
Si	1.64–1.86	245–300
Ti	4.3–4.7	245–460
Al	1.35–1.65	245–400
Fe	6.2–6.6	245–450
Mg	no peak	275–285
Ca	3.5–3.87	310–400
Na	no peak	325–335, 560–600, 815–825
K	3.1–3.5	760–775
P	no visible peak	245–260

Root mean squared errors from cross-validation of the models (RMSECVs) were calculated with two methods: leave-one-out (LOO), which is similar to a simple calibration RMSE, and a more rigorous cross

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A red circular graphic with a gradient, appearing as a partial circle or a stylized arrow pointing to the right, located to the right of the authors' names.

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Computer Vision -- ACCV 2014 Daniel Cremers, Ian Reid, Hideo Saito, Ming-Hsuan Yang, 2015-04-16 The five volume set LNCS 9003 9007 constitutes the thoroughly refereed post conference proceedings of the 12th Asian Conference on Computer Vision ACCV 2014 held in Singapore Singapore in November 2014 The total of 227 contributions presented in these volumes was carefully reviewed and selected from 814 submissions The papers are organized in topical sections on recognition 3D vision low level vision and features segmentation face and gesture tracking stereo physics video and events and poster sessions 1 3

Computer Vision - ACCV 2014 Workshops C.V. Jawahar, Shiguang Shan, 2015-04-11 The three volume set consisting of LNCS 9008 9009 and 9010 contains carefully reviewed and selected papers presented at 15 workshops held in conjunction with the 12th Asian Conference on Computer Vision ACCV 2014 in Singapore in November 2014 The 153 full papers presented were selected from numerous submissions LNCS 9008 contains the papers selected for the Workshop on Human Gait and Action Analysis in the Wild the Second International Workshop on Big Data in 3D Computer Vision the Workshop on Deep Learning on Visual Data the Workshop on Scene Understanding for Autonomous Systems and the Workshop on Robust Local Descriptors for Computer Vision LNCS 9009 contains the papers selected for the Workshop on Emerging Topics on Image Restoration and Enhancement the First International Workshop on Robust Reading the Second Workshop on User Centred Computer Vision the International Workshop on Video Segmentation in Computer Vision the Workshop My Car Has Eyes Intelligent Vehicle with Vision Technology the Third Workshop on E Heritage and the Workshop on Computer Vision for Affective Computing LNCS 9010 contains the papers selected for the Workshop on Feature and Similarity for Computer Vision the Third International Workshop on Intelligent Mobile and Egocentric Vision and the Workshop on Human Identification for Surveillance

Power and Energy Richard Kong, 2015-05-06 Power and Energy contains 86 selected papers from the International Conference on Power and Energy CPE 2014 Shanghai China 29 30 November 2014 and presents a wide range of topics Energy management planning and policy making Energy technologies and environment Energy prospects Conventional and renewable power generation Power system man

Recent Advances in Intelligent Information Hiding and Multimedia Signal Processing Jeng-Shyang Pan, Akinori Ito, Pei-Wei Tsai, Lakhmi C. Jain, 2018-11-10 This book features papers presented at IIH MSP 2018 the 14th International Conference on Intelligent Information Hiding and Multimedia Signal Processing The scope of IIH MSP included information hiding and security multimedia signal processing and networking and bio inspired multimedia technologies and systems The book discusses subjects related to massive image video compression and transmission for emerging networks advances in speech and language processing recent advances in information hiding and signal processing for audio and speech signals intelligent distribution systems and applications recent advances in security and privacy for multimodal network environments multimedia signal processing and machine learning Presenting the latest research outcomes and findings it is suitable for

researchers and students who are interested in the corresponding fields IHH MSP 2018 was held in Sendai Japan on 26-28 November 2018. It was hosted by Tohoku University and was co-sponsored by the Fujian University of Technology in China, the Taiwan Association for Web Intelligence Consortium in Taiwan and the Swinburne University of Technology in Australia, as well as the Fujian Provincial Key Laboratory of Big Data Mining and Applications, Fujian University of Technology and the Harbin Institute of Technology Shenzhen Graduate School in China.

Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications Eduardo Bayro-Corrochano, Edwin Hancock, 2014-10-23. This book constitutes the refereed proceedings of the 19th Iberoamerican Congress on Pattern Recognition CIARP 2014 held in Puerto Vallarta, Jalisco, Mexico in November 2014. The 115 papers presented were carefully reviewed and selected from 160 submissions. The papers are organized in topical sections on: image coding, processing and analysis; segmentation; analysis of shape and texture; analysis of signal, speech and language; document processing and recognition; feature extraction; clustering and classification; pattern recognition and machine learning; neural networks for pattern recognition; computer vision and robot vision; video segmentation and tracking.

