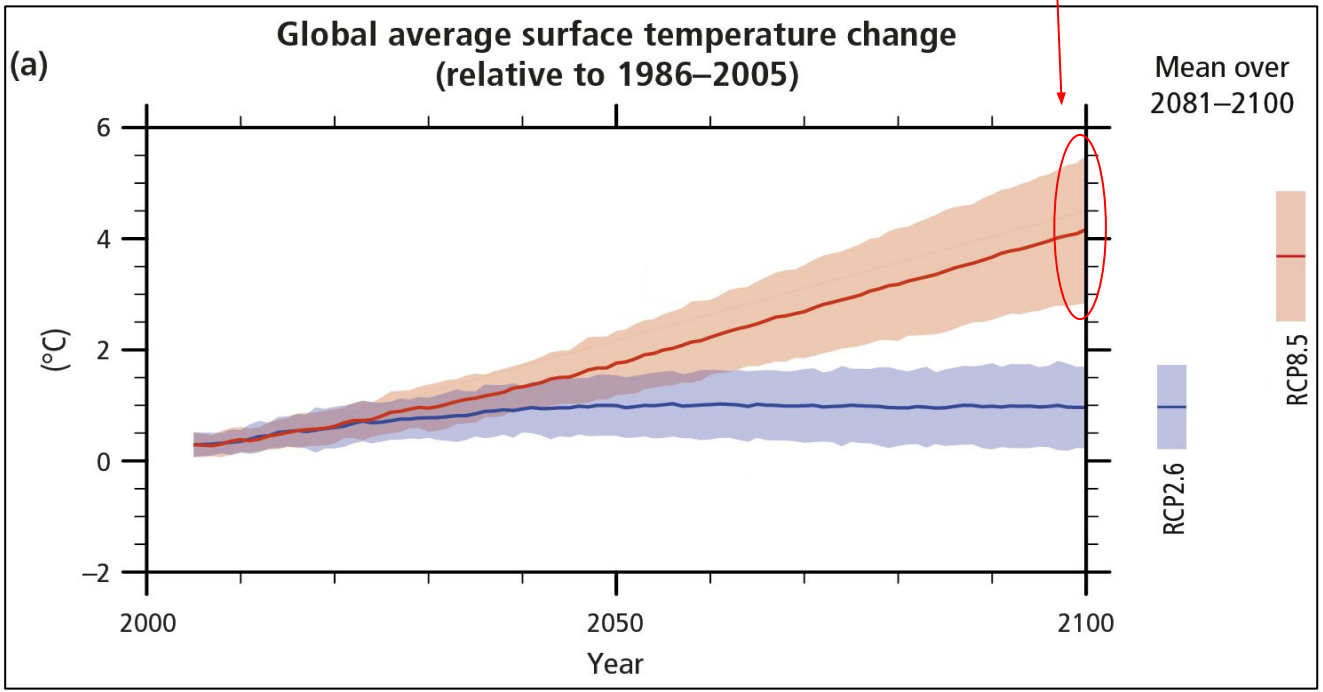
Identifying Clouds Using Neural Networks

Sean Richardson and Jeff Mullins

Image: René Magritte - La reconnaissance infinie (1963)

Motivation: Clouds Contribute the Greatest Uncertainty to Climate Model Projections

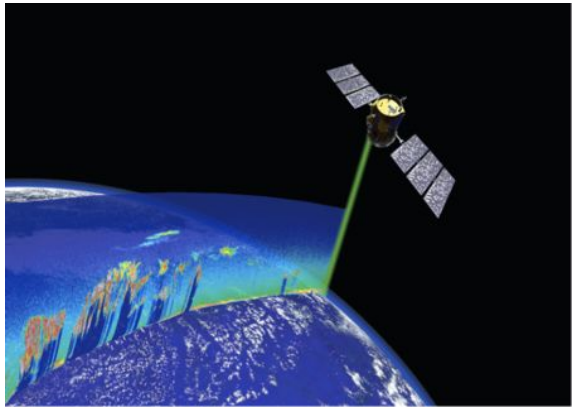


Source: IPCC 2014,
Summary for Policymakers

We need cloud observations to validate and improve climate models.

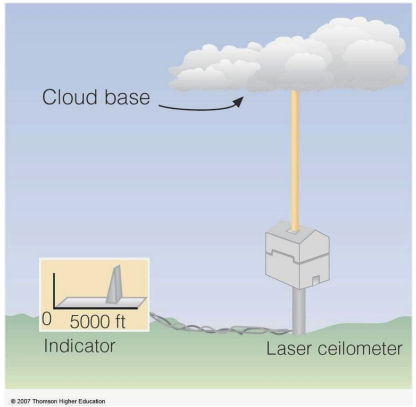
How do we observe clouds?

Satellites (laser, IR & vis.)



Source: NASA CALIPSO satellite

Ground-based laser & radar



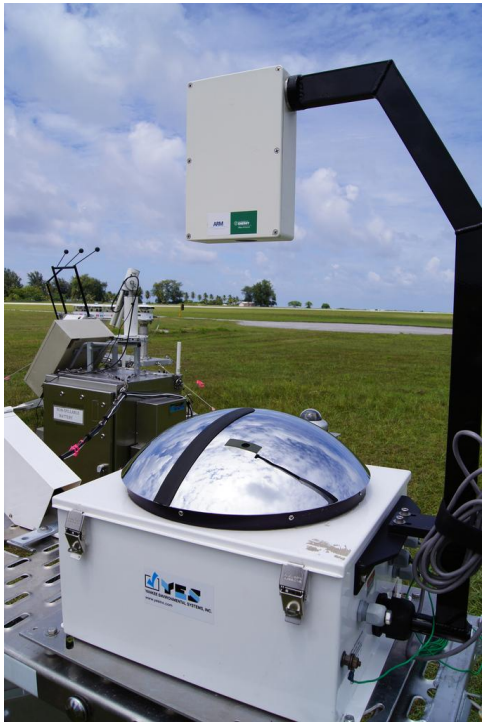
Source: © 2007 Thomson Higher Ed

Ground-based images

- Consistent with historical records
- Need image processing techniques

Source: International cloud atlas (WMO)

Total Sky Imager (TSI)

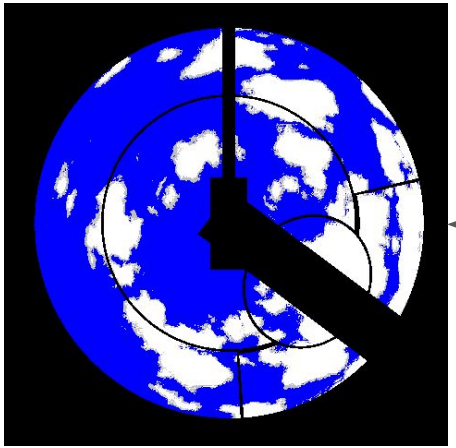


Tasks

Segmentation

Classification

Input:

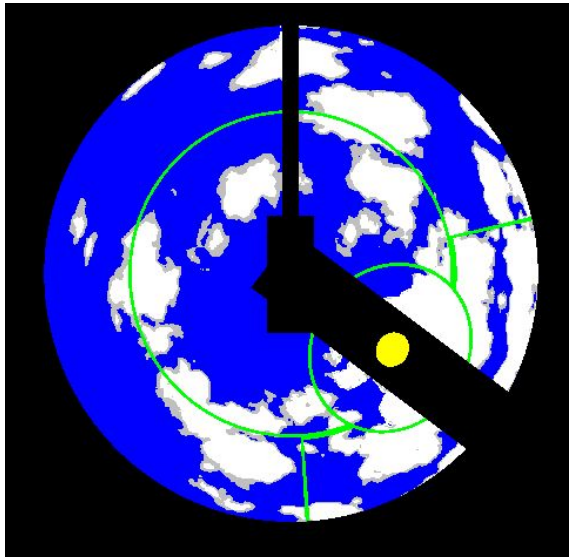


“Cumulus”

