ML for Astronomy:
Cautionary Tales for the Community

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Astro2020 Decadal Report:

Machine learning has already shown significant success at providing tools for identifying anomalies in data, and can speed up parameter estimation in large data sets by significant factors… These techniques could lead to **transformative discoveries** from the new data sets available in the 2020s.

Astronomy a perfect sandbox for machine learning.

- Minimal privacy concerns.
- Culture of sharing data.
- Well-posed questions.
- Public interest and support.
- Data are non-monetizable.
- *This does not exempt us from ethical concerns!*

Is machine learning the right tool for astronomy?

Science

Community

Science

- Interpreting photons
- Interpreting simulations
- Performing tedious tasks

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- Interpreting simulations
- Performing tedious tasks

Community

- Hiring and awards
- Resource allocation
- Predicting research trends
- Selecting targets for follow-up

Science

- Can ML be used to make new physical discoveries?
- Is it fast and reproducible?
- Can we establish proper standards for understanding failure modes?
- Is it sufficiently transparent?

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Community

- Can ML be applied more fairly than “human” approaches?
- Can it point us toward our own biases?
- Is it sufficiently transparent?

1. Build trustworthy models with Interpretation

Skin Cancer Classifier

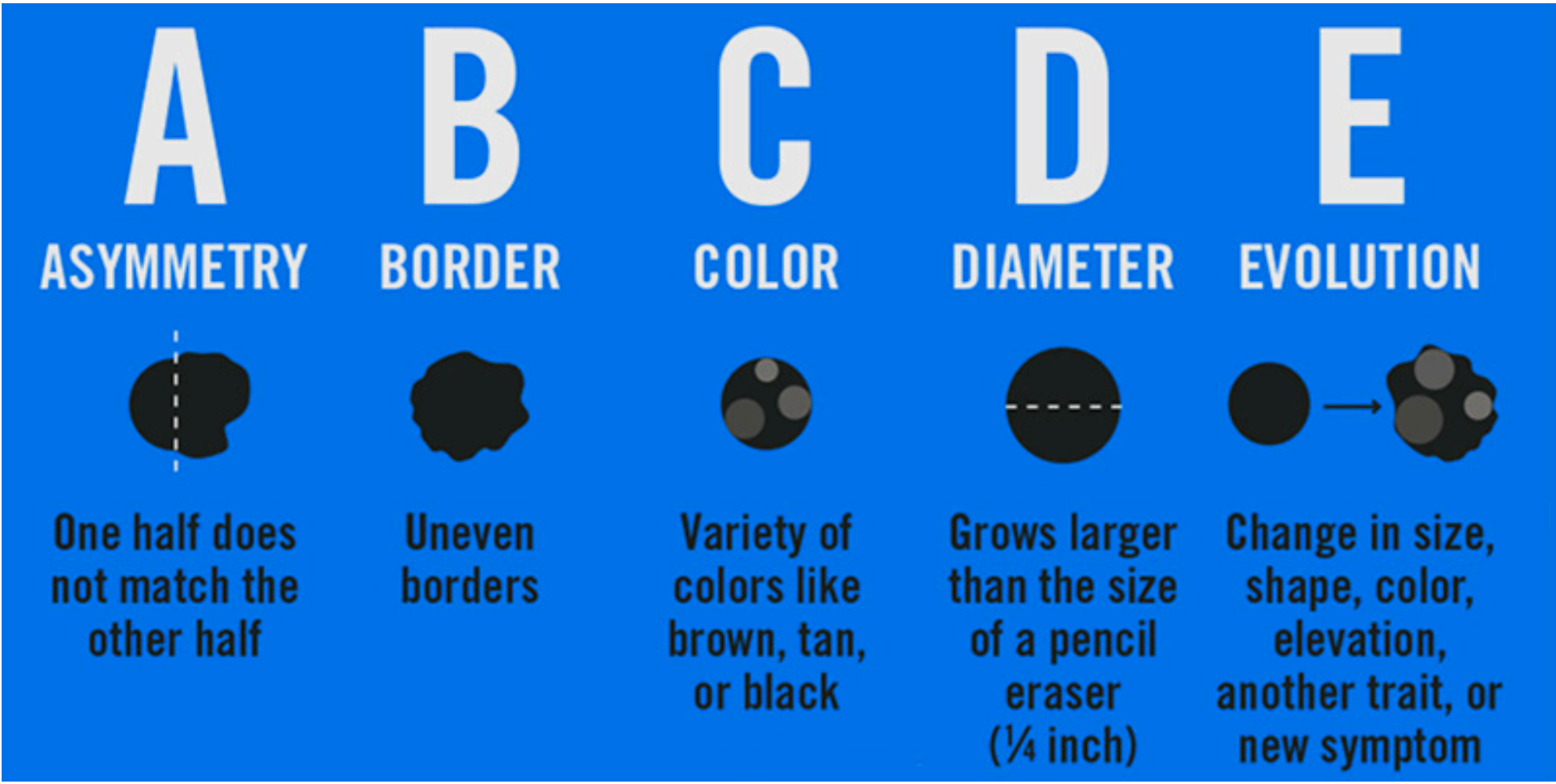
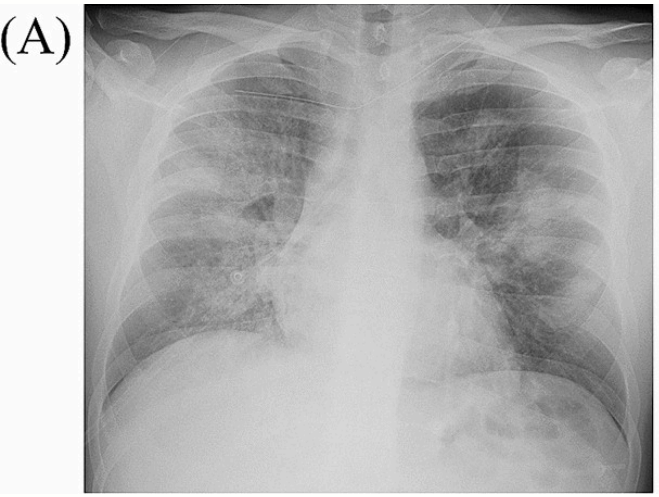
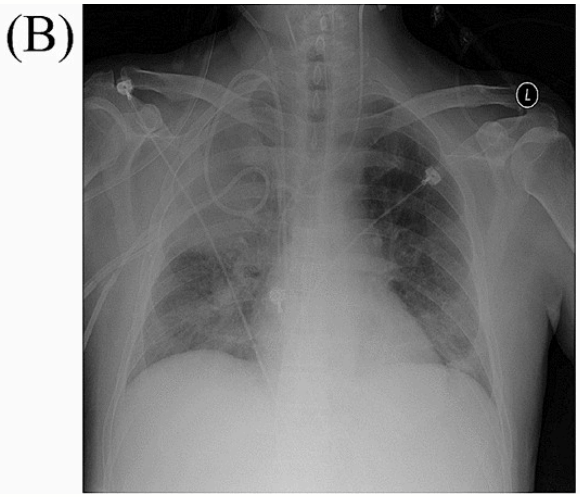


