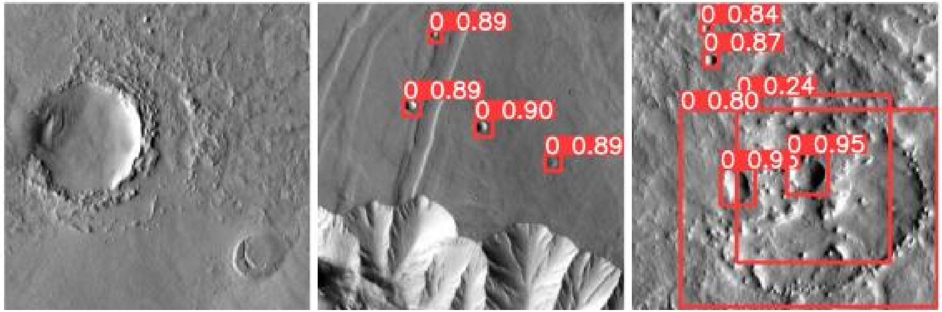
Automated Crater Detection and Classification with Machine Learning



Final Presentation
by
Sihang Zhao

[1] P. R. Christensen, B. M. Jakosky, H. H. Kieffer, M. C. Malin, H. Y. McSween, K. Nealson, G. L. Mehall, S. H. Silverman, S. Ferry, M. Caplinger et al., "The thermal emission imaging system (themis) for the mars 2001 odyssey mission," Space Science Reviews, vol. 110, no. 1, pp. 85–130, 2004

Source: THEMIS[1] images annotated by Sihang via YOLO V5

About Me

ZHAO, Sihang

- BEng Computer Science
- MSc ACSE (if this project goes well...)

Favourtite ACSE Module:

- Computational Mathematics
- Machine Learning

Research Interest:

- NLP
- Machine Learning
- Pokémon
- Texas hold'em
- Meme

Source: photo by Miss XU, Weiyu
July, 2022

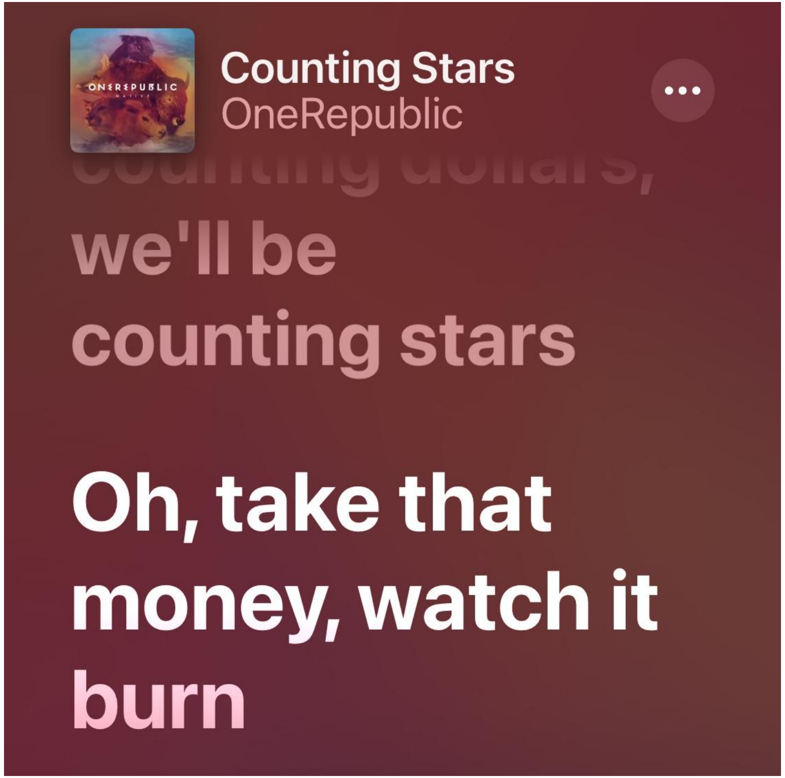
Introduction of Crater Detection Task:

We want to...

- Counting craters on Mars
- Design a crater detection algorithm (CDA)

Because...

- Craters contains rich information
- Detecting all the craters manually is impossible



Source: Image of The Thermal Emission Imaging System (THEMIS)

Source: Screenshot by Siang's iPhone
《Counting Stars》by OneRepublic
Apple Music

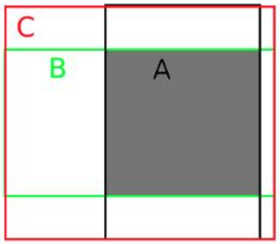
[1] P. R. Christensen, B. M. Jakosky, H. H. Kieffer, M. C. Malin, H. Y. McSween, K. Nealson, G. L. Mehall, S. H. Silverman, S. Ferry, M. Caplinger et al., "The thermal emission imaging system (themis) for the mars 2001 odyssey mission," Space Science Reviews, vol. 110, no. 1, pp. 85–130, 2004

Short Introduction of Object Detection (OD) Algorithm:

The Model in this work: YOLO V5[3]

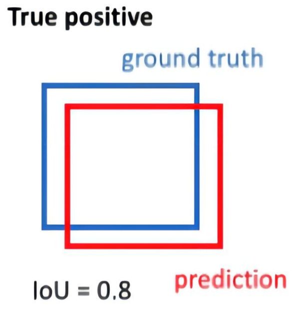
- Input: Images
- Output: Bounding boxes
- Loss Function: GIoU

C is the smallest box that can contain A and B



How True positive is given:

Example
Threshold: 0.5



Algorithm 1: Generalized Intersection over Union

input : Two arbitrary convex shapes: $A, B \subseteq \mathbb{S} \in \mathbb{R}^n$
output: $GIoU$