Improving Segmentation

TSI Sky Image

TSI Mask



Current process compares pixel values to a threshold

- Requires tedious hand-tuning
- Prone to errors

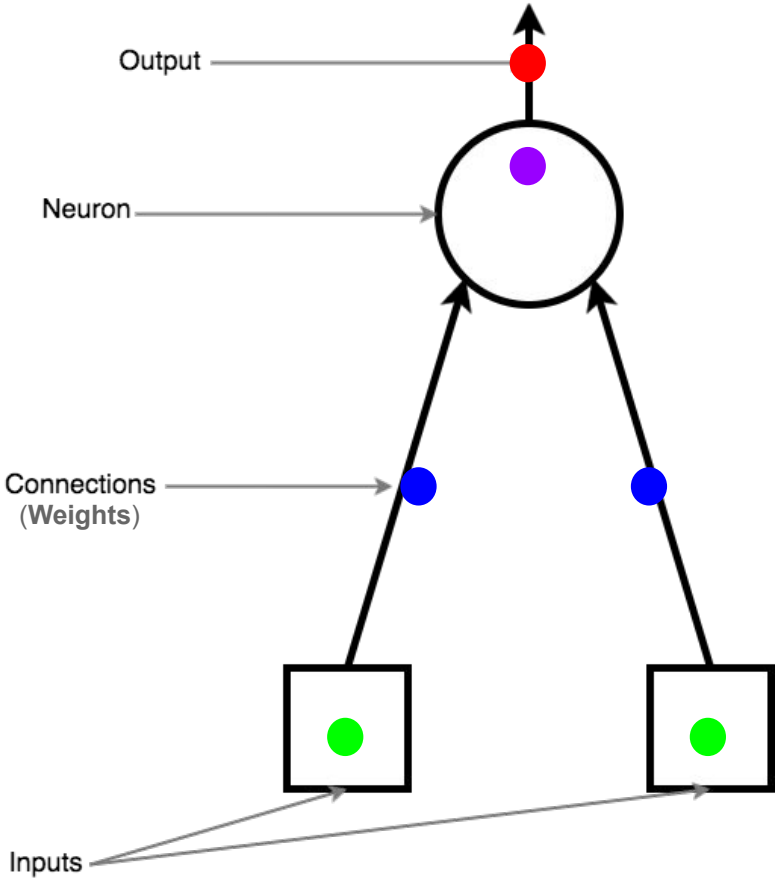
New approach: neural network

Neural Networks

Made of linked “neurons” that work together to compute a complicated function

Can learn a function from failing examples and changing to get better

Artificial Neuron



Biological Neuron