Image credit: Orange County Scars Center

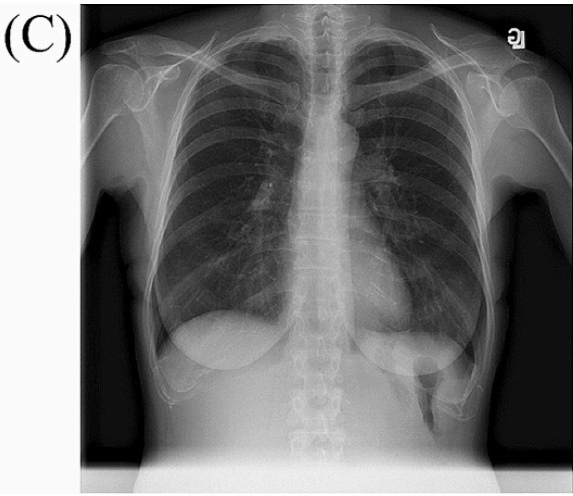
Winkler et al., 2019



Covid



Pneumonia



Healthy

image credit: Nishia et al., 2020

ARTIFICIAL INTELLIGENCE

Hundreds of AI tools have been built to catch covid. None of them helped.

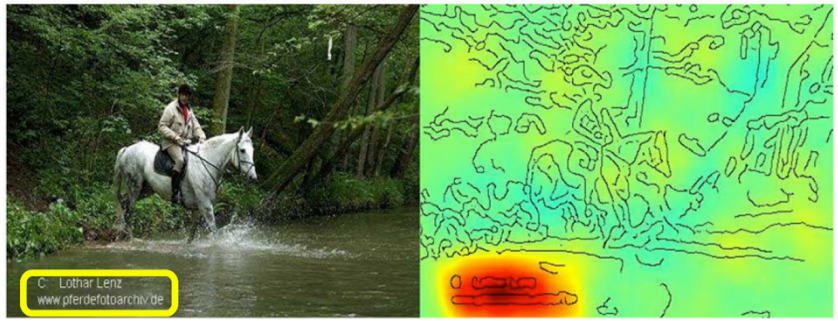
Some have been used in hospitals, despite not being properly tested. But the pandemic could help make medical AI better.

