What Neural Networks Can Teach Us About Geomorphic Transport Laws

Jo Martin[1] and Gregory Tucker[1]

[1]Cooperative Institute for Research in Environmental Sciences (CIRES) and University of Colorado Boulder, Department of Geology

The Streampower-Diffusion Model

A simple landscape evolution model that is controlled by the ratio of K and D

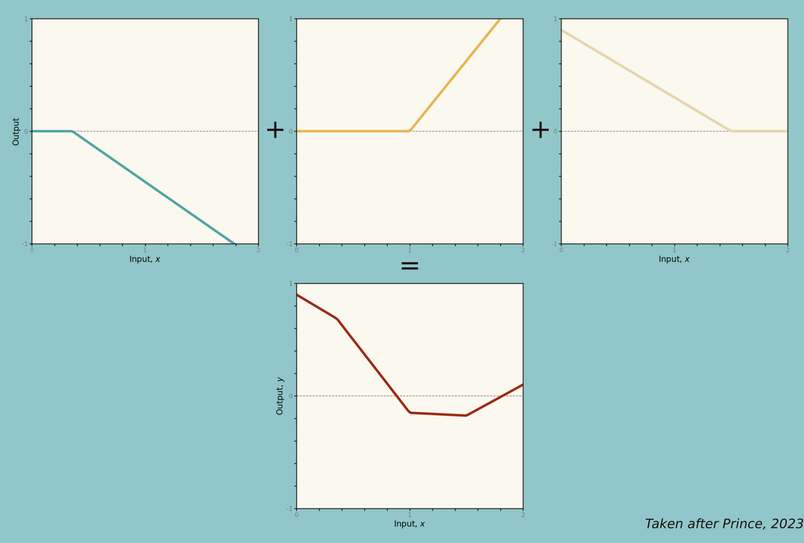
Streampower (overland flow)

$$\frac{\partial z}{\partial t} = D\nabla^2 z - K A^m |\nabla z|^n + U$$

Diffusion (hillslope processes) — Uplift

What is a neural network?

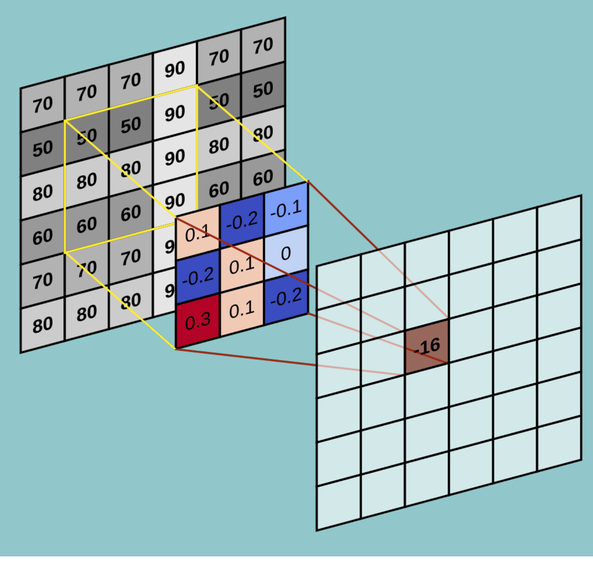
A way to combine lots of simple functions to approximate a more complex one