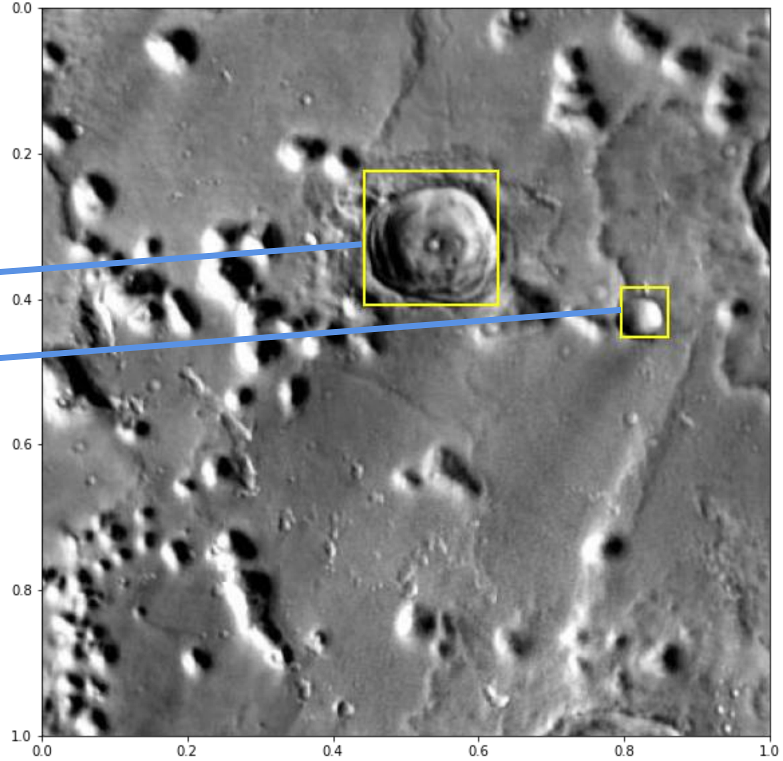
1. For A and B, find the smallest enclosing convex object C, where $C \subseteq \mathbb{S} \in \mathbb{R}^n$
2. $IoU = \frac{|A \cap B|}{|A \cup B|}$
3. $GIoU = IoU - \frac{|C \backslash (A \cup B)|}{|C|}$

[3] https://github.com/ultralytics/yolov5

Source: [4] https://blog.csdn.net/weixin_41735859/article/details/89288493

Training source description:

class	x	y	w	h
0	0.5348557692307693	0.3161057692307692	0.18509615384615385	0.18509615384615385
0	0.828125	0.4182692307692308	0.06490384615384616	0.0673076923076923



Source: THEMIS[1] images annotated by Sihang

- 3,556 tiles with 7048 labeled craters. 100m/pixel 416*416 pixels each image
- latitudinal band from 35◦N to 35◦S of the equator selected by [2]Benedix et al.

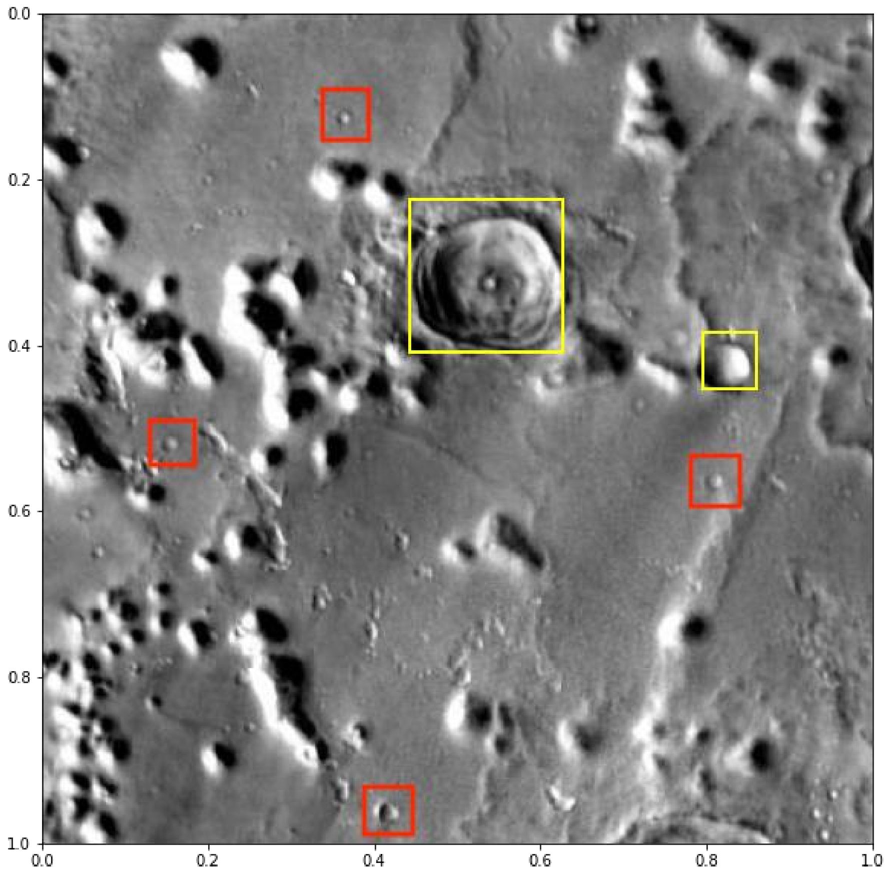
[2] G. Benedix, A. Lagain, K. Chai, S. Meka, S. Anderson, C. Norman, P. Bland, J. Paxman, M. Towner, and T. Tan, "Deriving surface ages on mars using automated crater counting," Earth and Space Science, vol. 7, no. 3, p. e2019EA001005, 2020.

