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The Moon Zoo citizen science project: Preliminary results for the Apollo 17 landing site

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ABSTRACT

Moon Zoo is a citizen science project that utilises internet crowd-sourcing techniques. Moon Zoo users are asked to review high spatial resolution images from the Lunar Reconnaissance Orbiter Camera (LROC), onboard NASA's LRO spacecraft, and perform characterisation such as measuring impact crater sizes and identify morphological 'features of interest'. The tasks are designed to address issues in lunar science and to aid future exploration of the Moon. We have tested various methodologies and parameters therein to interrogate and reduce the Moon Zoo crater location and size dataset against a validated expert survey. We chose the Apollo 17 region as a test area since it offers a broad range of cratered terrains, including secondary-rich areas, older maria, and uplands. The assessment involved parallel testing in three key areas: (1) filtering of data to remove problematic mark-ups; (2) clustering methods of multiple notations per crater; and (3) derivation of alternative crater degradation indices, based on the statistical variability of multiple notations and the smoothness of local image structures. We compared different combinations of methods and parameters and assessed correlations between resulting crater summaries and the expert census.

We derived the optimal data reduction steps and settings of the existing Moon Zoo crater data to agree with the expert census. Further, the regolith depth and crater degradation states derived from the data are also found to be in broad agreement with other estimates for the Apollo 17 region. Our study supports the validity of this citizen science project but also recommends improvements in key elements of the data acquisition planning and production.

1. Introduction

The Moon is the only extra-terrestrial planetary body where the provenance of geological samples and their absolute radiometric ages are known accurately: correlations between these data and censuses of local crater populations with known surface ages have been used to determine crater production functions over time (e.g., Hartmann, 1970; Neukum et al., 2001). This has allowed the derivation of age estimates for lunar terrains where radiometrically dated samples are not in hand. This approach has also been adapted to other planetary bodies with due allowance for variations in impactor populations, fluxes and velocities in different parts of the Solar System (Hartmann, 1977; Ivanov et al., 2000).

The seemingly straightforward survey of crater features on the lunar surface is complicated by several factors, not least the discrimination between primary and secondary impacts (McEwen and Bierhaus, 2006), the effects of various forms of erosion on crater morphology, which act to soften the appearance of the crater form, and the influence of illumination in remotely-sensed images, which may serve either to hide or exaggerate topography. The combination of the human eye and brain remains unparalleled in pattern recognition of the kind required to accurately identify, characterize and quantify crater populations and the morphology of individual circular features. However, human efforts are constrained by the scale of the task, the substantial numbers of craters

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and time required to catalogue them; even relatively small mare regions (few hundred km^2) contain tens of thousands of craters.

Increases in computing power and the development of suitable pattern recognition algorithms, along with expanding catalogue of high-resolution planetary images, have spurred novel approaches to automated crater surveys (e.g., Urbach and Stepinski, 2006; Vijayan et al., 2013). Nevertheless, these techniques have yet to achieve the accuracy of a human observer. Citizen science initiatives seek to bridge the gap between the human and the computational techniques (e.g., Joy et al., 2011; Robbins et al., 2014).

Moon Zoo (www.moonzoo.org) is part of the suite of Zooniverse citizen science projects (Lintott et al., 2008, 2011), which enlist thousands of science enthusiasts around the world to carry out large-scale mapping and cataloguing of astronomical phenomena. Moon Zoo is specifically devoted to mapping features on the lunar surface and forms the basis for the work reported here.

1.1. Aims of this study

The aim of this study is to gain a level of confidence in the Moon Zoo citizen science data to generate reliable crater size-frequency distributions across the lunar surface. We also test the validity of interpreting crater size spread among users as an index of crater erosion, and by implication, age. This work focuses on the statistical analysis of small (< 500 m diameter) impact craters surveyed near the Apollo 17 landing site. This region was selected for a number of reasons: (a) it is the best geologically constrained Apollo landing site; (b) a wide range of NAC images at different illumination conditions were available at the time of the Moon Zoo interface design; (c) its geomorphologic diversity, ranging from uplands, downslopes, old maria, regolith porosity variations, and extensive secondary craters fields; (d) the 40th anniversary of the Apollo landing coincided with the start of this project and we used this opportunity to rekindle the public interest in Moon Zoo by focusing efforts on this region. Indeed, for a period of time (18 months) only images covering the Apollo 17 site were offered to the Moon Zoo users.