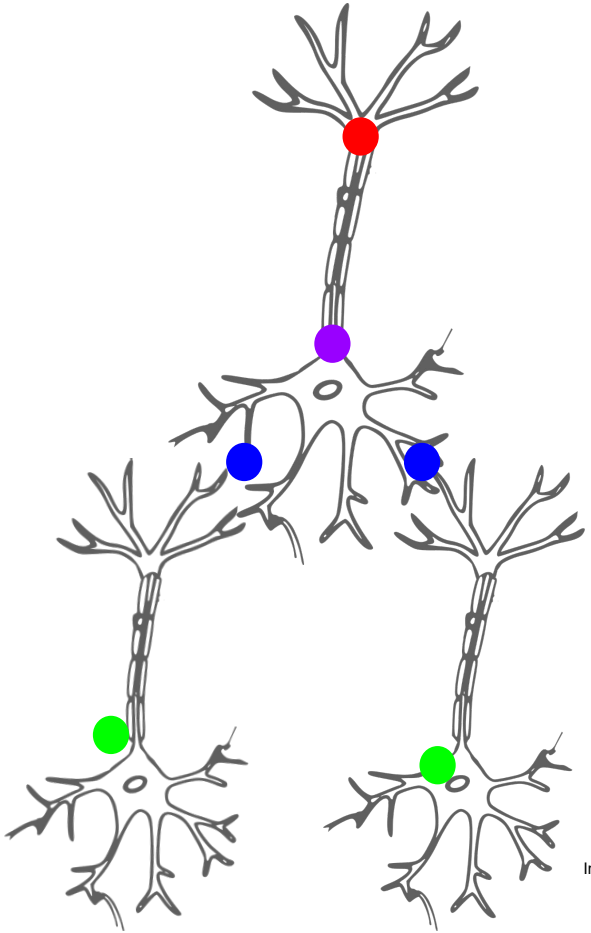


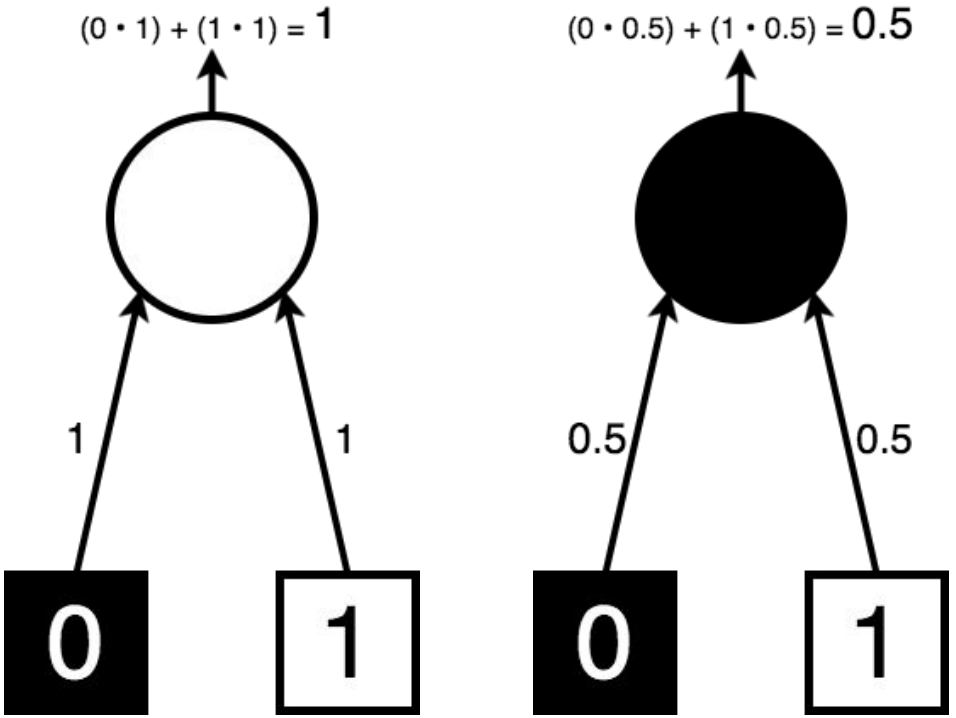
Image: pixabay.com

What activates a neuron

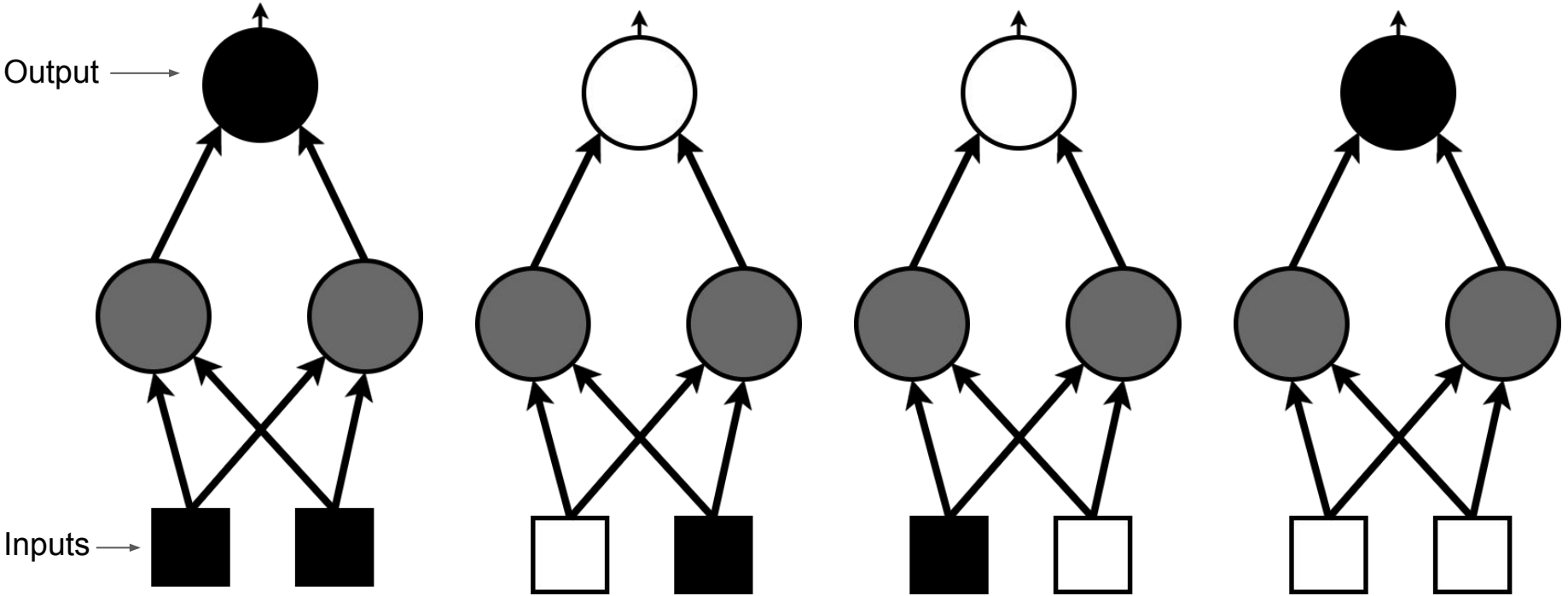
Find weighted sum of inputs

On (white) if sum ≥ 1

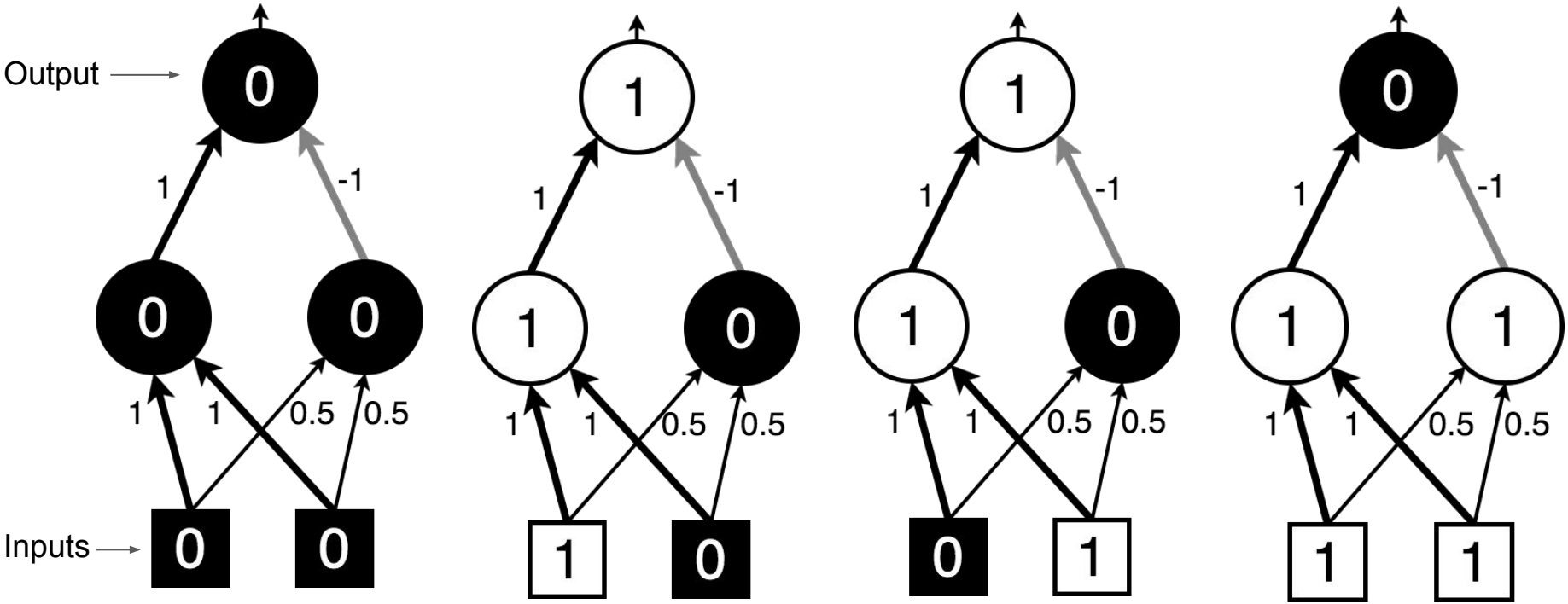
Off (black) otherwise



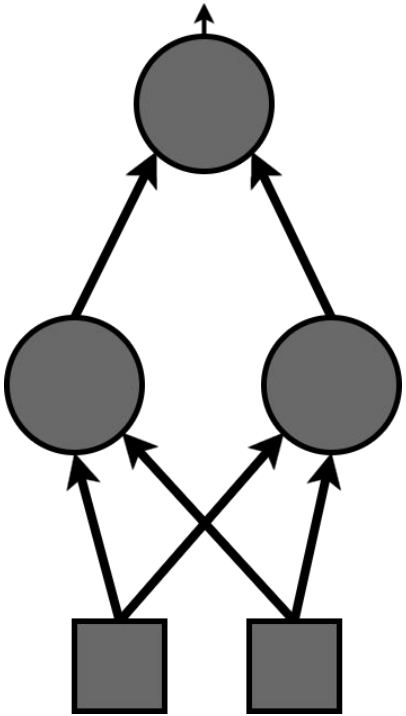
The exclusive OR (XOR) function: are the inputs different?



Computing the exclusive OR function



The Learning Process