Problem description:

Existing dataset is not perfect:

- Small craters are hard to identify
- Some labels are deviated from the craters

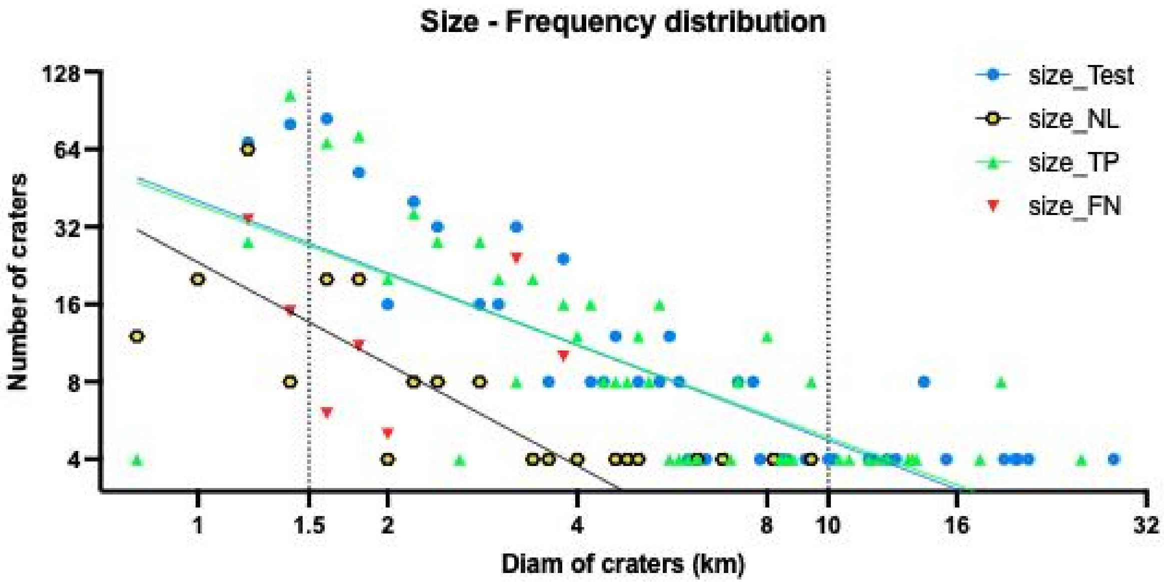
- Unlabelled craters in training set -> Poor training effect
- Unlabelled craters in test set -> Irresponsible evaluation



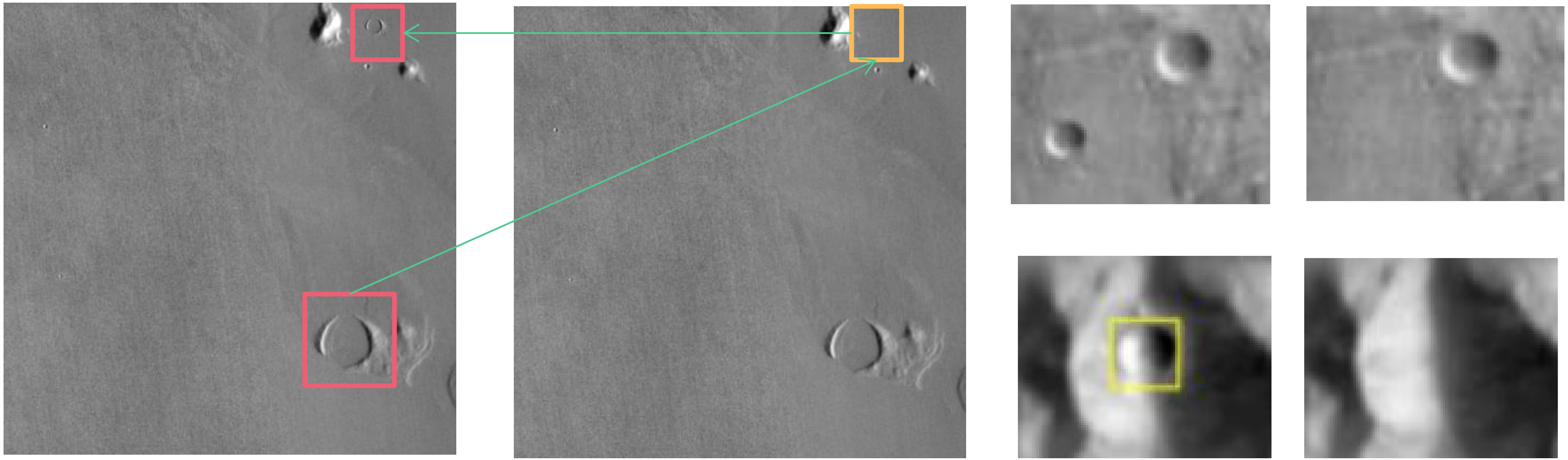
Source: THEMIS[1] images annotated by Sihang

Size-Frequency Distribution:

- False Negative cases are small craters



My solution: Metamorphic Crater Generator (MCG)



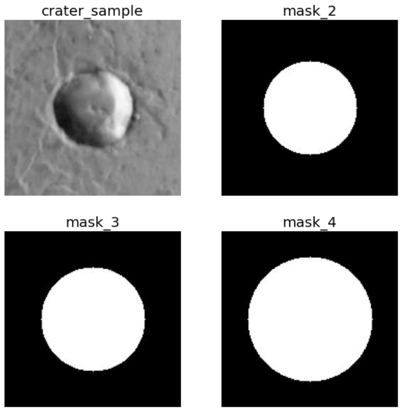
- Generating the metamorphic craters with different sizes
- Pasting them into the particular position