By Will Douglas Heaven

July 30, 2021

Saliency Maps

Horse-picture from Pascal VOC data set



Source tag present

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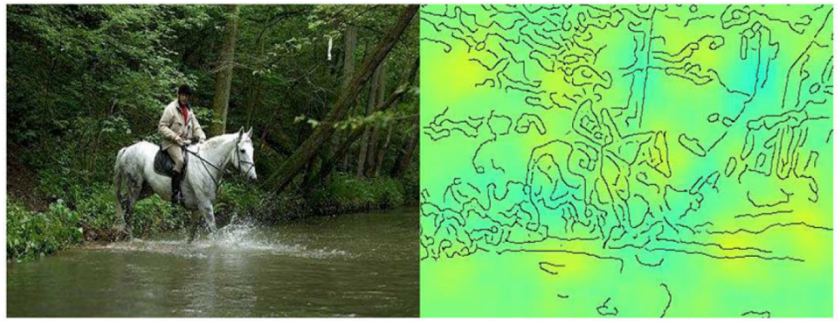
Classified as horse



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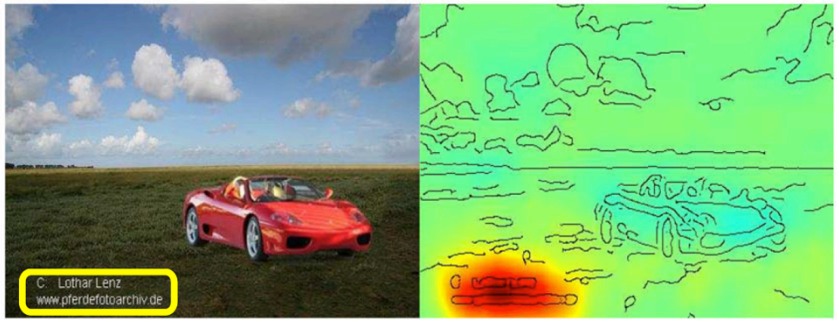
Not classified as horse

Artificial picture of a car



Lapuschkin et al., 2019

2. Build trustworthy models with Concise Language

Did I Overfit or Overspecialize?

Overfit: the model has learned the noise of the training data.

★ Overfitting gives larger errors on the test set!

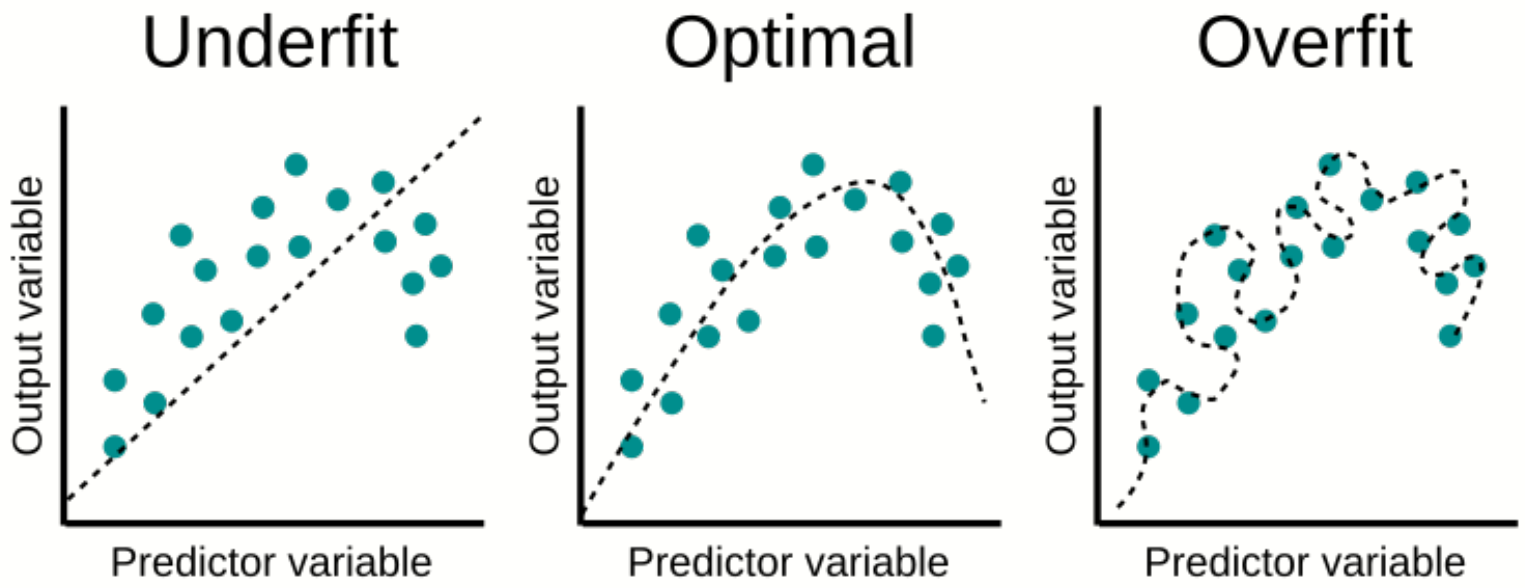


image credit: educative.io

Did I Overfit or Overspecialize?