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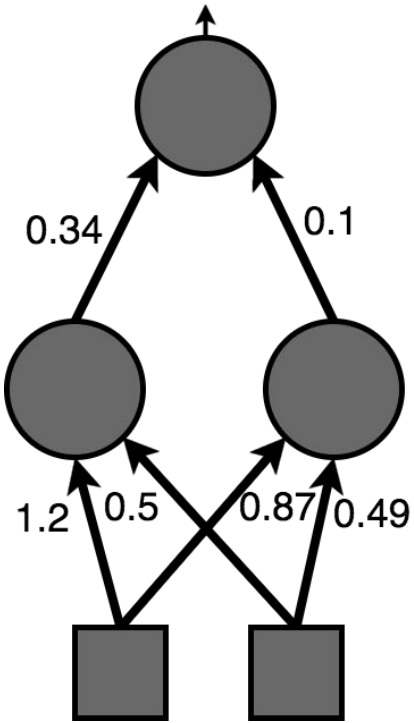
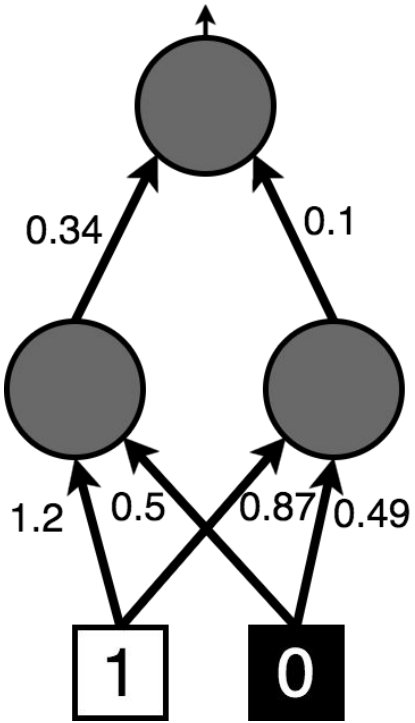
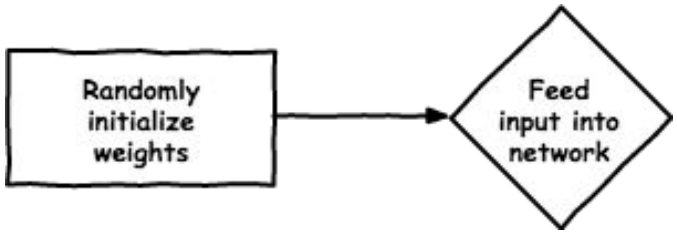


Randomly initialize weights

The Learning Process





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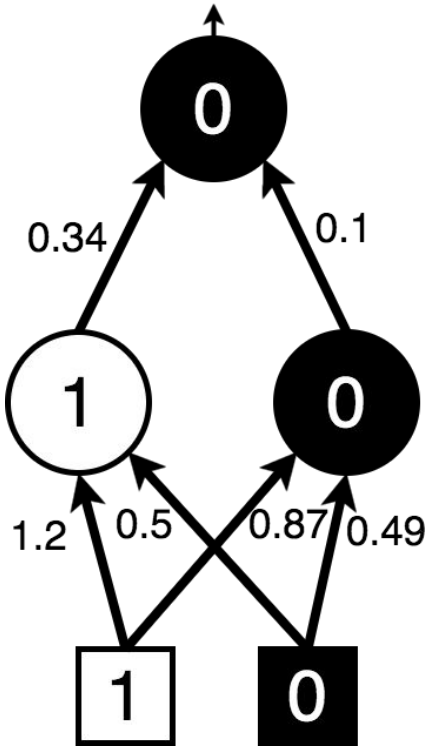
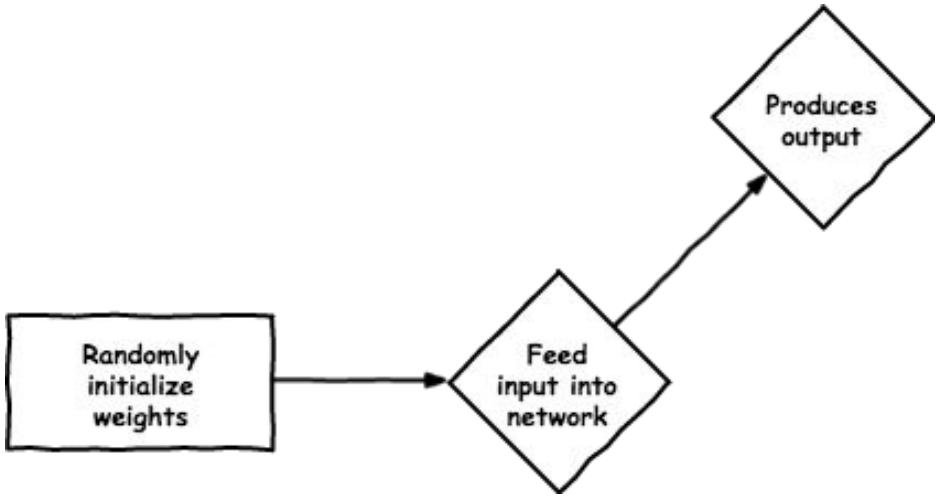
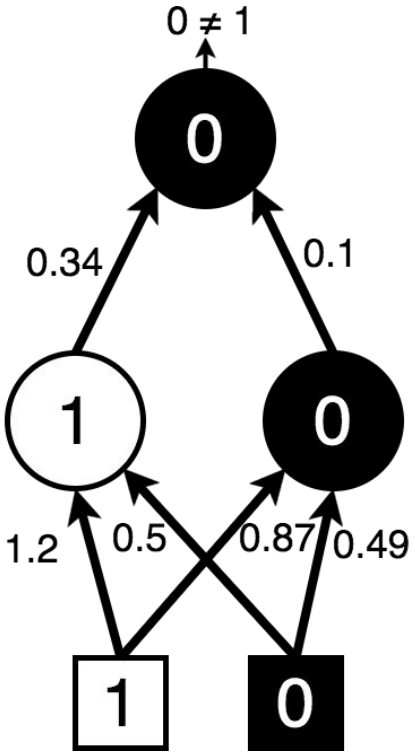
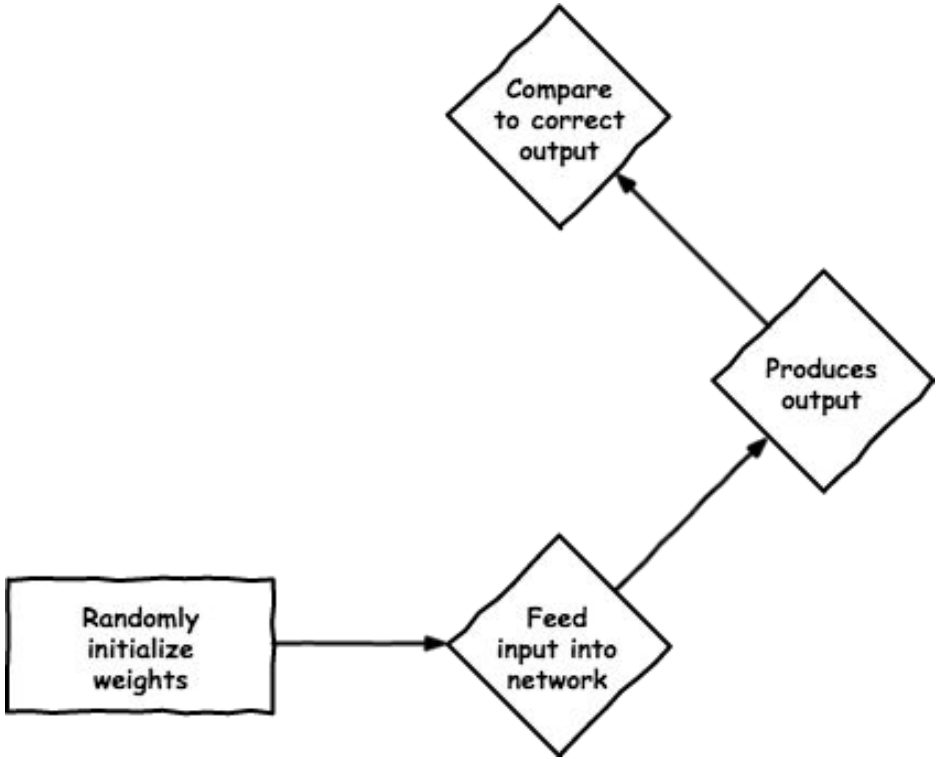


