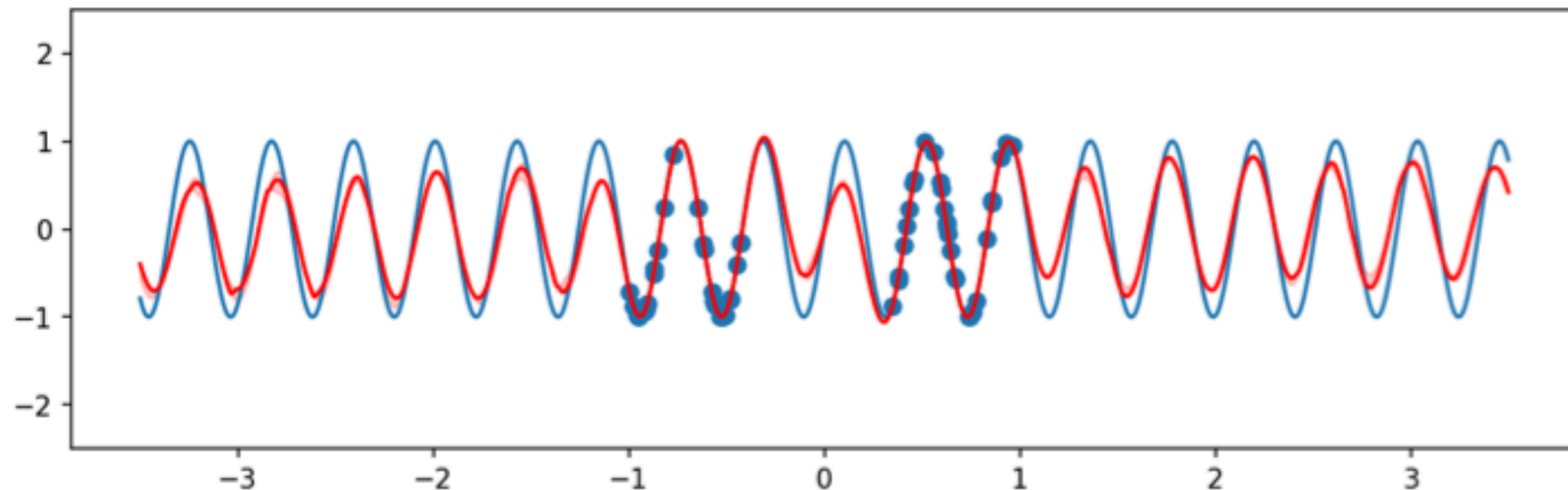


# Neural Networks can learn periodic data

<https://arxiv.org/abs/2006.08195>

**Tilman Hartwig**

with