Taken after Prince, 2023

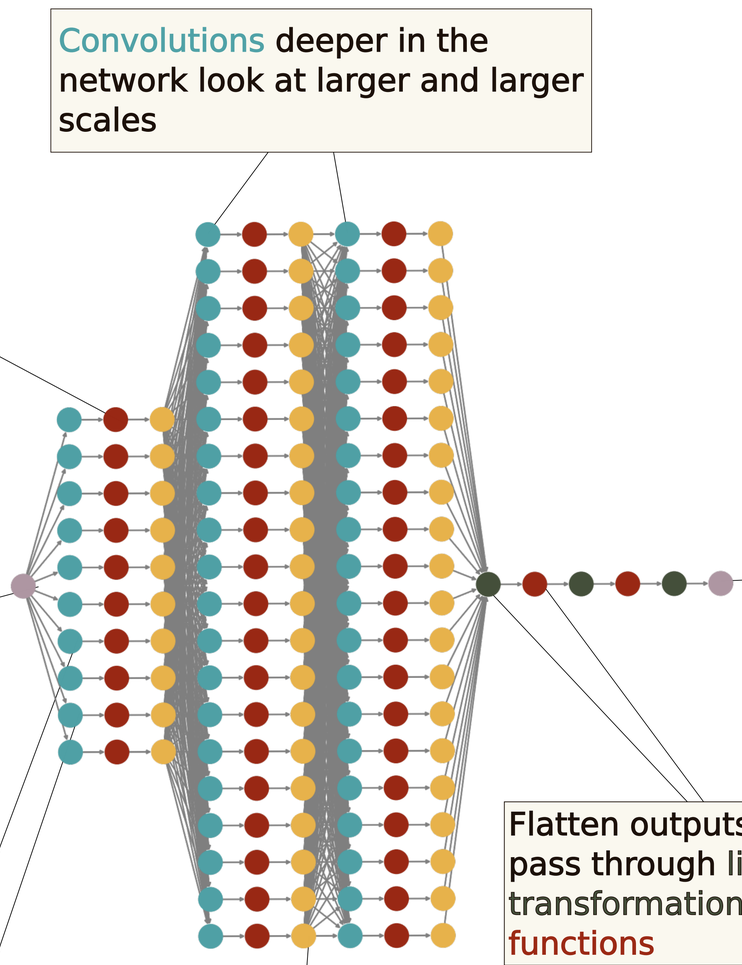
Combine Convolutions to approximate spatial functions

Convolutions are sets of 2D weights that sweep across the input. The Weights are linear combined with the section of the input it overlaps with, creating one pixel in the 2D output (a feature map)

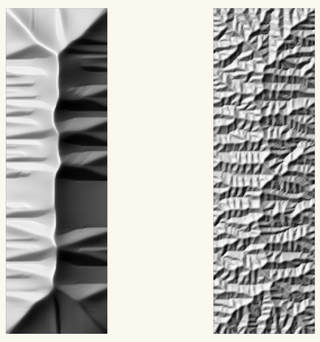


Convolutions deeper in the network look at larger and larger scales

Pass output through an "activation function" to introduce nonlinearity



Low K/D — High K/D

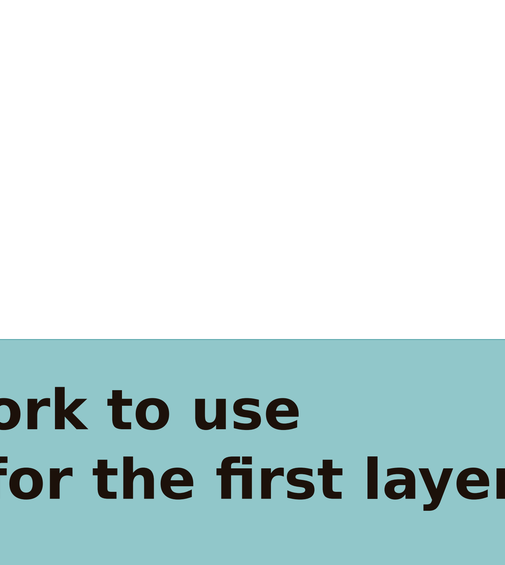


Feed in the topography from a streampower diffusion data

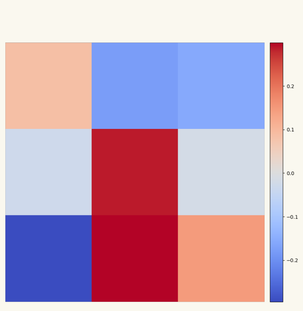
Flatten outputs to a vector and pass through linear transformations and activation functions

