A GENETIC OPTIMIZATION TOOL FOR PREDICTING LUNAR IMPACTOR PROPERTIES BASED ON OBSERVED CRATER DIAMETER J. R. Elliott[1] and J. Pouplin[2*], [1]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN 47907. [2]School of Aeronautics and Astronautics, Purdue University, West Lafayette, IN 47907. jpouplin@purdue.edu

Introduction: Numerical modelling of impact mechanisms based on observed crater properties allows for a better understanding of planetary surface and subsurface properties [1]. Although large scale lunar crater population counts have been conducted, an estimation of the impactor population properties, such as mass, impact angle, and velocity, based on the observed crater diameters has yet to be performed. In this study, we use a genetic algorithm to estimate of the impactor properties of 8713 lunar craters [2].

Optimization methodology: A genetic algorithm optimization method was chosen based on the fact that the impactor's properties can vary within a range of value, that once chosen would define a calculated crater diameter that needs to match the observable crater diameter.

The algorithm's objective is to minimize the norm of the apparent diameter of a crater, D_{known} and its calculated counterpart, D_{calc} :

$$f(x) = |D_{known} - D_{calc}|$$

D_{calc} is computed using well-established pi-group scaling laws [3] for apparent diameter. The scaling law is modified for impact angle [4] and crater collapse [5]. We limit the material properties to a dunite impactor and hard rock target with granite density. The design variable is thus:

$$\boldsymbol{x} = [\theta \; a_i \; v_i],$$

where θ is the impact angle, a_i is the impactor radius, and v_i is the impact angle.

The genetic algorithm utilized was provided by Prof. Bill Crossley from Purdue University, based on [6]. The genetic algorithm uses 36 bits for each variable. The chromosome length is 550, the probability of crossover is 50%, and a probability of mutation is 2.3×10^{-4}. Each simulation uses a population of 2200 individuals.

Robustness of the genetic algorithm: A verification of the optimization code was performed based on Copernicus crater, which has a 79 km apparent diameter. As impact angle is currently the least constrainable variable, we limit the angle to 90° for this verification. After running this specific crater for 100 iterations, the predicted impactor properties from the genetic algorithm converge to an impactor of 4.83 ± 0.16 km diameter and 19.7 ± 0.23 km/s impact velocity. While those results differs from the previously selected impactors of [7], the fitness function averages a 1.19×10^{-8} meter variation from the observed crater diameter, indicating that this solution is valid and robust. However, the fact that [7] was able to reproduce Copernicus indicates that several solutions may be valid. The impact scaling laws [3] are under-constrained at the moment to allow the prediction of a unique impactor. Rather, while the answers provided by the genetic algorithm are following the impact scaling laws and do produce the desired crater, they should be regarded as a starting point when constraining impactor properties. Further investigation of the crater of interest is needed to truly constrain the impactor.

Results for a crater population: Given the automation of the genetic algorithm, it seems natural to apply it to the lunar crater population to derive possible impactor populations. Similar to our validation process, we first run the algorithm with a constrained impact angle of 90°. Figure 1 displays the obtained velocity distribution in blue. The impactor population has mean and median of 18.5 km/s and a standard deviation of 2.3 km/s. This is within range of the estimated mean impact velocity of 16 km/s [8]. The distribution is very close to the results of the orbital simulation of lunar impactors originating in the main asteroid belt [7].

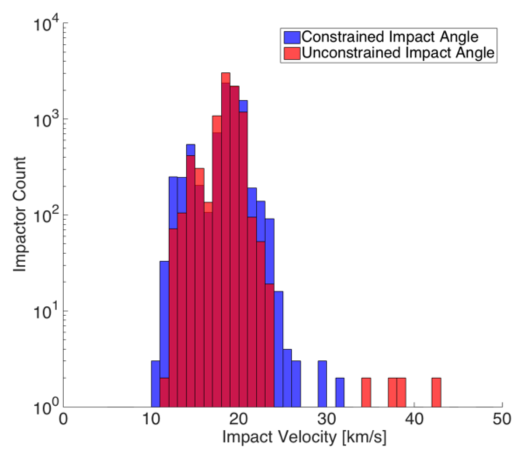

Figure 1. Histogram of impact velocities for 90° (blue) and unconstrained (red) impact angles. Note that the magenta color is where the velocities overlap.

If we remove the constraint on the impact angle possible, allowing for a range of 0-90°, we obtain a surprisingly similar distribution. Figure 1 shows the distribution in red. It has a median and mean 18.5 km/s, with a standard deviation of 1.9 km/s. Thus, the impact angle choice does not appear to severely affect the impactor velocities. The corresponding histogram of impact angles selected by the genetic algorithm are shown in Figure 2.

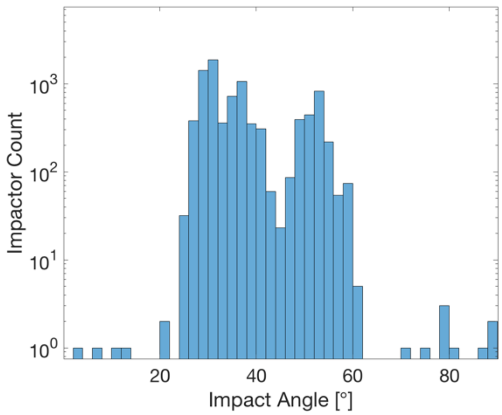

Figure 2. Histogram of impact angles.

The dip at 45° is quite surprising, as that is widely considered to be the most frequent impact angle [9]. It is clear that the impact angle needs to be constrained, perhaps with crater ellipticity [10] or the ejecta blanket distribution [11].

Future Work: In order to further constrain the predicted impact angle, the observed ellipticity of crater population will be assessed [10]. A larger lunar crater database containing ellipticity measurements will be used [12]. The results based on ellipticity will be assessed and compared to those obtained at 90° angle of impact for the whole crater population to estimate its effect. The spatial variability of impact angles and velocities will be assessed to determine if certain locations deviate from the global average.

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