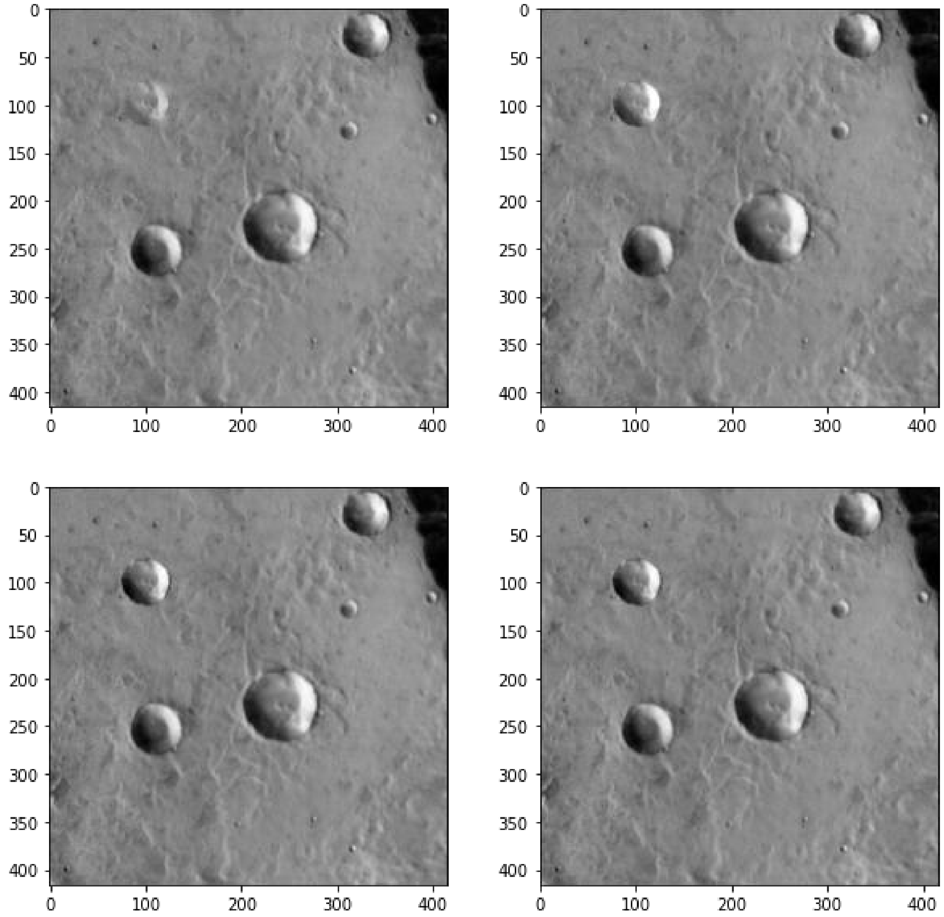
Source: Examples of the THEMIS[1] images which are annotated and processed by Sihang via MCG

Tricks of MCG Implementation

The trick to make natural edges

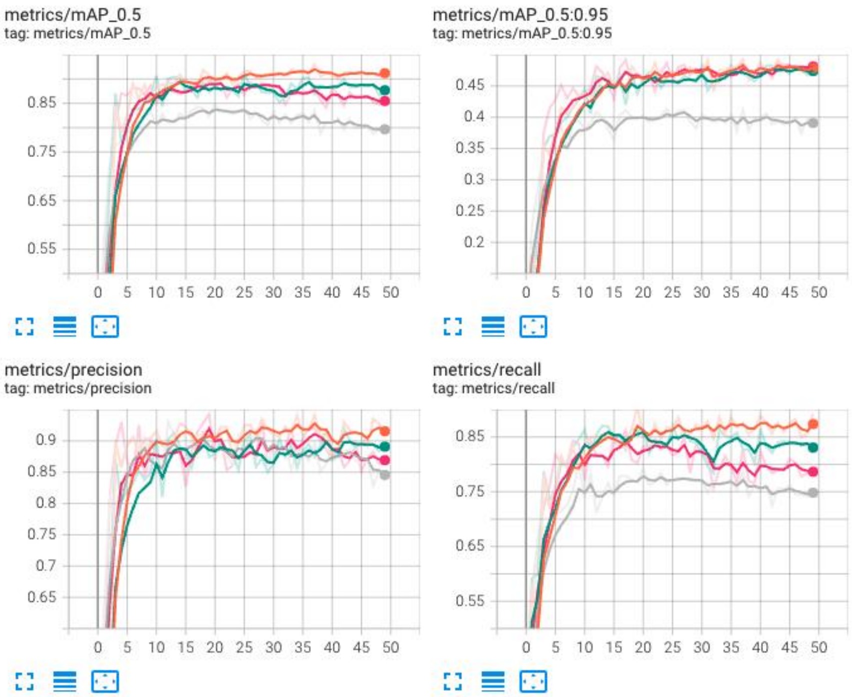
- Poisson Fusion[5]
- Making the “best” masks

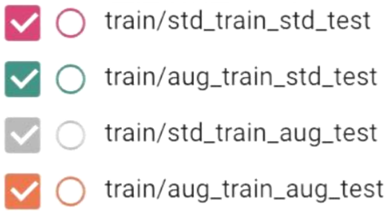




[5] P. P´erez, M. Gangnet, and A. Blake, “Poisson image editing,” in ACM SIGGRAPH 2003 Papers, 2003, pp. 313–318.

Result of MCG Augmentation:





1. An improvement can be observed, which is intuitive (This model is better at identifying more small craters)

2. We can obvious the decline of neally all the score especially recall rate and mAP 0.5

For craters in smaller sizes

Table 1.1 The Comparison between YOLO V5 with default hyperparameters and the CDA given by Benedix et al. YOLO V5 are tested on our divided test set.

