PROPOSAL-BASED CRATER DETECTION ALGORITHM FOR ONE-CLICK CRATER ANNOTATION: .
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Introduction: Despite the existence of automated crater detection algorithms (CDAs), human-created crater annotations are still used in all major impact crater surveys. Because of the high level of scrutiny that planetary scientists put into classifying features as craters or non-craters and measuring them, all current CDAs provide noisier results than expert annotations.

The ultimate goal of any CDA is to reduce the amount of expert time required to carry out a reliable impact crater survey.

To make progress towards this goal, this is an exploration of a "human-in-the-loop" automated crater detection system.

Proposal-Based Detection: The proposed approach to this crater annotation system is to use an optimized computer vision algorithm to precisely define a crater given a coarse proposal. A "coarse" proposal is a "one-click" input by the annotator.

3 – Point Regression: There are a number of types of crater annotations, including circles (3-points), ellipses (5-points), and traces (N-points).

While this approach can be extended to support any of the mentioned annotations types, the 3-point circle annotation is used in this project as a proof-of-concept. Other output types are reserved for future work and will be important when geometric properties of craters are needed in a given study.

Coarse Proposals: The goal of the coarse proposal system is to enable the expert annotator to provide enough information to specify the feature in question with just a single click. A click provides a rough crater center (x, y coordinates), but a very coarse crater size is also needed to specify precisely which feature is in question.

To allow the user to specify a rough scale, one of four different crater sizing bin settings are supported:

0 – 8 pixels radius

8 – 16 pixels radius

16 – 32 pixels radius

32 – 100 pixels radius

With a given setting activated, both the rough location and the approximate size of the crater can be provided by an expert annotator with a single click.

Scope: While the ultimate goal of this project is to provide user-friendly software for annotators, the focus of this study has been on optimizing the computer vision model for the regression problem at hand.

Problem Setup: The regression model takes raw pixels as an input and outputs three parameters: two location parameters (x, y) and a radius parameter (r).

To solve this problem, a convolutional neural network with a regression objective is applied. Analogous applications of this type of model include, as an example, human pose estimation [1].

The proposal is provided implicitly by the pixels passed to the model itself. The proposed system translates a proposal into a cropping of the input image, and the task is reduced to locating the crater within the subset of pixels passed to the regression model.

Training: Expert-generated crater annotations on a variety of Martian and Lunar surfaces were used to generate training examples for the model.

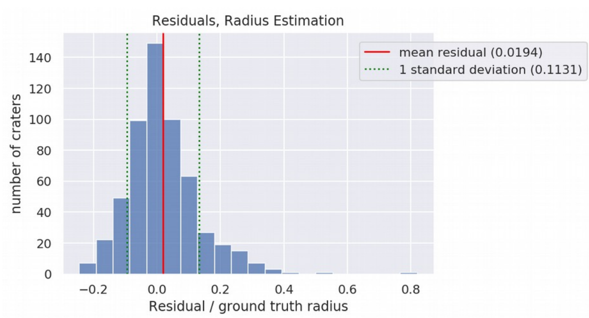
The training procedure takes an expert-labeled crater and adds random noise to both its location and size. These noisy annotations are used to simulate user-provided proposals.

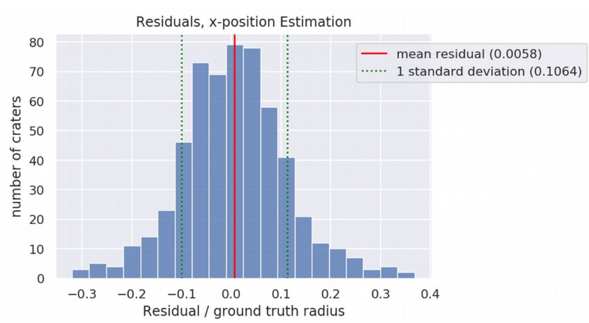
After a synthetic proposal is generated, the known "ground truth" crater annotation is used to generate a target output value. The model parameters are then optimized using mini-batch training and Adam[2].

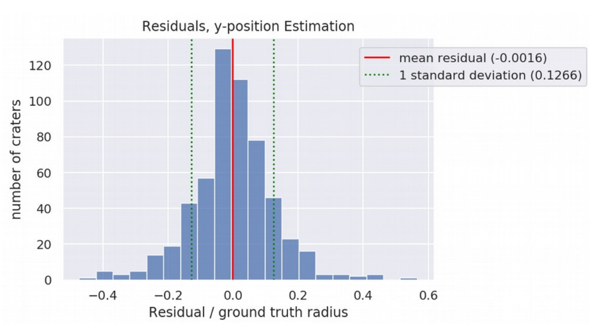
Validation: During training, a number of craters are "held out." These craters are then used to provide estimation error statistics. As in during training, noise is added to annotated craters to simulate human-provided proposals.

It must be noted that these held-out craters are taken from the same images that are used to train the system, although these particular craters have not been used in training. Performance should be expected to be generally worse on unseen terrain.

Estimation residual distributions for the three target parameters are as follows:







This variance in estimation may be compared to the variance in human-generated annotations, as in [3].

Prototype System: To demonstrate the viability of this approach, a prototype graphical user interface has been developed. That software can be found at https://github.com/AlliedToasters/OneClickCDA.

The prototype system deploys the validated model presented here and accepts user-provided one-click annotations to perform regression on craters. The system maps the model outputs back into the coordinates of the original image. Results can be written to a .csv file.

Future Work: The aim of this prototype is to demonstrate the viability of this approach towards the stated goal of reducing the amount of expert time required to carry out a reliable crater survey.

Future work will involve:

-Improving performance through the use of more training and validation data.

-Improving performance through further experimentation with different neural network architectures

-Creating a model to support ellipse (5-point) and trace (N-point) annotation outputs.

-Creating a production-ready system perhaps by integrating with existing crater annotation software.

References:

[1] A. Toshev and C. Szegedy (2014) *DeepPose: Human Pose Estimation via Deep Neural Networks*. [2] D. Kingma and J. Lei Ba (2015) *Adam: A Method for Stochastic Optimization*. [3] S. Robbins, et al. (2014) *The variability of crater identification among expert and community crater analysts.*

Additional Information: For additional information about this system, please contact Michael Klear by email (michael.r.klear@gmail.com) or by phone (1 650 218 1844).