Improvements to basic CNN architecture

(2015) Highlight one: ResNet "skip connections" enables much deeper NNs w/ more vanishing/exploding gradients
e.g. 500 layers! 150 (otherwise, 100 layers!)

\[ F(x) \]
\[ NNI \]
\[ F(x) + x \]
\[ NNI \]
Learn residual mapping

Different blocks can learn different features without needing to match dimensions
Can skip blocks

Can also add weight in front of \( x \) "gate" might need zero padding around clipping to match \( |dF(x)| \)

Seems almost trivial but it dramatically improves performance!

* Also: DenseNet — concat instead of add!

* Also: UNet used to map images to other images
  - denoising
  - segmentation
  - object detection
  - decoder/encoder
Top tagging challenge - ResNet improved on simple CNN by 20-30% in bg rejection @ 0 for 20%

Example 2: Galaxy Zoo Kaggle Competition
(from 2014 - predates ResNet!)

Based on Galaxy Zoo 2 dataset - 304k galaxies from 5055
1308.3496
60M classifications
80,000 volunteers
Decomposed
questionnaire w/ 11 Q's -> 37 possible responses
(unique paths through the tree)
Same Galaxy classified by multiple people.
regression now classification
get prob dists of each response, questionnaire
Goal is to mimic citizen scientists
AI scientist!
Metric was matching these probabilities vs simple MSE
\[ L = \sum_{i=1}^{n} (p_{i} - p_{i})^2 \]
More NN architectures beyond CNNs

Another popular framework also permutation invariant:
graph neural networks "message passing NN"

View data as a graph — more flexible than images!

E.g.: jet constituents better characterize images

Graphs have nodes and edges

Attributes (p_i, p_x, p_y) e.g.

Different types of graphs: fully connected

- Sets (no connections)
- Hierarchical trees
- Locally connected
  - Each node connected to nearest neighbors by some local metric

Message passing framework

A node

\[ \text{node}(p(e_i, e_j, \ldots), a) = a' \]

A edge

\[ \text{edge}(e, a, b) = e' \]

\[ \text{edge node} \rightarrow \text{MLPs usually} \]

Symmetric for eg sum, mean

Weight shown like conv filters!