Liu Ziyin & Masahito Ueda



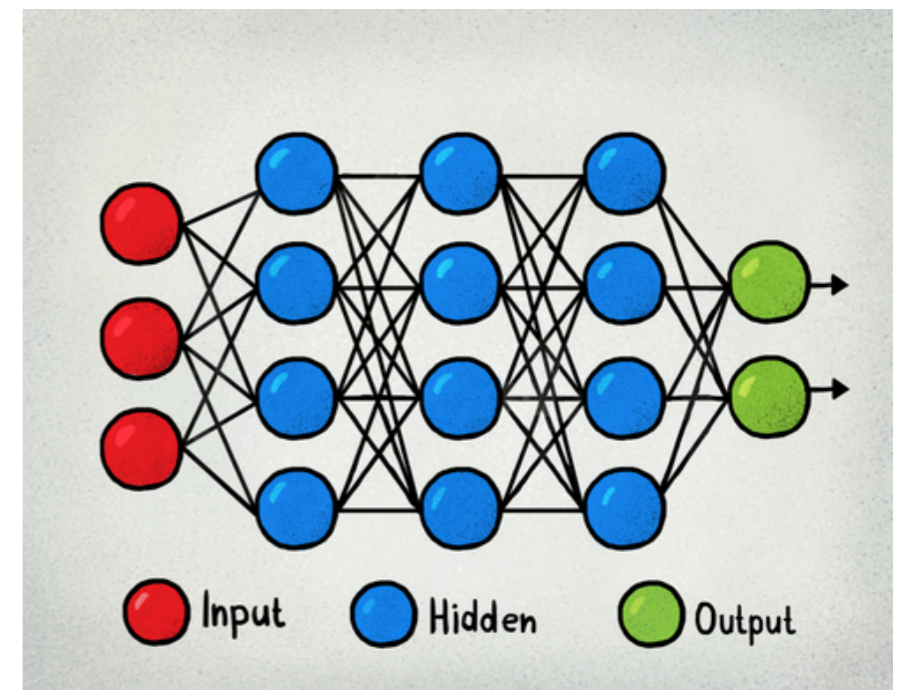
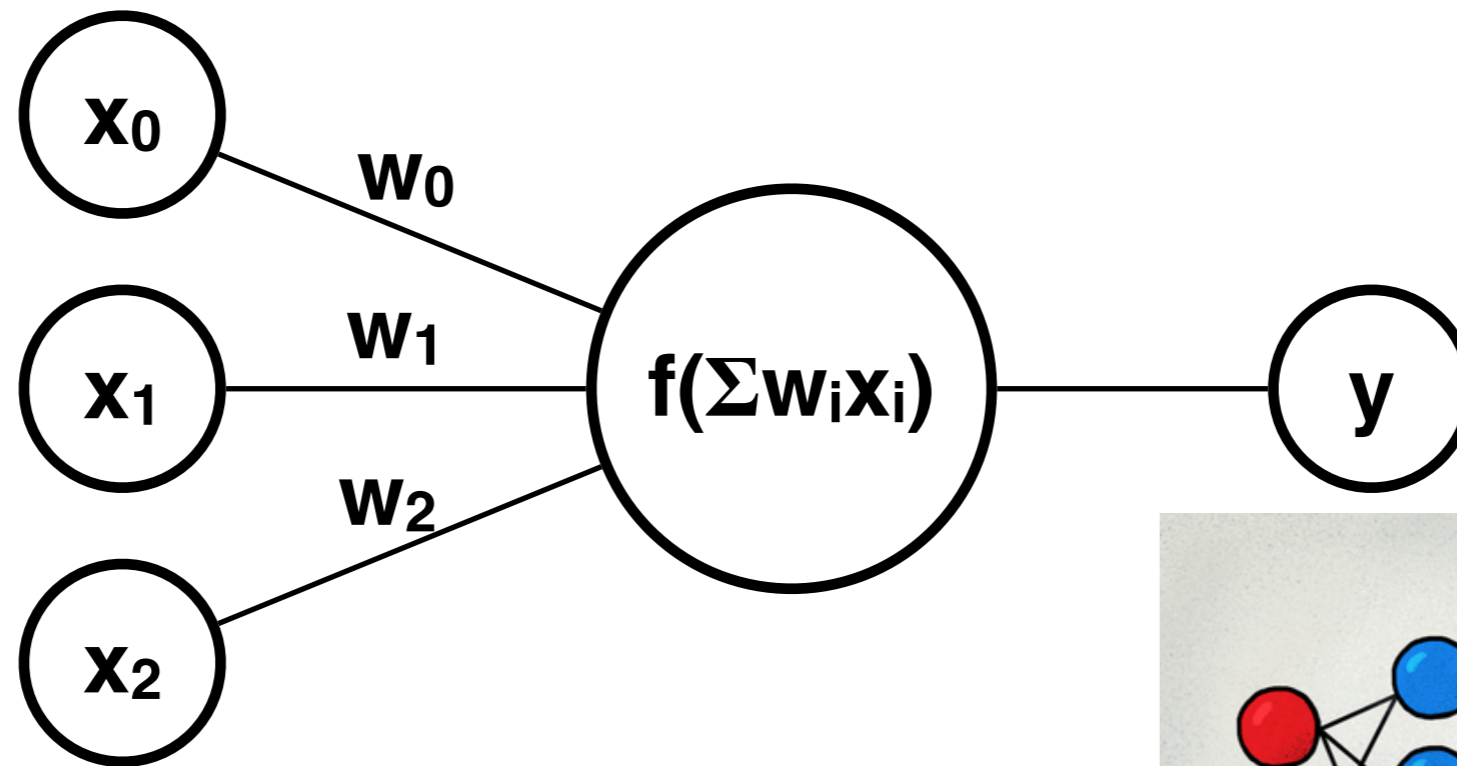
RESCEU Summer School - August, 18th