Overfit: the model has learned the noise of the training data.

★ Overfitting gives larger errors on the test set!

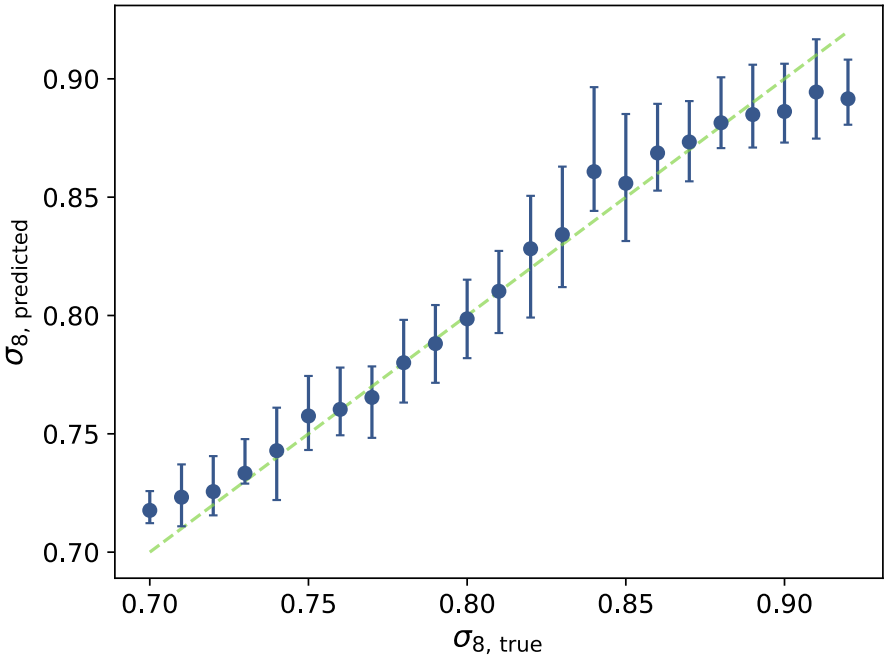
Overspecialized: the model has learned subtleties of the simulation that are not true of reality.

★ Overspecialization gives smaller errors on the test set!

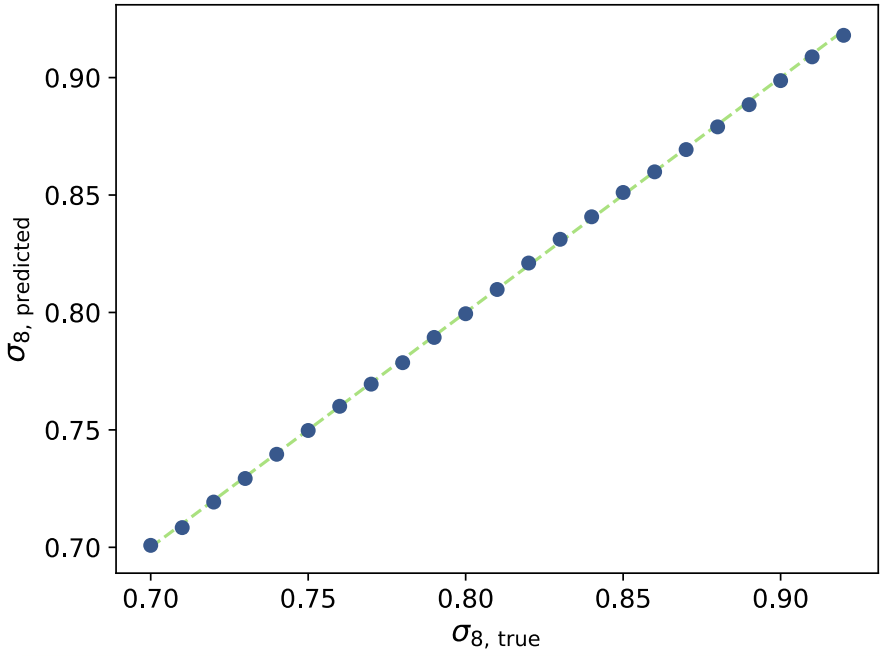
3. Build trustworthy models by Scrutinizing

These results look *suspicious*! Did the ML cheat?

Trustworthy Results:



Suspicious Results:



Here, we find a factor-of-10 better results. But is it trustworthy? Will it generalize to real data?