Advances in Neural Networks - ISNN 2014 Zhigang Zeng, Yangmin Li, Irwin King, 2014-11-28. The volume LNCS 8866 constitutes the refereed proceedings of the 11th International Symposium on Neural Networks ISNN 2014 held in Hong Kong and Macao, China, on November-December 2014. The 71 revised full papers presented were carefully reviewed and selected from 119 submissions. These papers cover all major topics of the theoretical research, empirical study and applications of neural networks research as follows. The focus is on the following topics such as: analysis, modeling and applications.

Advanced Machine Learning Technologies and Applications Aboul Ella Hassanien, Mohamed Tolba, Ahmad Taher Azar, 2014-11-04. This book constitutes the refereed proceedings of the Second International Conference on Advanced Machine Learning Technologies and Applications AMLTA 2014 held in Cairo, Egypt, in November 2014. The 49 full papers presented were carefully reviewed and selected from 101 initial submissions. The papers are organized in topical sections on: machine learning in Arabic text recognition and assistive technology; recommendation systems for cloud services; machine learning in watermarking; authentication and virtual machines; features extraction and classification; rough fuzzy sets and applications; fuzzy multi-criteria decision making; Web-based application and case-based reasoning; construction social networks and big data sets.

Digital Forensics and Watermarking Hongxia Wang, Xianfeng Zhao, Yunqing Shi, Hyoung Joong Kim, Alessandro Piva, 2020-03-25. The 22 full papers and 12 short papers presented in this volume were carefully reviewed and selected from 70 submissions. The contributions are covering the following topics: deep learning for multimedia security; digital forensics and anti-forensics; digital watermarking; information hiding; steganography and steganalysis; authentication and security.

Cognitive Systems and Signal Processing Fuchun Sun, Huaping Liu, Dewen Hu, 2019-04-27. This two-volume set CCIS 1005 and CCIS 1006 constitutes the refereed proceedings of the 4th International Conference on Cognitive Systems and Signal Processing ICCSIP 2018 held in Beijing, China, in

November and December 2018 The 96 revised full papers presented were carefully reviewed and selected from 169 submissions The papers are organized in topical sections on vision and image algorithms robotics human computer interaction deep learning information processing and automatic driving Genetic and Evolutionary Computing Jeng-Shyang Pan, Jerry Chun-Wei Lin, Yongquan Liang, Shu-Chuan Chu, 2020-03-12 This book gathers papers presented at the 13th International Conference on Genetic and Evolutionary Computing ICGEC 2019 which was held in Qingdao China from 1st to 3rd November 2019 Since it was established in 2006 the ICGEC conference series has been devoted to new approaches with a focus on evolutionary computing Today it is a forum for the researchers and professionals in all areas of computational intelligence including evolutionary computing machine learning soft computing data mining multimedia and signal processing swarm intelligence and security The book appeals to policymakers academics educators researchers in pedagogy and learning theory school teachers and other professionals in the learning industry and further and continuing education **Omics Data Integration towards Mining of Phenotype Specific Biomarkers in Cancer - Volume II** Liang Cheng, Lei Deng, Chuan-Xing Li, Yan Zhang, Mingxiang Teng, 2022-11-29 **ECAI 2020** G. De Giacomo, A. Catala, B. Dilkina, 2020-09-11 This book presents the proceedings of the 24th European Conference on Artificial Intelligence ECAI 2020 held in Santiago de Compostela Spain from 29 August to 8 September 2020 The conference was postponed from June and much of it conducted online due to the COVID 19 restrictions The conference is one of the principal occasions for researchers and practitioners of AI to meet and discuss the latest trends and challenges in all fields of AI and to demonstrate innovative applications and uses of advanced AI technology The book also includes the proceedings of the 10th Conference on Prestigious Applications of Artificial Intelligence PAIS 2020 held at the same time A record number of more than 1 700 submissions was received for ECAI 2020 of which 1 443 were reviewed Of these 361 full papers and 36 highlight papers were accepted an acceptance rate of 25% for full papers and 45% for highlight papers The book is divided into three sections ECAI full papers ECAI highlight papers and PAIS papers The topics of these papers cover all aspects of AI including Agent based and Multi agent Systems Computational Intelligence Constraints and Satisfiability Games and Virtual Environments Heuristic Search Human Aspects in AI Information Retrieval and Filtering Knowledge Representation and Reasoning Machine Learning Multidisciplinary Topics and Applications Natural Language Processing Planning and Scheduling Robotics Safe Explainable and Trustworthy AI Semantic Technologies Uncertainty in AI and Vision The book will be of interest to all those whose work involves the use of AI technology **State-of-the-art Technology and Applications in Crop Phenomics** Wanneng Yang, John Doonan, Tony Pridmore, Malcolm John Hawkesford, Ji Zhou, 2021-12-01 Pattern Recognition and Computer Vision Zhouchen Lin, Liang Wang, Jian Yang, Guangming Shi, Tieniu Tan, Nanning Zheng, Xilin Chen, Yanning Zhang, 2019-10-31 The three volume set LNCS 11857 11858 and 11859 constitutes the refereed proceedings of the Second Chinese Conference on Pattern Recognition and Computer Vision PRCV 2019 held in Xi an China in November 2019 The 165