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Physics of  
Intelligence  
知の物理学



# Artificial Neural Network



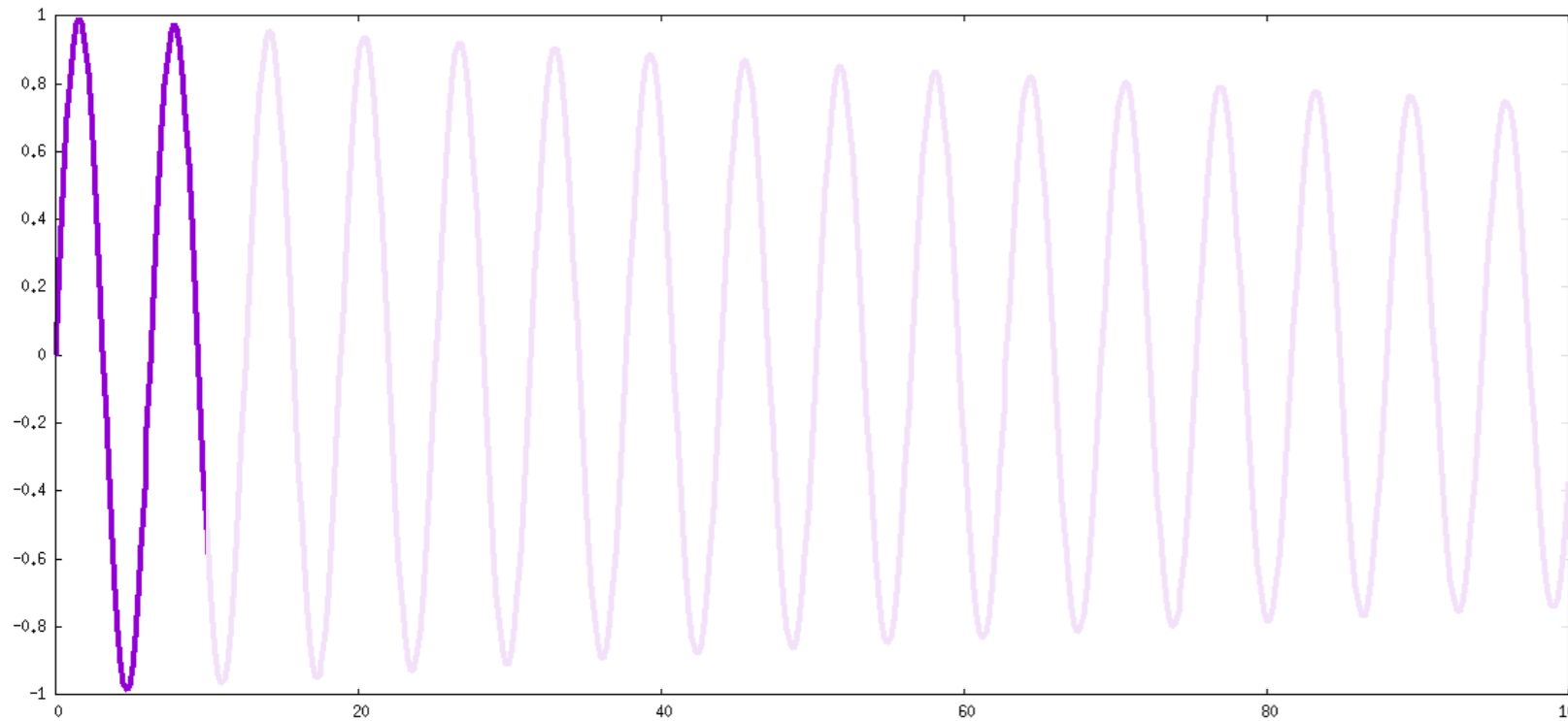
Input data:  $x_i$  (e.g. pixel values)