Crater size	1.5~10 km		All diam	
Model	V5 default	Benedix et al.	V5 Default	Benedix et al.
Absolute Count Each Set	448	296048	648	669486
True Positive	376	229413	547	564790
Recall Rate	83.929%	77.492%	84.414%	84.362%

Table 1.2 The Comparison between YOLO V5 with and without MCG augmentation, evaluated on standard test set and MCG augmented test set.

Crater size	1.5~10 km		Smaller than 1.5 km			
Model	V5 default	MCG Trained	V5 Default	MCG Trained	V5 Default and MCG test	MCG Trained and MCG test
Absolute Count Each Set	448	448	148	148	268	268
True Positive	376	404	108	116	191	226
Recall Rate	83.929%	90.179%	72.973%	78.378%	71.271%	84.323%

Table 2. The Comparison betwen YOLO V5 wih default hyperparameters and the CDA given by benedix et al. in different scales of sizes

Pros and Cons of MCG:

Pros:
- Novelty
- Generalizability
- Flexibility

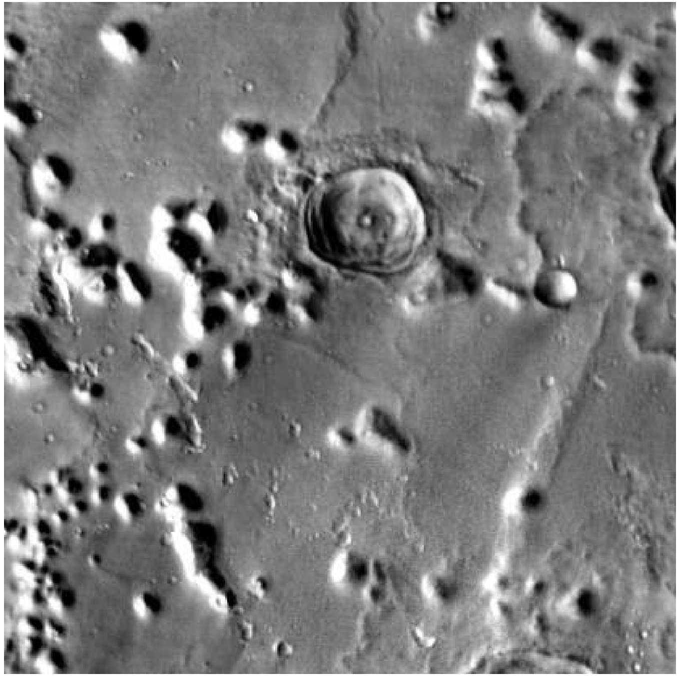
Cons:
- The unlabelled craters are still existing

source: @TEMPLATES_FOR_MEMES
Produced by Sihang

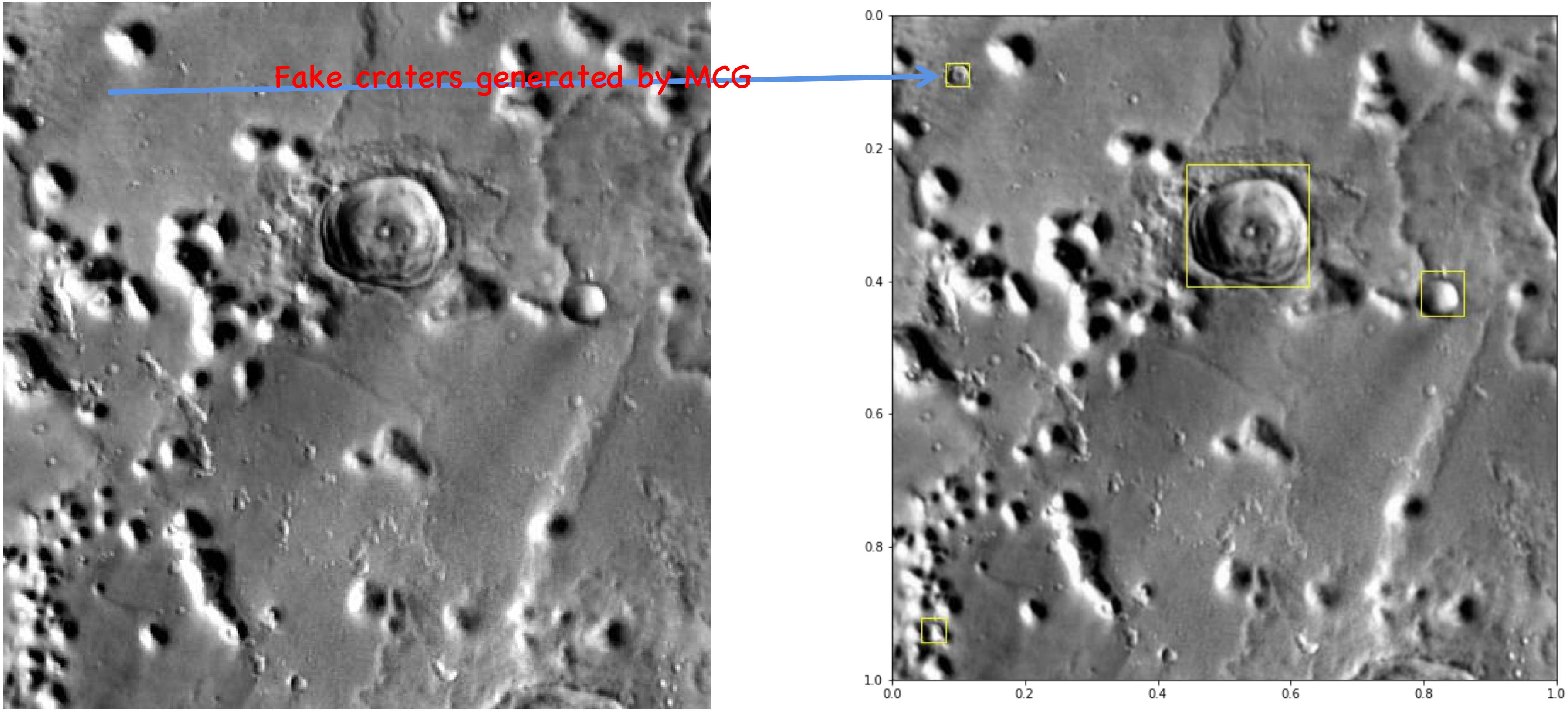
New idea: Training - Iteration Strategy (TIS) based on MCG