revised full papers presented were carefully reviewed and selected from 412 submissions The papers have been organized in the following topical sections Part I Object Detection Tracking and Recognition Part II Image Video Processing and Analysis Part III Data Analysis and Optimization *Handbook of Research on Machine Learning Techniques for Pattern Recognition and Information Security* Dua, Mohit,Jain, Ankit Kumar,2021-05-14 The artificial intelligence subset machine learning has become a popular technique in professional fields as many are finding new ways to apply this trending technology into their everyday practices Two fields that have majorly benefited from this are pattern recognition and information security The ability of these intelligent algorithms to learn complex patterns from data and attain new performance techniques has created a wide variety of uses and applications within the data security industry There is a need for research on the specific uses machine learning methods have within these fields along with future perspectives The Handbook of Research on Machine Learning Techniques for Pattern Recognition and Information Security is a collection of innovative research on the current impact of machine learning methods within data security as well as its various applications and newfound challenges While highlighting topics including anomaly detection systems biometrics and intrusion management this book is ideally designed for industrial experts researchers IT professionals network developers policymakers computer scientists educators and students seeking current research on implementing machine learning tactics to enhance the performance of information security Neural Information Processing Chu Kiong Loo,Yap Keem Siah,Kok Wai Wong,Andrew Teoh Beng Jin,Kaizhu Huang,2014-10-21 The three volume set LNCS 8834 LNCS 8835 and LNCS 8836 constitutes the proceedings of the 20th International Conference on Neural Information Processing ICONIP 2014 held in Kuching Malaysia in November 2014 The 231 full papers presented were carefully reviewed and selected from 375 submissions The selected papers cover major topics of theoretical research empirical study and applications of neural information processing research The 3 volumes represent topical sections containing articles on cognitive science neural networks and learning systems theory and design applications kernel and statistical methods evolutionary computation and hybrid intelligent systems signal and image processing and special sessions intelligent systems for supporting decision making processes theories and applications cognitive robotics and learning systems for social network and web mining **Intelligent Sustainable Systems** Atulya Nagar,Dharm Singh Jat,Durgesh Mishra,Amit Joshi,2025-08-02 This book provides insights of World Conference on Smart Trends in Systems Security and Sustainability WS4 2024 which is divided into different sections such as Smart IT Infrastructure for Sustainable Society Smart Management Prospective for Sustainable Society Smart Secure Systems for Next Generation Technologies Smart Trends for Computational Graphics and Image Modeling and Smart Trends for Biomedical and Health Informatics The proceedings is presented in four volumes The book is helpful for active researchers and practitioners in the field

Conference Proceeding. New Perspectives in Scienze Education Pixel,2016-03-04 *Computer Vision - ACCV 2016 Workshops* Chu-Song Chen,Jiwen Lu,Kai-Kuang Ma,2017-03-14 The three volume set consisting of LNCS 10116 10117

and 10118 contains carefully reviewed and selected papers presented at 17 workshops held in conjunction with the 13th Asian Conference on Computer Vision ACCV 2016 in Taipei Taiwan in November 2016 The 134 full papers presented were selected from 223 submissions LNCS 10116 contains the papers selected **Security and Privacy in Digital Economy** Shui Yu, Peter Mueller, Jiangbo Qian, 2020-10-22 This book constitutes the refereed proceedings of the First International Conference on Security and Privacy in Digital Economy SPDE 2020 held in Quzhou China in October 2020 The 49 revised full papers and 2 short papers were carefully reviewed and selected from 132 submissions The papers are organized in topical sections cyberspace security privacy protection anomaly and intrusion detection trust computation and forensics attacks and countermeasures covert communication security protocol anonymous communication security and privacy from social science The conference was held virtually due to the COVID 19 pandemic

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