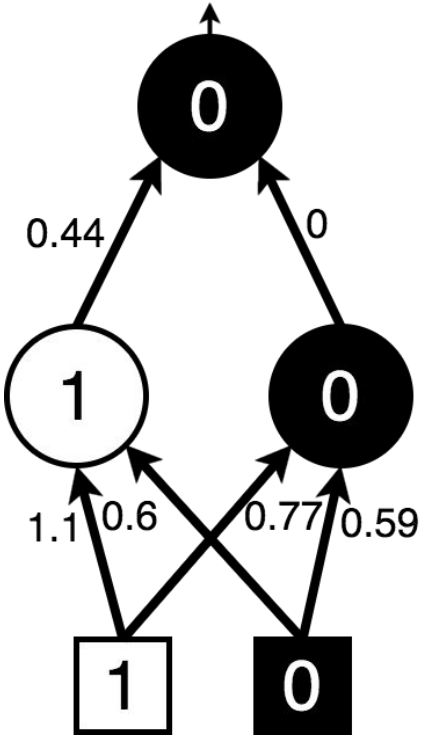


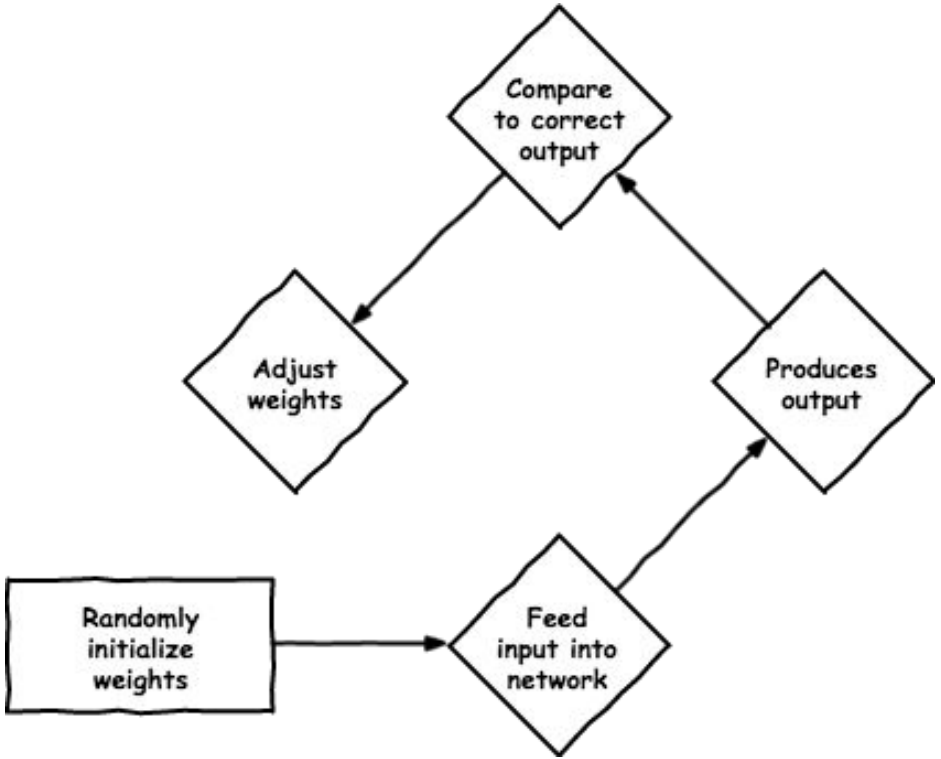
The Learning Process



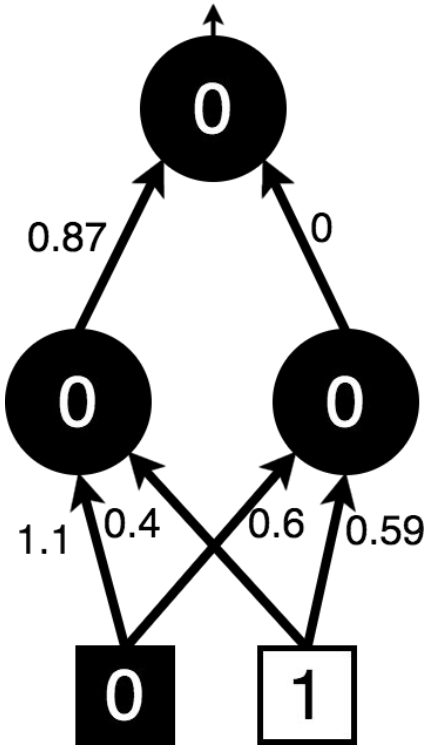


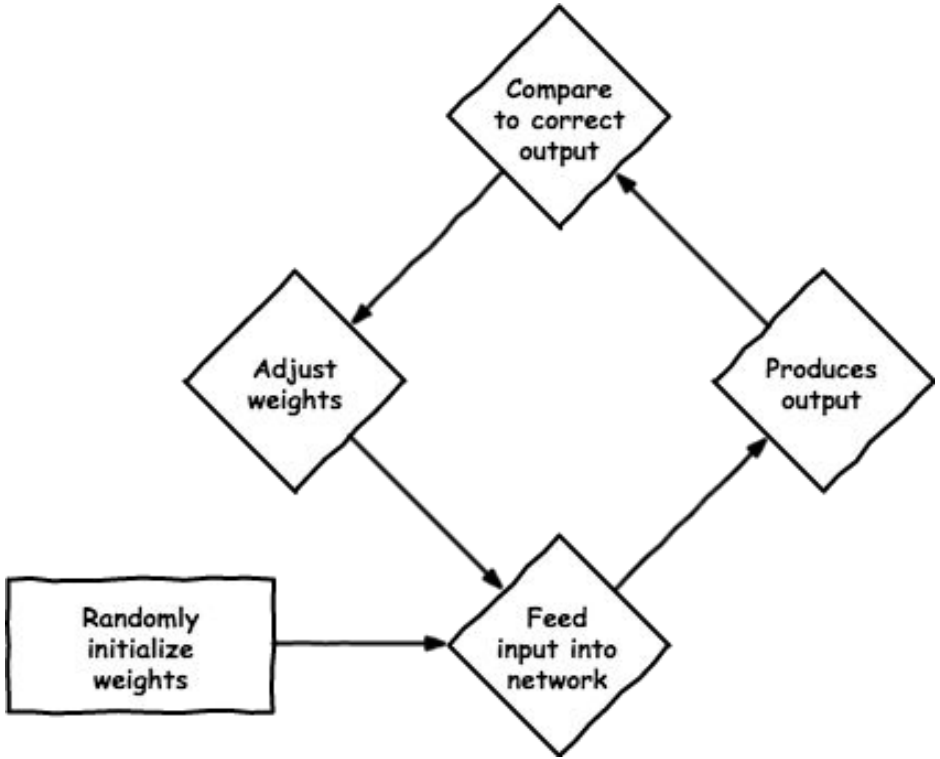
The Learning Process





The Learning Process





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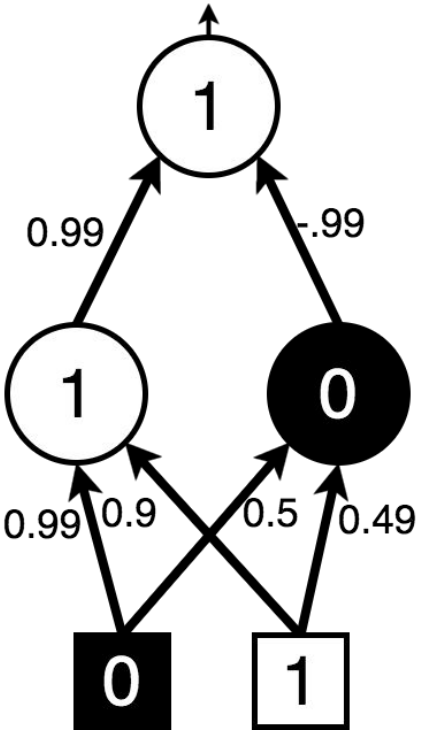
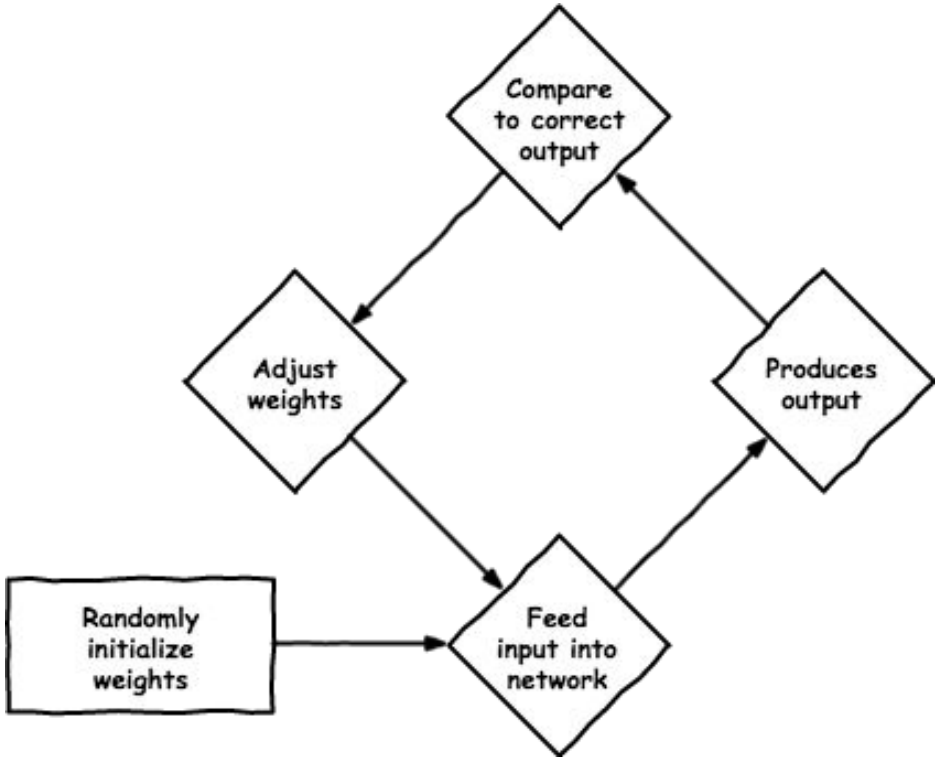
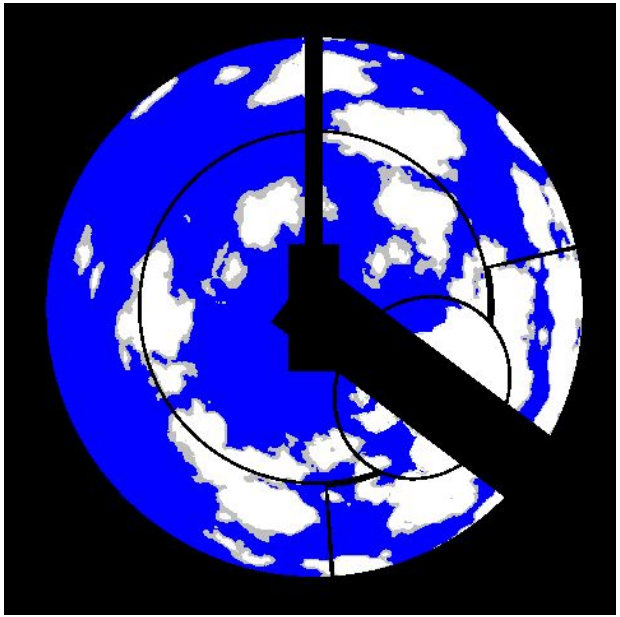




Training a Network on TSI Data

Input:

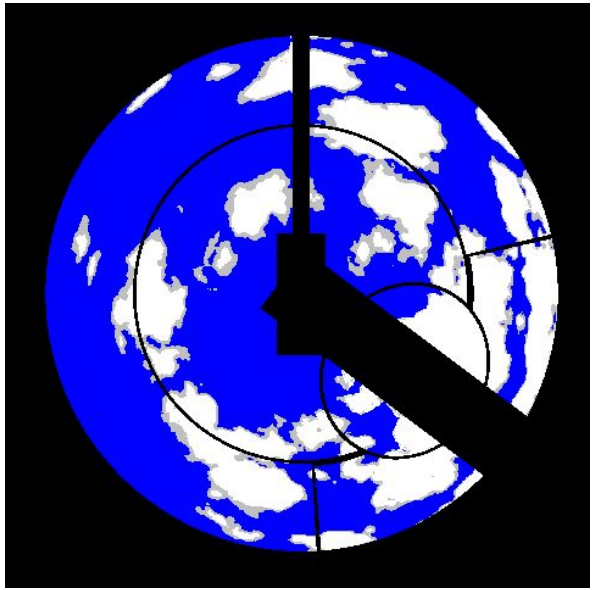
Correct Answer:



