Convolutional Neural Nets & Image Exploration in Astronomy

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with

Craig K. Jones, Jonathan Hargis, Rick White
hypothesis generation in the big data era is an unsolved problem
Astronomers know how to look at the sky in 3 ways:

- Black-Sky Segmentation
- Bespoke Algorithms
- Power Spectra
Astronomers know how to look at the sky in 3 ways:

- **Power Spectra**: is this a bunch of points?
- **Black-Sky Segmentation**: any image
- **Bespoke Algorithms**: is this a filament?
- **Random Field**: is this a Gaussian Random Field?
A tool to deal with complex raw pixel data is a critical missing piece.* beyond zooniverse
Neural Networks are actually pretty simple

Mass $X_1$

Color $X_2$
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Deep Neural Networks use Many Hidden Layers; hard for many inputs

\# Weights \propto \# neuron^2 \times \# layers
Convolutional Neural Networks are designed for images
CNNs are exploding in their usage in the astronomical literature.

Astronomy Convolutional Neural Net Papers by Year

Papers by Type

- strong
- solar
- time domain
- diffuse
- particle
- culture
- galaxy
- artifacts
- star/galaxy
- image
- probes
- photoz
- resolved
- spectra
Galaxy Morphology was the “starting gun” for astro CNNs

Dieleman+2015
CNNs can extract shape information from Weak Lensing maps.

Schmelzle+2017
CNNs are extraordinary for classifying artifacts

Zevin+2016, George+2017
CNNs are extraordinary for classifying artifacts
Transfer learning: many parts of networks are highly portable

Imagenet: $> 10^6$ images, $> 1000$ categories

George+2017
Transfer learning allows for unsupervised learning and discovery.

"None of the above"
"Extremely Loud"
"Blip"

unsupervised artifact clustering

George+2017
Transfer learning for image discovery in MAST?

velvet: 10%
binder: 8.2%
jean: 6.4%
stingray: 4.5%
hammerhead: 3.8%
book jacket: 3.1%
handkerchief: 2.1%
prayer rug: 1.5%
tiger shark: 1.4%
...

Image Cutouts Existing Network Feature Vector Clustered data

Peek, Jones, Hargis, White +2017
Transfer learning can be used to find similar structures in images.
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Transfer learning can be used to find similar structures in images.
Live demo of totally untested software!
What could go wrong!?
• Can transfer learning from terrestrial images inform us about astronomical image similarity?

• Will astronomers ever be willing to look at a plot with unlabeled axes?

• Do science centers and archives have a role to play in the machine learning landscape?

• What is the killer use case for this technology? Is there one?

• How will we know such a system works? Won’t work?
If you are interested in neural nets and astronomy join us at deepskieslab.com

PEOPLE

Camille Avestruz (co-convener)
KICP/Fermi Fellow at University of Chicago
Interests: Strong lensing, classification, regression
Affiliated research group/team: DeepSkies@Chicagoland

Brian Nord (co-convener)
Associate Scientist, Fermilab Machine Intelligence Group; Senior Member, Kavli Institute for Cosmological Physics at University of Chicago
Interests: Strong lensing, cosmological parameter estimation, autoencoders
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Joshua Peek (co-convener)
Associate Astronomer & Project Scientist Data Science Mission Office, Space Telescope Science Institute
Interests: Interstellar Medium, Dust Reddening, ConvNets
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• hypothesis generation in the big data era is an unsolved problem

• we need new ways to explore images

• convolutional neural nets are being used, with some success, across astronomy

• transfer learning methods provide a way to search for similar images in big data sets

• We are building a prototype of such a system at MAST

• join us at deepskieslab.com