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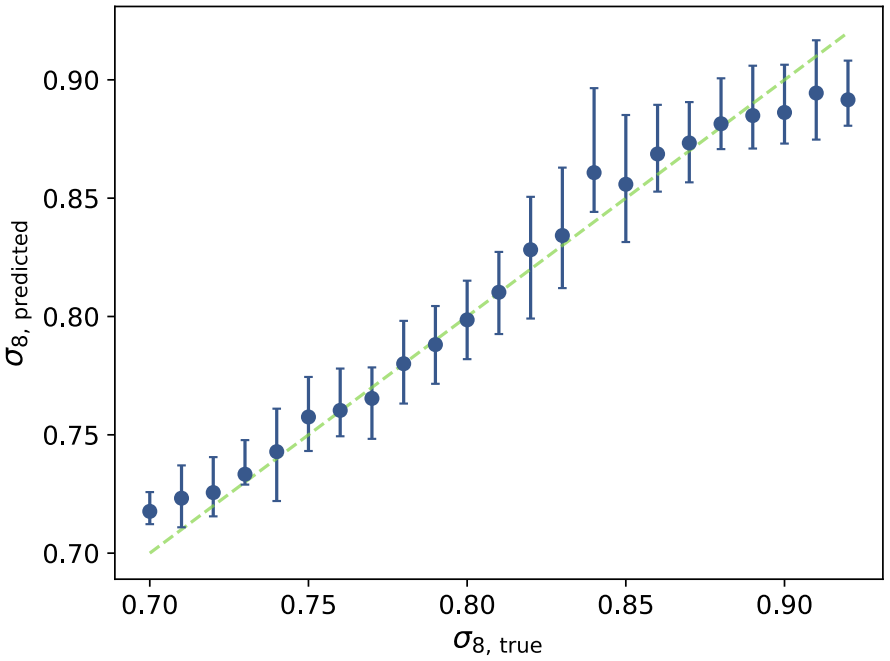
Trustworthy Results:



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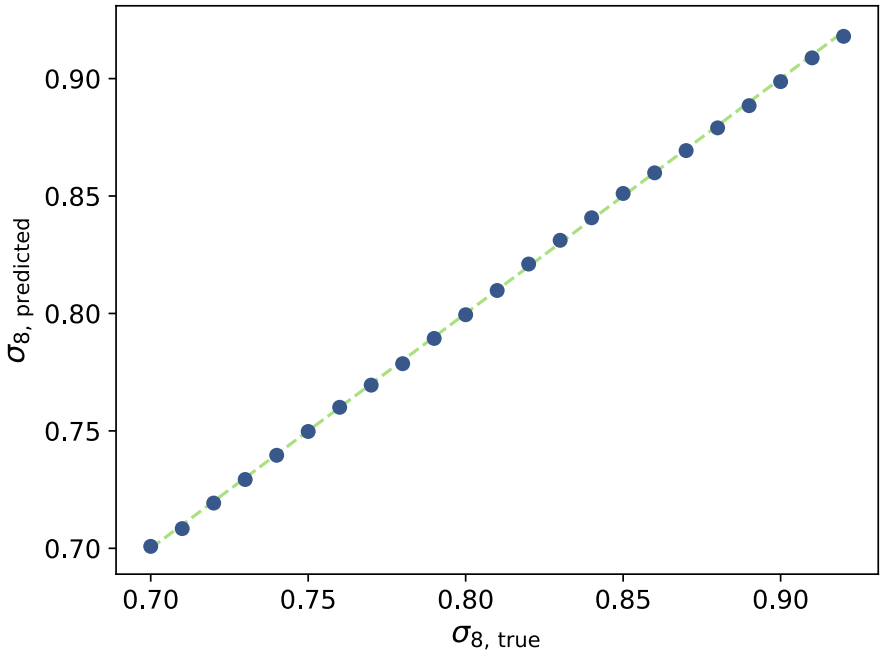
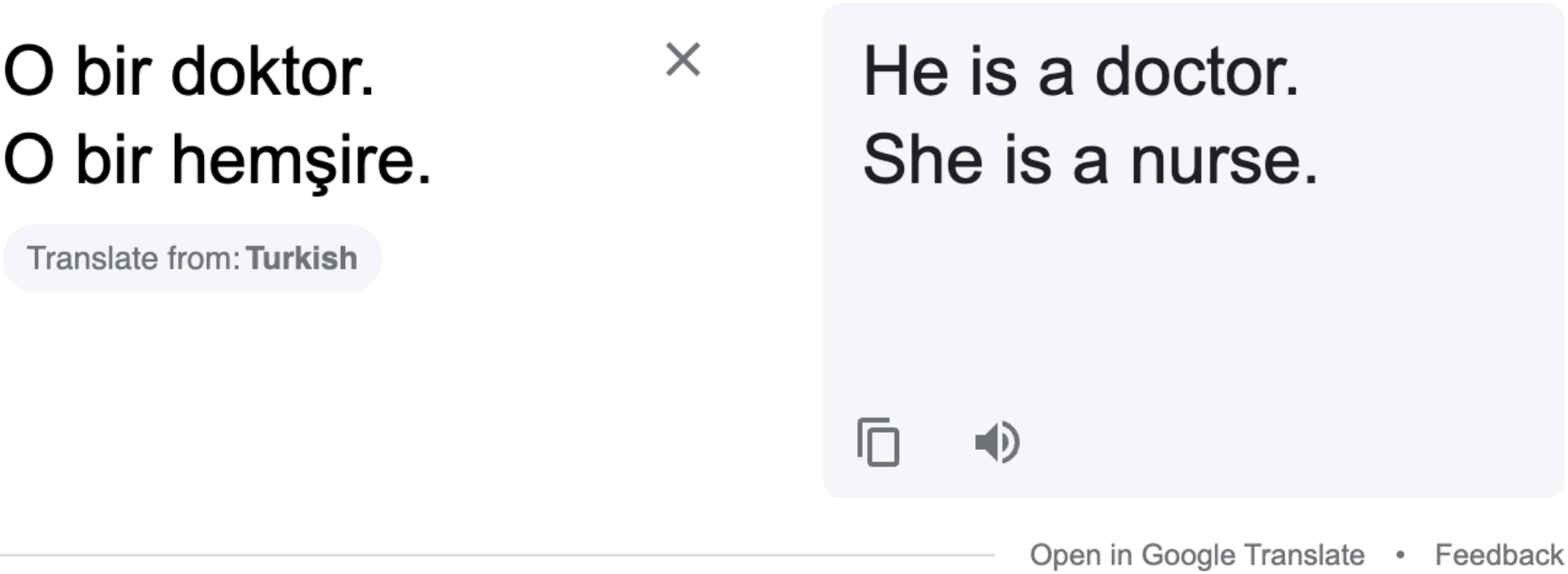