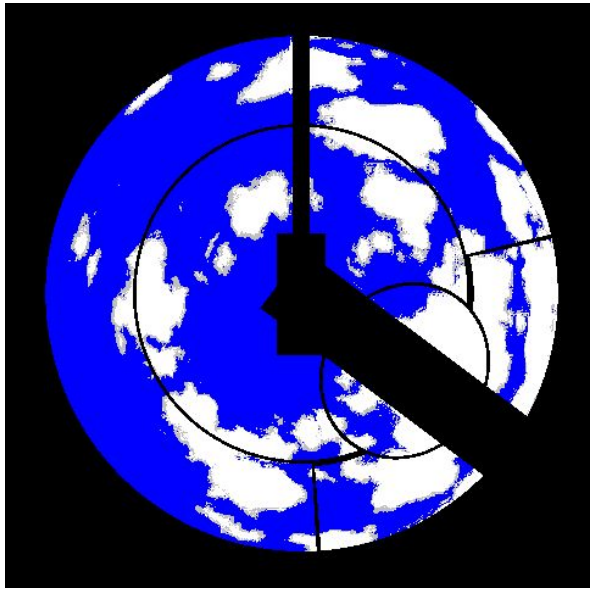
Results

TSI Sky Image

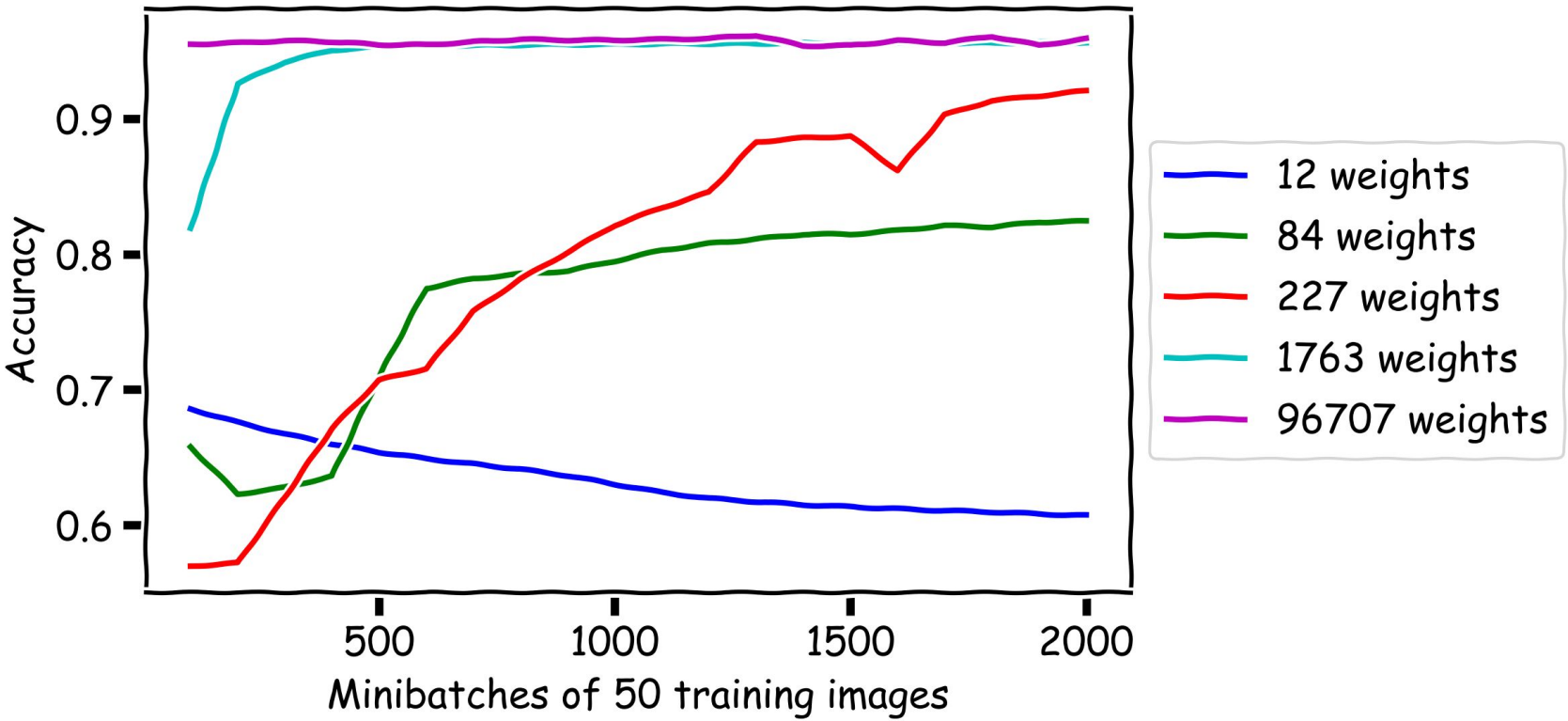
TSI Mask



Network Output



Learning Curves



Summary

- Clouds are the largest source of uncertainty for climate models
- We created a neural network to segment cloud images
- This is the first application of this technique to this problem
- It performs approximately as well as hand crafted systems
- This can validate and improve climate models

Future work

1. Segmentation of the camera arm
2. Classification
3. Additional inputs
    a. Lasers
    b. Radar
    c. Satellite images

Acknowledgments

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Portland State University

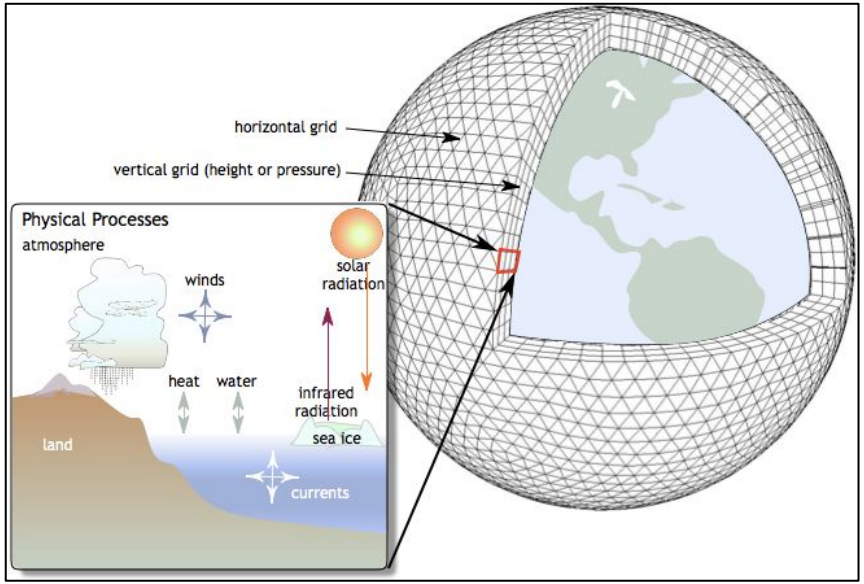
Lewis & Clark College

John S. Rogers Science Program

M. J. Murdock Charitable Trust

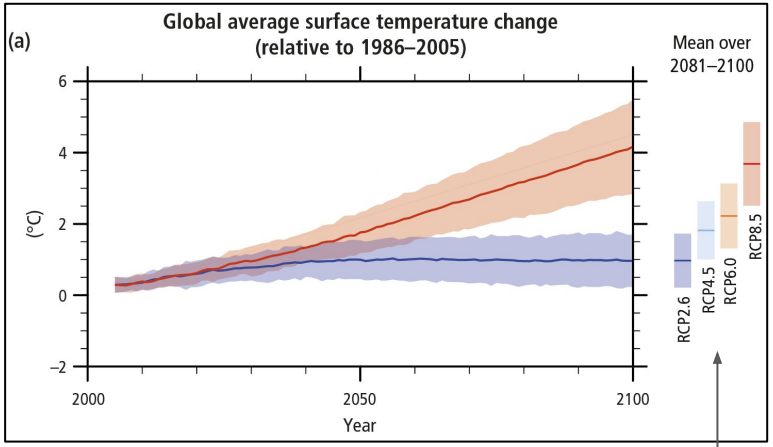
Motivation: Clouds Contribute the Greatest Uncertainty to Climate Model Projections

Climate models:



Source: Center for Multiscale Modeling of Atmospheric Processes

Climate model projections:



Source: IPCC 2014, Summary for Policymakers

Different emissions scenarios

We need cloud observations to validate and improve climate models.

How our results can improve climate models

- Example high-resolution cloud model output →

Future work

1. Segmentation of camera arm
2. Cloud Classification
3. Additional inputs
    a. Lasers
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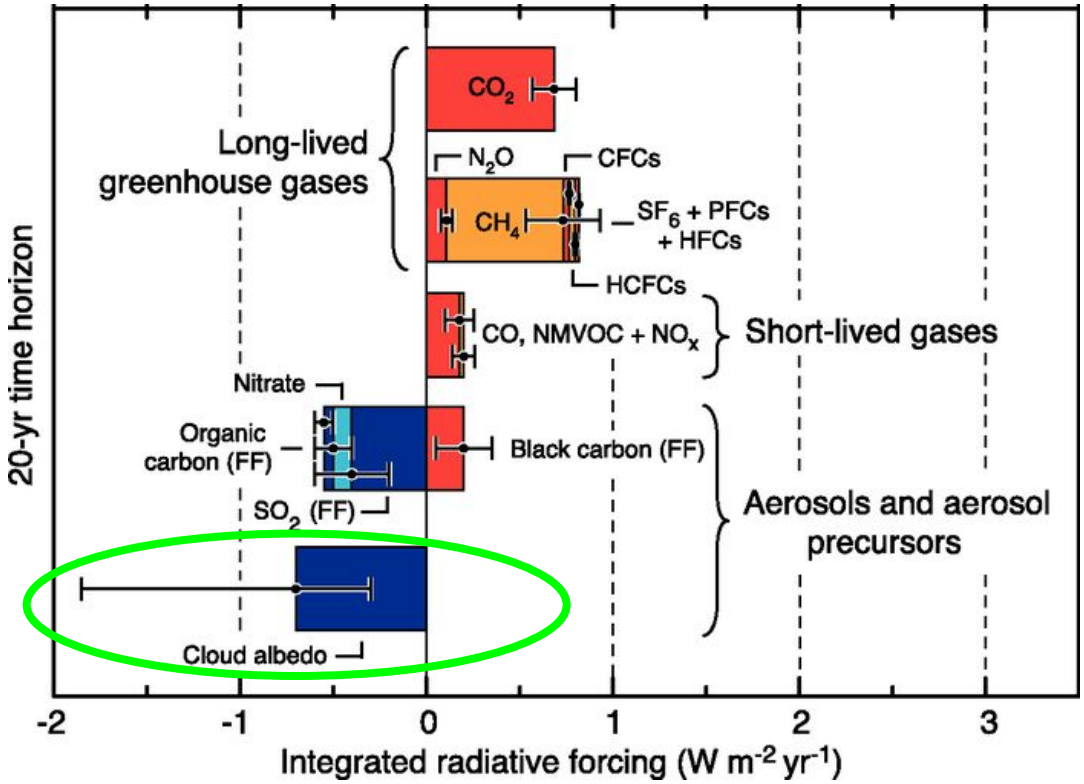
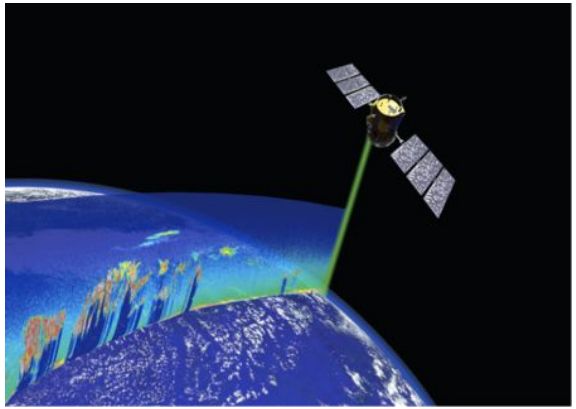


Image: IPCC 2007

How do we observe clouds? (to improve climate models)

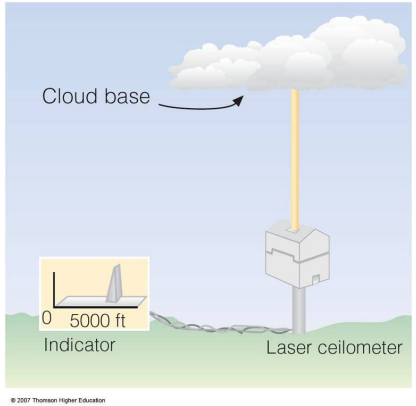
Satellites (laser, IR & vis.)



- Good global coverage
- Low spatial resolution
- Low clouds occluded.

Source: NASA CALIPSO satellite

Ceilometers (laser & radar)



- Only at a point location
- Very precise
- High clouds occluded.