1.2. Methodology

In order to assess the reliability of the Moon Zoo citizen science output, an expert crater survey was carried out (Section **4**). A subset was marked by three other planetary scientists for validation of the larger set. We also considered the input behavioural pattern of each Moon Zoo user in order to allocate individual ‘confidence’ weighting parameters (Section **5.1**). Further, we developed a new method to coalesce crater data annotations (lat., long, radius) from several non-projected, uncalibrated NAC images into single, map-projected entries (Section **5.2**).

Based on the strengths and weaknesses found we propose changes and improvements in several areas of the Moon Zoo interface (Section **7**). These recommendations are also applicable to other feature-marking citizen science projects.

2. Moon Zoo

One of the main advantages of Moon Zoo (Joy et al., 2011) and other planetary surface citizen science projects (e.g., “Clickworkers”: Kanefsky et al., 2001; “CosmoQuestX”: Robbins et al., 2012; “Be A Martian!”: http://beamartian.jpl.nasa.gov/maproom#/MapMars) is that they facilitate classification of large amounts of data by breaking it down into small independent observations and then recombining the results for scientific analysis. Additionally, educational research has being carried out to identify trends in the classification behaviour and site usage of Moon Zoo users over time, to assess public understanding of lunar concepts, and to determine what motivates users to take part in this project (Prather et al., 2013).

Moon Zoo was launched in May 2010 and planned to be retired by the end of 2015. Registered users identify, classify, and measure feature shapes on the surface of the Moon using a tailored graphical interface (Fig. 1). The interface is also linked to a wide range of education and public outreach material, including a forum and blog, with contributions and moderation by experts and invited specialists (Joy et al., 2011). Users undergo a preliminary training consisting of a video tutorial (although this is not

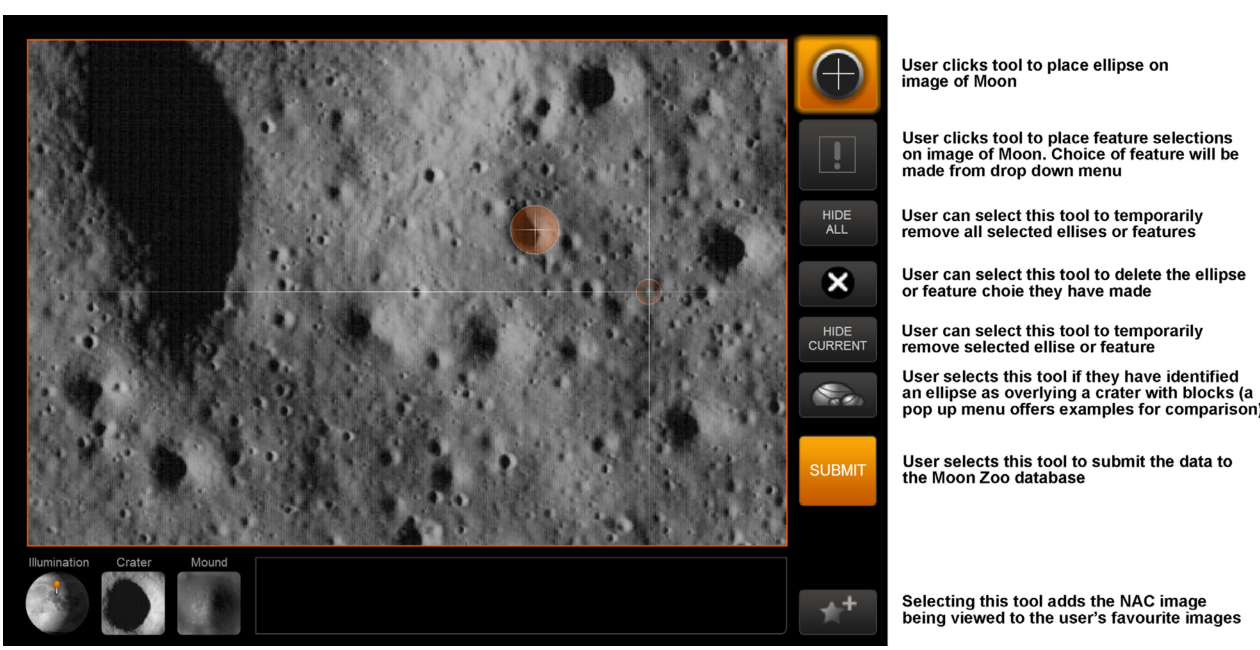

Fig. 1. The Moon Zoo GUI (Graphical User Interface) allows users to mark craters using the aim tool, including the option of confirming or modifying the selection before submitting. Other tools help to report craters with boulders and highlight any ‘interesting’ features. The key in the bottom left hand corner indicates to the user what feature is a mound and which is a crater based on shadow direction.