The verdict? For the "Suspicious Results," ML cheated.
The "Suspicious Results" are not robust. The model will not generalize to real observations because it depends on a simulation artifact.

4. Build trustworthy models by Being Aware of Bias

Bias in Language Translation



Caliskan+ 2017

Bias in Images

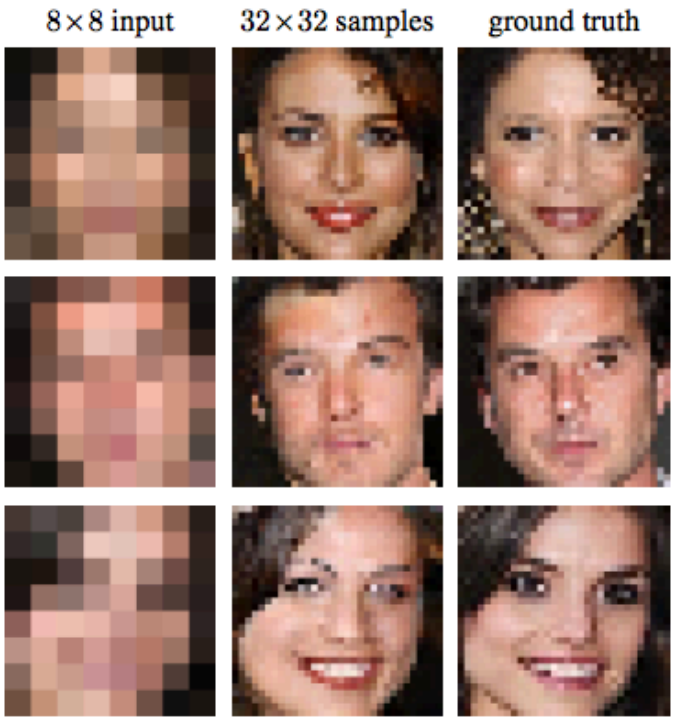
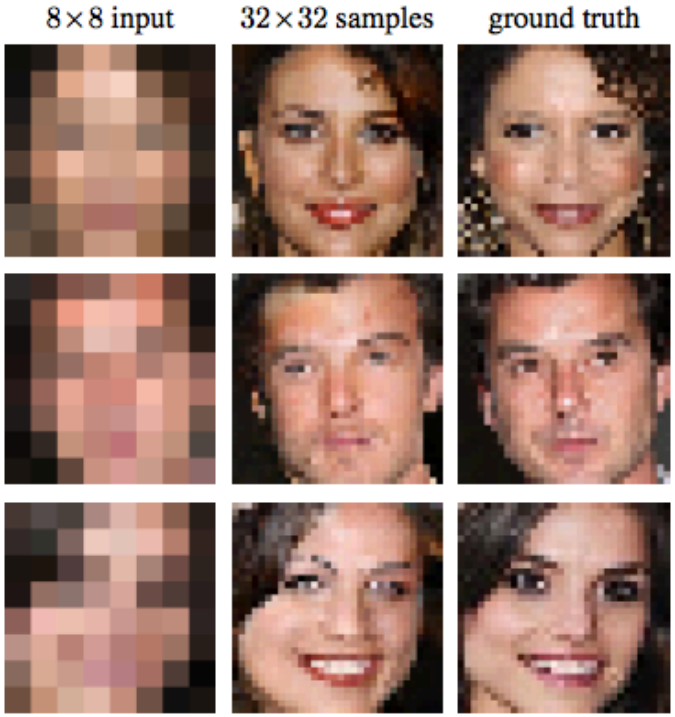