Reduce output resolution with a "pooling layer" to increase efficiency

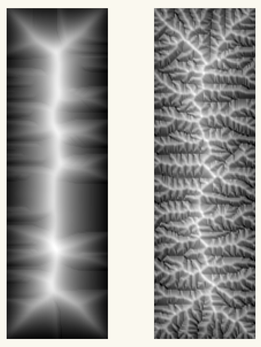
Compare the final number to the K/D ratio that generated the input topography



The network **can** infer the K/D Ratio

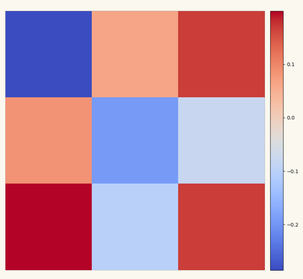


weights of convolution

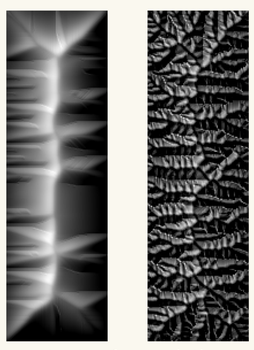


outputs of convolution

Does this neuron perform ridge detection?



weights of convolution



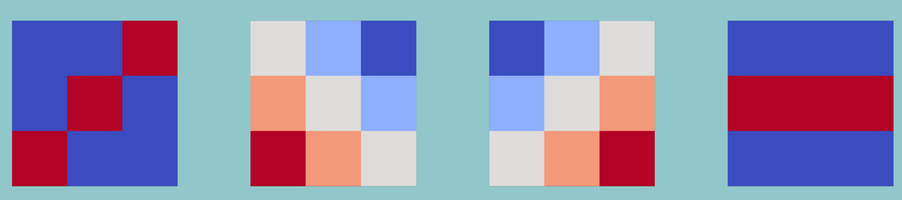
outputs of convolution

Does this neuron perform face detection?

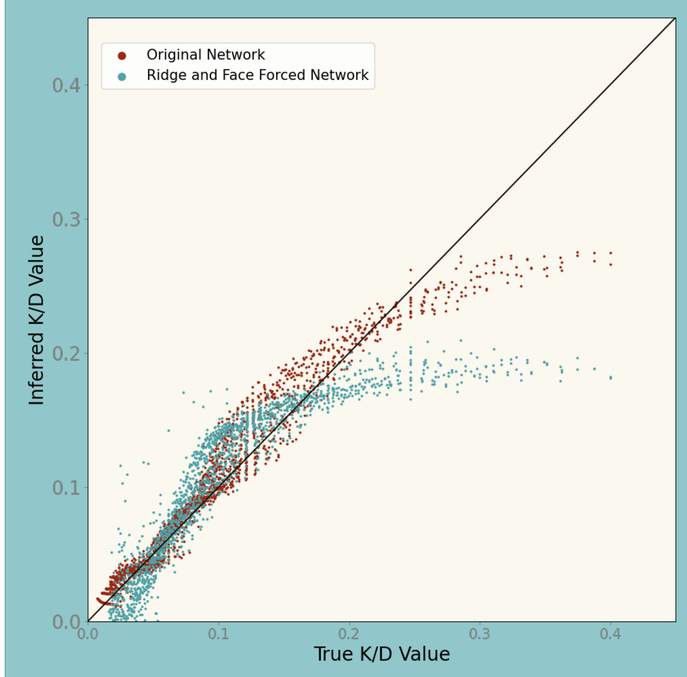
Are some convolutions geomorphic features?

What if we force a network to use ridge and face neurons for the first layer?

First layer weights fixed to:



and similar



- Forced network performs well when K/D is low.
- Forced network underestimates when K/D is high.
- Are ridges and valleys only useful when K/D is low?
- Or are the forced weights useless with early layers controlling the network when K/D is high, and later layers controlling when K/D is low?