Source: © 2007 Thomson Higher Ed

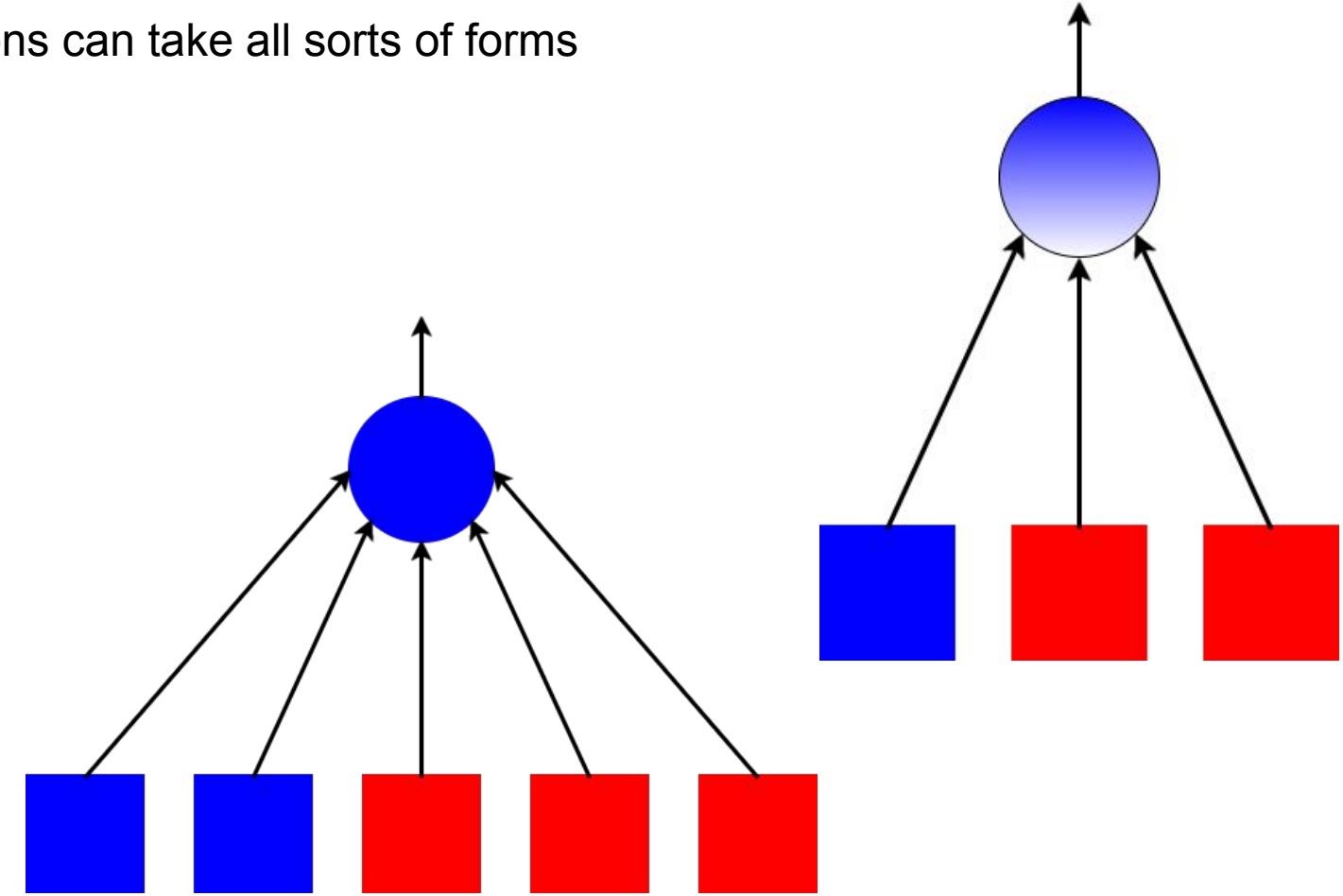
Ground-based images

- Observes an area of the sky
- Poor global coverage
- High clouds occluded.

- Consistent with historical records
- Need image processing techniques

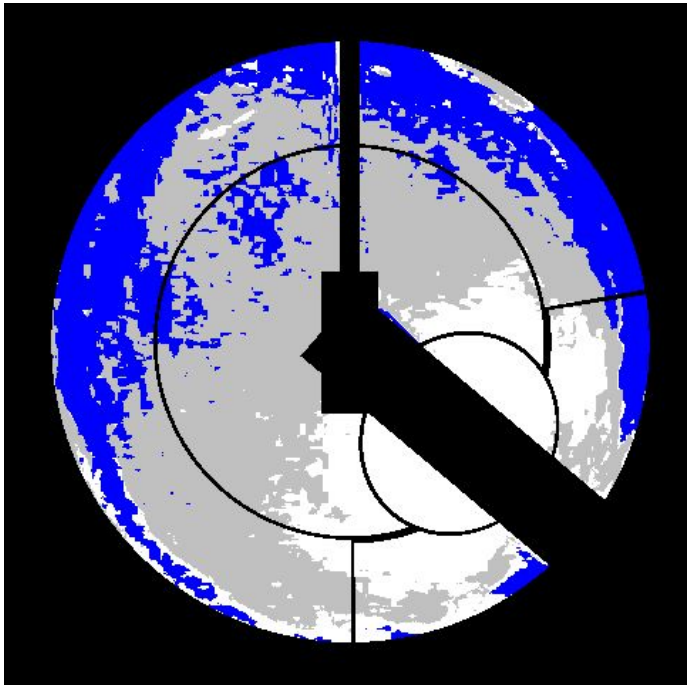
Source: International cloud atlas (WMO)

Neurons can take all sorts of forms



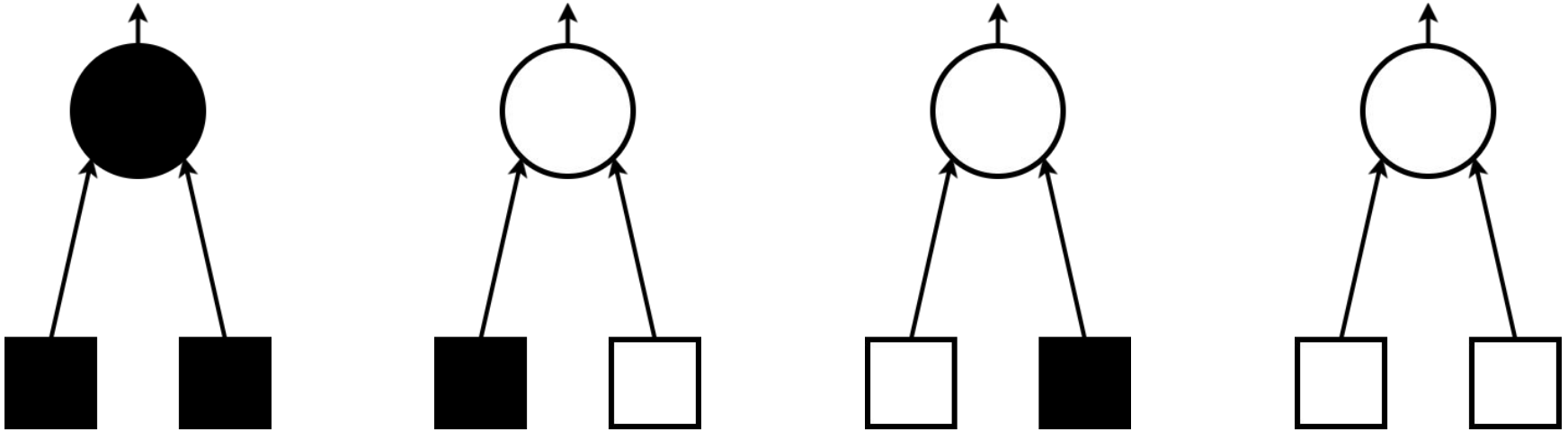
The last 4% isn’t necessarily wrong

The cloud mask generated by the TSI isn’t always correct



Neurons compute functions

An “OR” function being computed by a neuron



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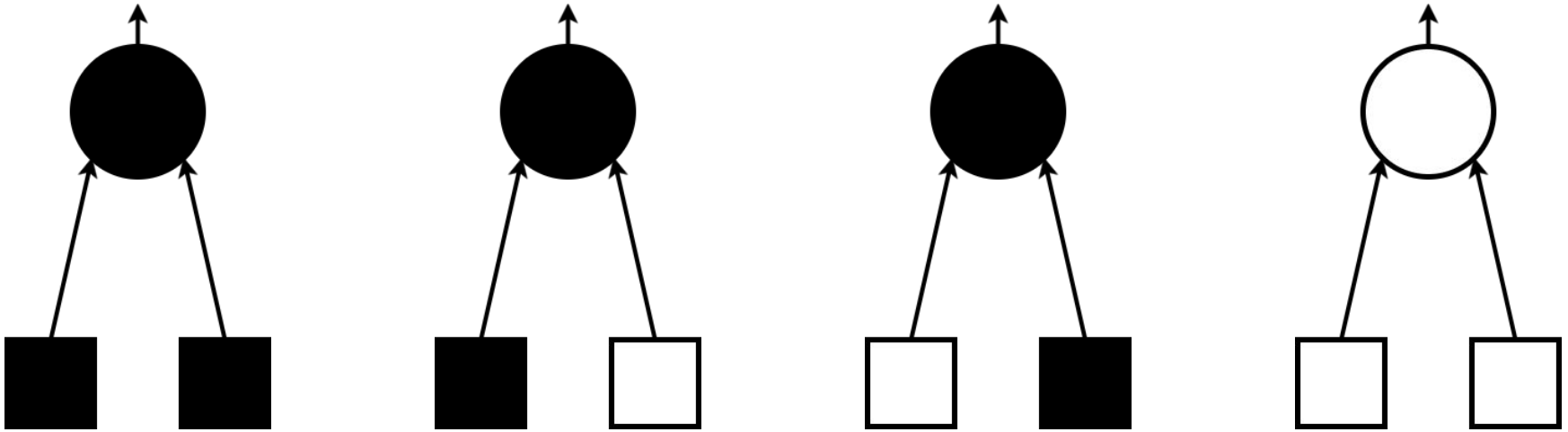