Figure 1: Illustration of our probabilistic pixel recursive super resolution model trained end-to-end on a dataset of celebrity faces. The left column shows 8×8 low resolution inputs from the test set. The middle and last columns show 32×32 images as predicted by our model *vs.* the ground truth. Our model incorporates strong face priors to synthesize realistic hair and skin details.

Dahl+ 2017

Bias in Images



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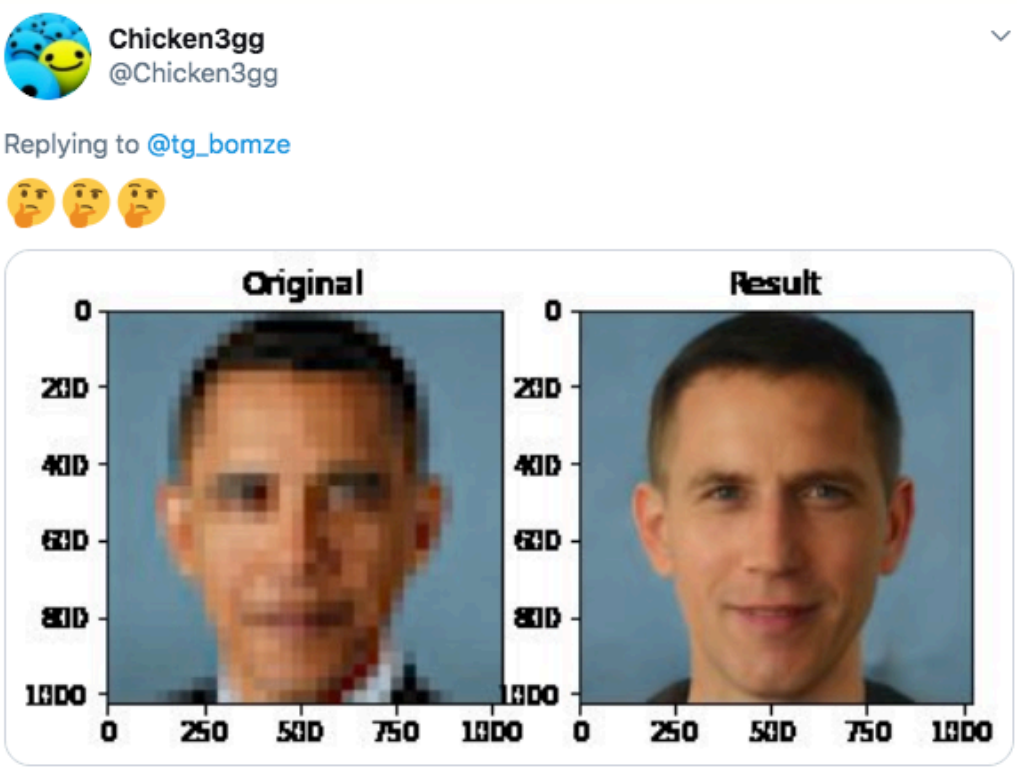

Dahl+ 2017

Automating Human Bias

Automating Human Bias

RETAIL OCTOBER 10, 2018 / 7:04 PM / UPDATED 4 YEARS AGO

Amazon scraps secret AI recruiting tool that showed bias against women

By Jeffrey Dastin

8 MIN READ

SAN FRANCISCO (Reuters) - Amazon.com Inc's AMZN.O machine-learning specialists uncovered a big problem: their new recruiting engine did not like women.

5. Build trustworthy models by

Considering Transparency & Fairness

Perceived Fairness

Newman et al. (2020): we perceive ML algorithms' evaluations of the quality of our work to be less fair.

Image Credit: piegov

6. Build trustworthy models by Using The Most Appropriate Tool

Holistic Rubrics

Arter & McTighe (2001): if distributed in advance, rubrics can improve the quality of submitted work.