Avoid check the unlabelled craters manually

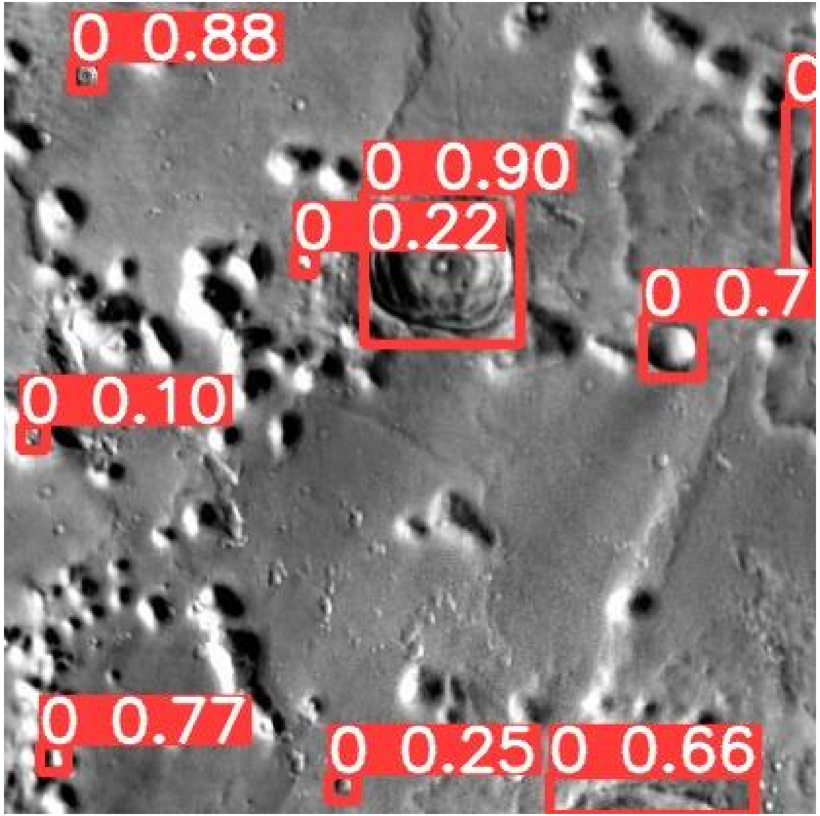
Eliminate the adverse effects of FFP cases

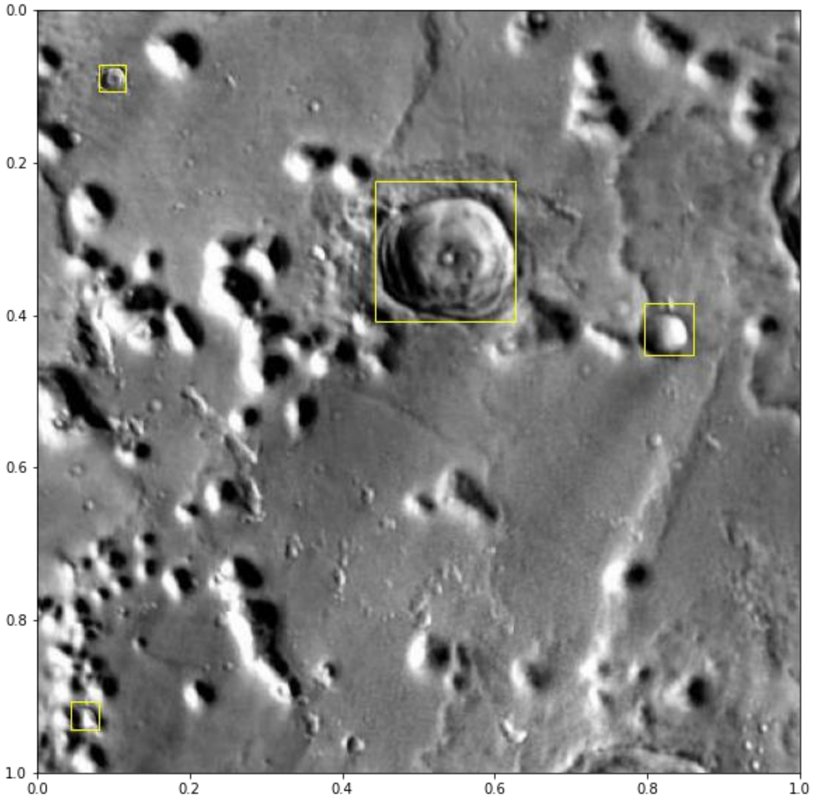


Source: Examples of the THEMIS[1] images which are annotated and processed by Sihang

