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MOON ZOO: FIRST SCIENCE RESULTS. C. J. Lintott[1],and the Moon Zoo Team. [2]Oxford University, Oxford, UK

Introduction: Moon Zoo (www.moonzoo.org) is an online lunar science project, inspired by the highly successful Galaxy Zoo project. It harnesses the widespread availability of fast internet connections to invite members of the public to identify craters and other features of interest in images drawn from the Lunar Reconnaissance Orbiter Camera data set. More than two million classifications were obtained in the first month of the project's operation from more than 20,000 volunteers. We will present the initial science results resulting from these classifications.

The Moon Zoo Concept: Moon Zoo, is an online citizen science project that asks users to identify, classify and measure the shape of features on the surface of the Moon using a specially designed graphical interface (Fig. 1). The interface will shortly be available in several languages to ensure that this is a truly international project.

Moon Zoo Data: The project utilizes Planetary Data System (PDS) released high spatial resolution images (with associated metadata) from NASA's Lunar Reconnaissance Orbiter Camera (LROC) instrument, which has been orbiting the Moon since June 2009. Statistical analysis of the Moon Zoo user data will allow us to address interesting lunar science topics, and will also aid the planning of future exploration of the Moon by robotic and manned missions.

Moon Zoo Science Goals: The Moon Zoo team identified four preliminarily Moon Zoo user projects [6, 7] that can be readily addressed by registered Moon Zoo users utilizing LROC data. These projects address a variety of important lunar science and exploration themes [8], and are briefly described below. We will present the first results obtained by Moon Zoo in each of these areas.

Project 1. Statistical populations survey of small craters. This project has been divided into two subtasks:

Project 1a. Count the number of and measure the dimensions of impact craters on the Moon (yielding both crater diameter and ellipticity) with the aim of improving the precision of small lunar crater population statistics. Crater counting allows us to calculate the apparent age of the lunar surface, by comparing the number of impact craters on different lunar surfaces (i.e. lava flows, basin impact melt sheets etc.). Technical issues such as classifying primary vs. secondary craters are beyond the scope of user classification tasks and so will form an important component of subsequent database exploitation and scientific interpretation. Understanding the age of different lunar lava flows and crustal surfaces will shed new light on the temporal thermal and magmatic history of the Moon, and will have important implications for understanding heating processes of small rocky planetary bodies.

Other science goals include identifying small highly elliptical impact craters that may have preferentially preserved impacting meteoritic material [9] and producing maps of crater degradation state (see section about Validation below). The database will have numerous other uses. For example, the location of lunar craters can be used to develop a control net of lunar crater location to help cartographic database and improve lunar coordinate system. Additionally we envisage that the results of citizen science crater dimension studies could be compared with automatic computer algorithm methods to assess the capabilities of automatic counting systems and citizen science efforts.

Project 1b. Users will also be asked to assess a scale of blockiness state (ejected boulder concentration) of crater rims, to classify them and help to determine local regolith thickness variation [10].

Project 2. Users will assess the degree of boulder hazards on the lunar surface by comparing two images (of similar scale and similar illumination conditions), and identifying the one with the higher boulder density. These results will produce relative boulder-density hazard maps to help identify the most suitable locations for sending future robotic and manned missions to the Moon.

Project 4: We will also ask Moon Zoo users participating in both Project 1a and 1b to identify, and therefore catalogue, the location of interesting lunar features such as lava channels (rilles), volcanic eruptive centers (pyroclastic deposits), crater chains, bench craters, and bright fresh rayed craters within the scale size of the LROC image. We hope that members of the wider lunar science community will then be able to utilize this database to aid their own research objectives.

An additional project (project 3) involving comparison with Apollo-era data for the purposes of finding changes on the lunar surface is still in development.

Moon Zoo Development:

Graphical interfaces for Project 1, Project 2 and Project 4 tasks have been developed using Flash software for the main classification interface (Fig. 1). The Moon Zoo software API and database laver have been developed by the team at Oxford University, based on their experience with storing and analyzing large amounts of citizen science data.

Validation: The Galaxy Zoo project utilizes a variety of statistic analysis tools to study the quality of user classifications (i.e. how often they get the 'correct' answer compared to an expert classification; how varied the classification result is between users; identification of potentially malicious classifications etc.). We will present the results of employing similar tools for exploiting the Moon Zoo user databases.

A variety of data reduction techniques have be employed to turn raw data collected by the Moon Zoo website into science-ready outputs. For example, it is possible to 'weight' users according to their degree of agreement with expert classifications (or other results), and then iterate these results through the database. This technique has proved to be effective in obtaining high fidelity results even for apparently difficult citizen science tasks [1-4].

We will also review the ability of the validation process to produce additional science results in itself, for example, analysis of the standard deviation of the crater diameter histogram can help to reveal craters with degraded rims through slight variations in user measurements, because these will be the most difficult to measure.

Outreach and public engagement: Lunar science outreach information and links on the Moon Zoo website are being developed by the education team. A Moon Zoo exhibit is on the floor of the Adler Planetarium and we are working closely with the NASA Lunar Science Institute as part of their lunar science education programme. A companion abstract (Gay et al.) addresses further online educational efforts, specifically the inclusion for the first time of an assessment of content knowledge and the provision of substantial background material for volunteers.

Concluding Statement: The gold standard for citizen science projects is to produce real science. We will assess Moon Zoo's success in achieving these goals.

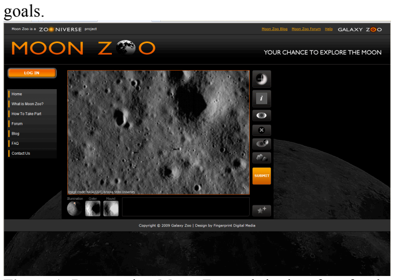

Figure 1. Beta-version Moon Zoo website interface for the crater dimension project. The GUI allows users to measure crater dimensions (Project 1a), identify craters with boulders (Project 1b) and spot any 'interesting' features (i.e. Project 4). Example lunar image courtesy of NASA/GSFC/Arizona State University.

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