Image Credit: cochrane.org

Random Choice

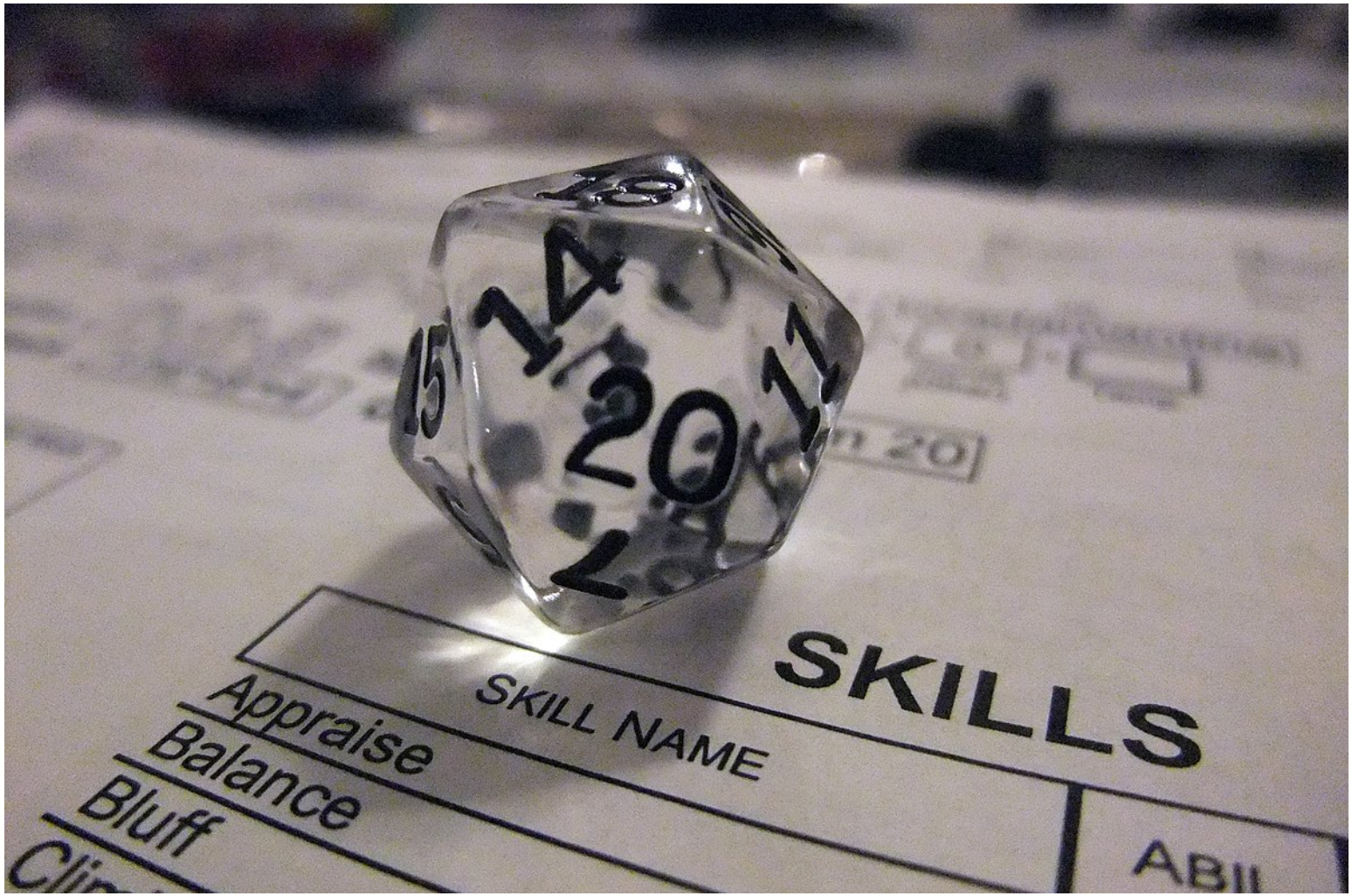

Image credit: Flickr2Commons

Astro2020 Decadal Report:

Data science, including applications of machine learning, will play an increasing role in astronomical research over the coming decade. **Incorporating training** in this area at the graduate level and beyond will better prepare researchers regardless of whether they pursue careers in astrophysics or in other STEM fields.

Is ML the right tool for astronomy?
Can ML be trusted?

Machine Learning *can be* the right tool for astronomy:

1. Interpretation
2. Concise Language
3. Scrutiny
4. Awareness of Sources of Bias
5. Transparency & Fairness
6. Appropriate Tool Choice

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Resources:

- **Article Summary**: https://www.stsci.edu/contents/newsletters/2022-volume-39-issue-01/machine-learning-in-astronomy-cautionary-tales-for-the-community
- **Holistic Rubrics**: https://gsi.berkeley.edu/gsi-guide-contents/grading-intro/grading-rubrics/rubrics-examples/

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