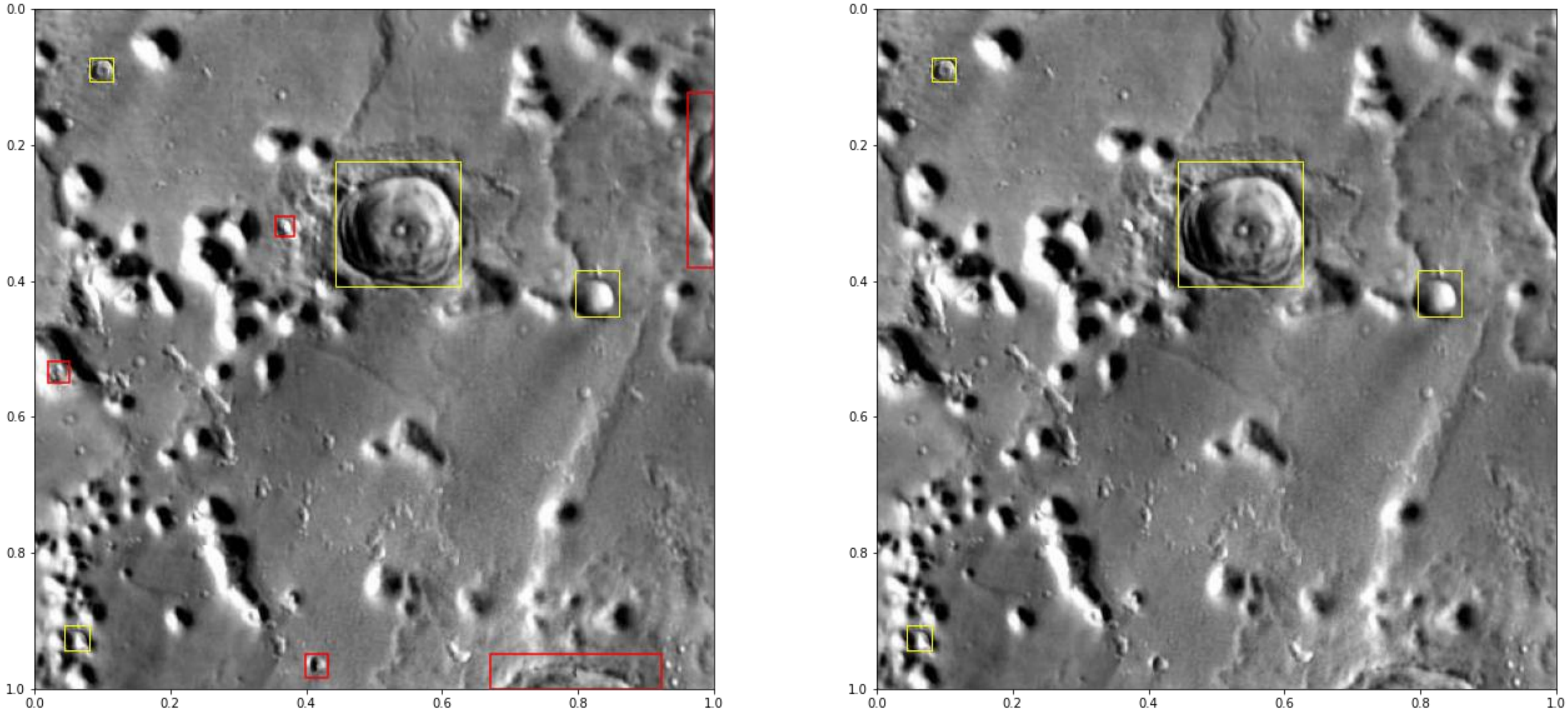

Fake craters generated by MCG
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0