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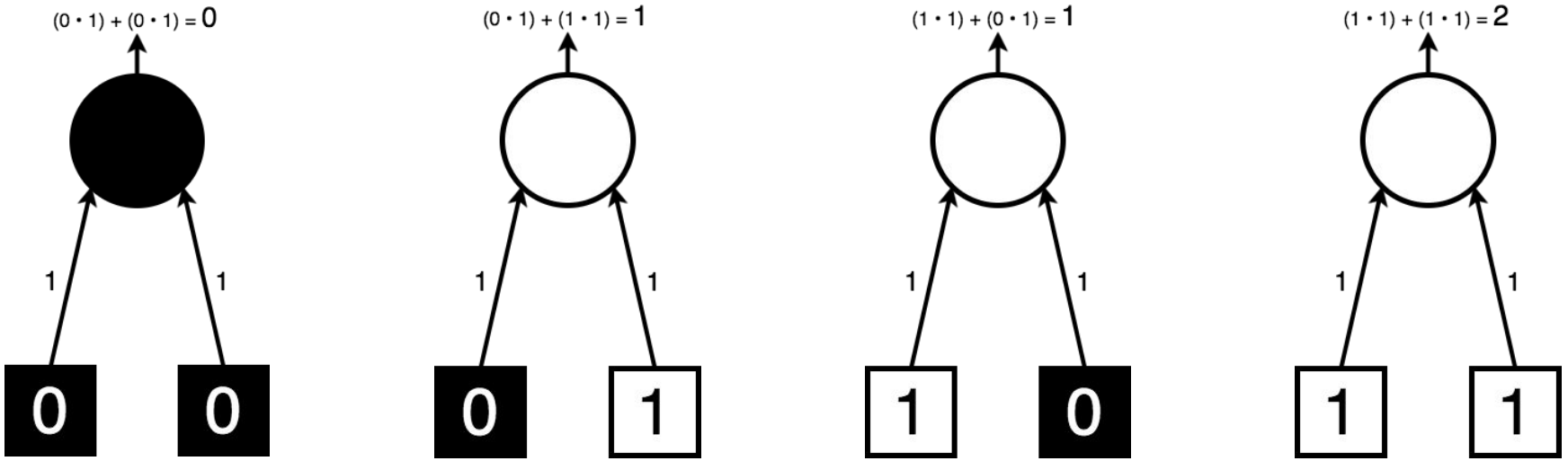

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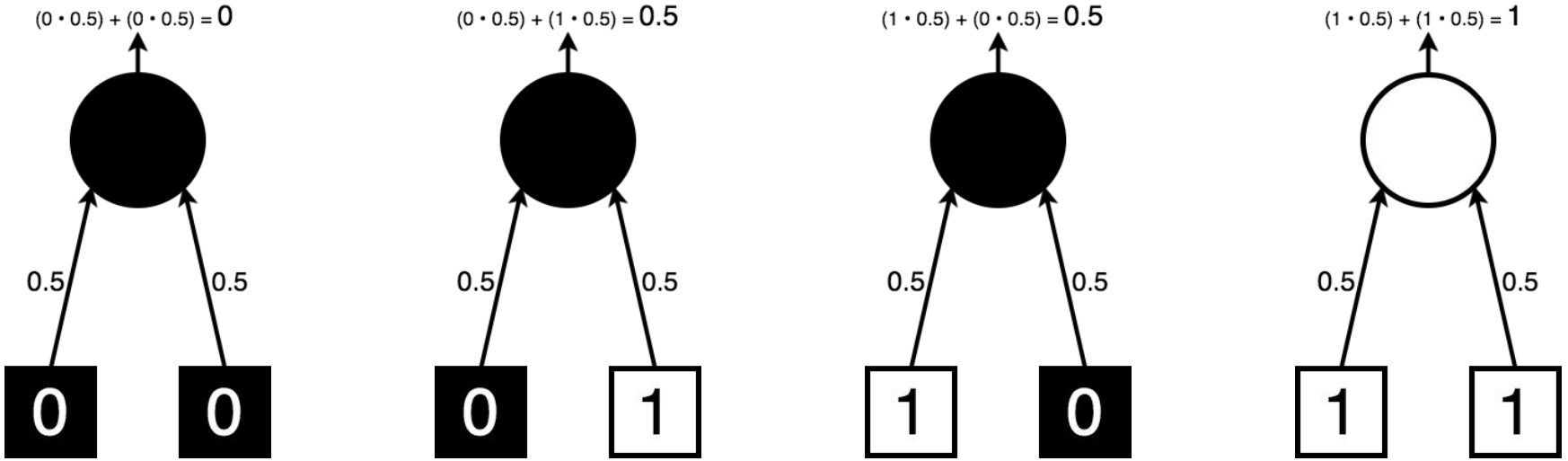
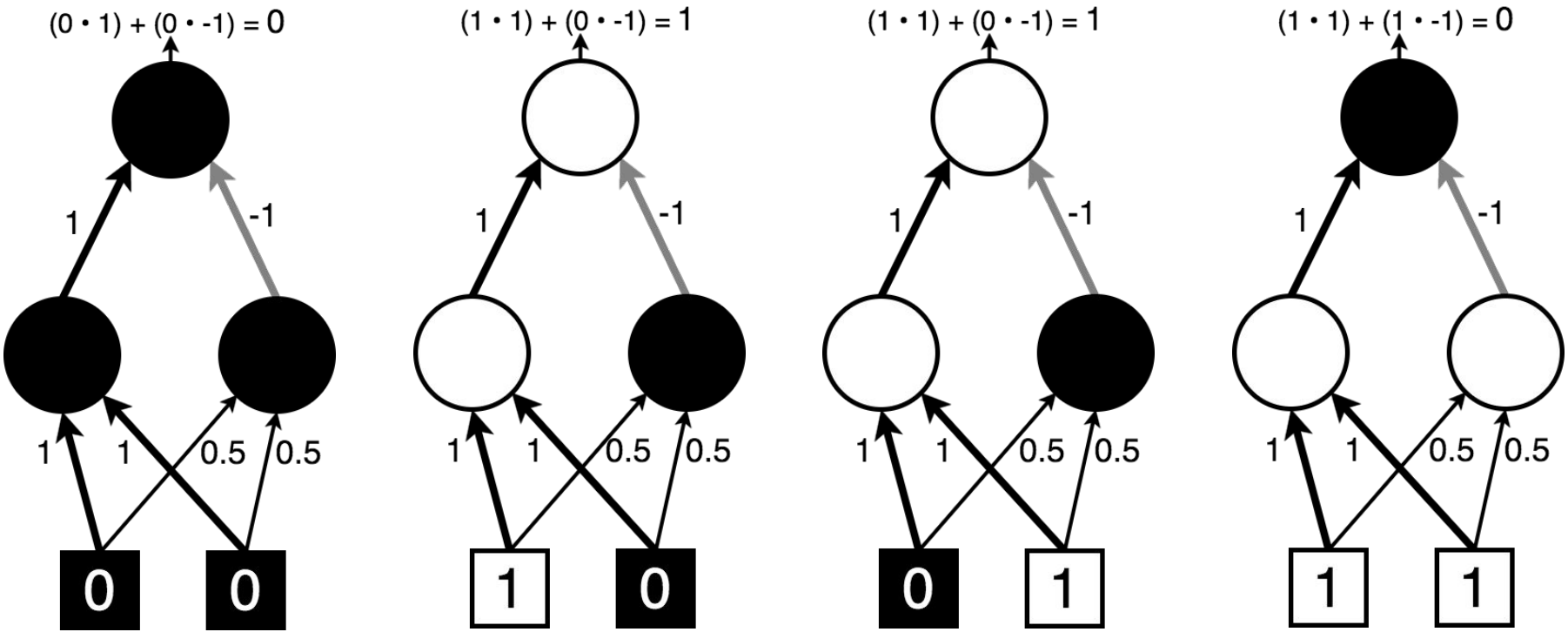


Computing the exclusive-OR function



Deep Neural Networks

A deep neural network has multiple layers of neurons

- The output of one layer is the input of the next
- Having multiple layers allows the network to compute more complex functions

Neural Networks and the Cloud Problem

Take in many types of data and produce an output

Once the network is trained it generates mask images quickly

Excellent for image classification

What you know

Neurons are digital object that compute a function

Neurons link together to make neural networks

Neural networks compute or estimate larger functions

Neural networks learn by updating parameters to function they compute, then testing if it was closer to being correct

Why these results are useful

Our network can be trained to recognise clouds in any environment

The network can continue to improve overtime

There is no need to tweak thresholds to try and find what works best for a set of images

This network is a stepping stone towards cloud classification

Stuff