GC67:Automated Crater Detection and Classification with Machine Learning

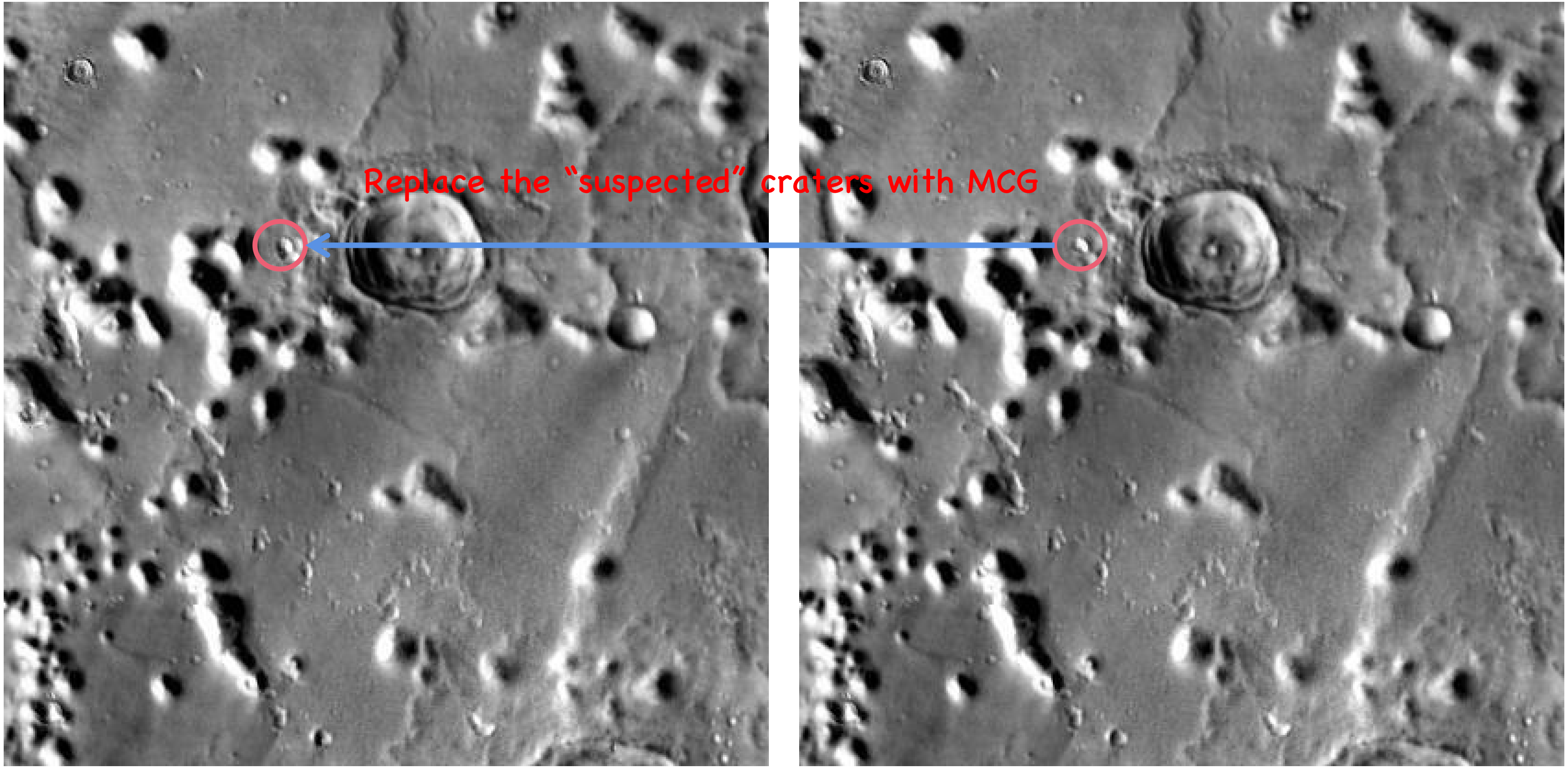




GC67:Automated Crater Detection and Classification with Machine Learning



GC67:Automated Crater Detection and Classification with Machine Learning



Result of Training - Iteration Strategy (TIS):

Table 2 The Comparison between YOLO V5 with default hyperparameters, YOLO V5 trained by our MCG training-iteration strategy, and the CDA given by Benedix et al.

Crater size	Smaller than 1.5 km			1.5 ~10km			All diam	
Model	Default	MCG-T-I	Benedix	Default	MCG-T-I	Benedix	Default	MCG-T-I
Absolute Count Each Set	148	148	296048	448	448	148	648	648
True Positive	108	116	229413	376	412	116	547	558
Recall Rate	72.973%	78.378%	77.492%	83.929%	91.964%	78.378%	84.414%	86.111%
mAP_0.5				74.606%	76.668%		88.738%	89.657%
Precision			73.322%	71.282%	75.054%	90.1132%	86.926%	92.983%

Table 2. The Comparison betwen YOLO V5 wih default hyperparameters, YOLO V5 trained by TIS and the CDA given by benedix et al.

Disscussions of Training-Iteration Strategy (Compared With Active Learning) and MCG:

Pros:

- No Manually Check anymore
- The result is good

Cons:

- The Model cannot learn new features
- Risk of overfitting

*Some further ideas:

- Using ensemble to bring in new features
- Using active learning and TIS together
- While using MCG in TIS, do some changes
- Crater with different sizes may have different features

source: @TEMPLATES_FOR_MEMES
Produced by Sihang

Reference

[1] P. R. Christensen, B. M. Jakosky, H. H. Kieffer, M. C. Malin, H. Y. McSween, K. Nealson, G. L. Mehall, S. H. Silverman, S. Ferry, M. Caplinger et al., “The thermal emission imaging system (themis) for the mars 2001 odyssey mission,” Space Science Reviews, vol. 110, no. 1, pp. 85–130, 2004

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[3] https://github.com/ultralytics/yolov5

[4]https://blog.csdn.net/weixin_41735859/article/details/89288493

[5] P. P´erez, M. Gangnet, and A. Blake, “Poisson image editing,” in ACM SIGGRAPH 2003 Papers, 2003, pp. 313–318.

Thank you

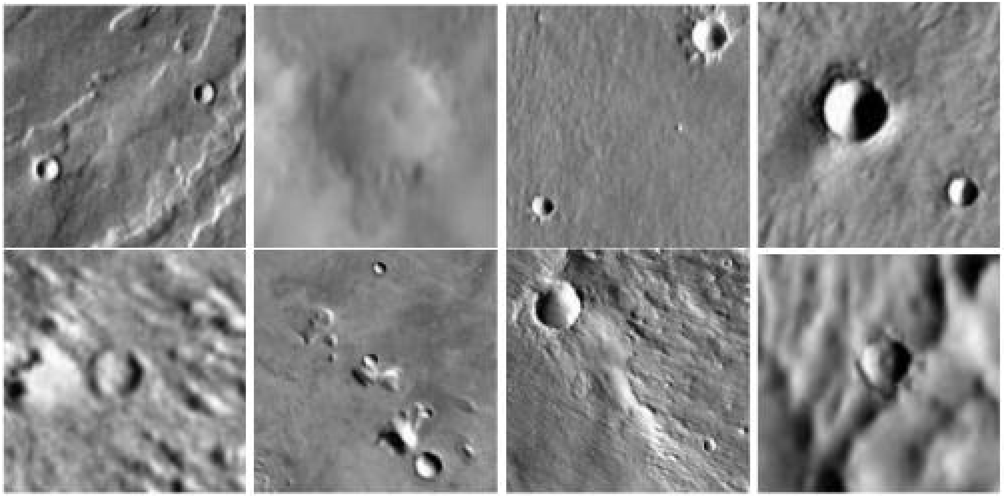

Image: Craters generated by MCG and their “parents”

“The hills melted like wax at the presence of the lord.” ***Psalm 97:5.***

Wouldn't the creation and weathering of craters,
and even the birth and annihilation of planets,
look like butter melting on a hot pan
if we were to observe them
from the perspective of infinite time

All the mysteries of the universe
would then look like short videos on tiktoks
Millions of years will be several mere moments

However, our time is limited,
and even quite short,
which is why we need this project
and why I developed MCG
:)