Learning: finding optimal weights  $w_i$

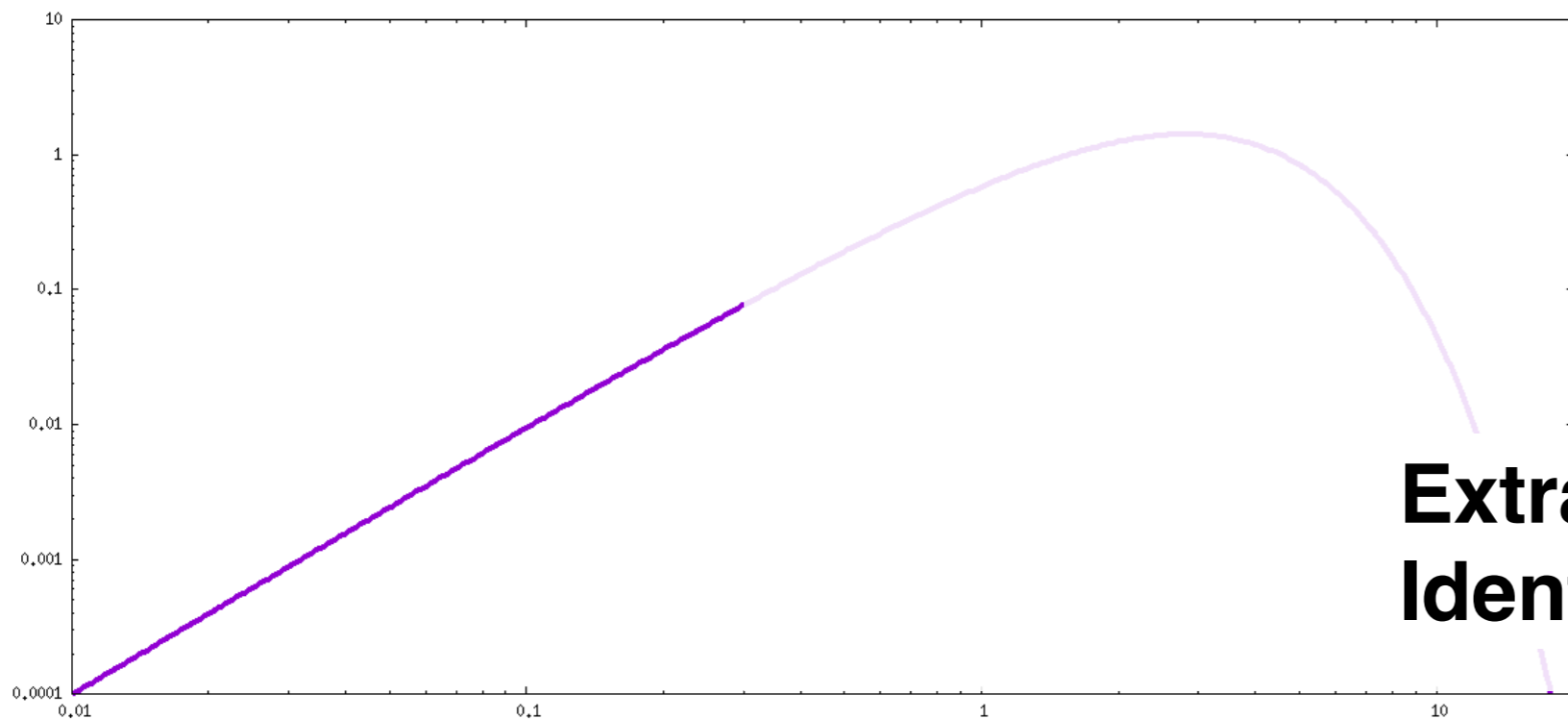
Output:  $y = f(w_0x_0 + w_1x_1 + w_2x_2)$  (e.g. cat/dog)

Activation Function  $f(x)$ : sigmoid, ReLU, step-function,...

# Extrapolate ("View Options" -> "Annotate")



*Damped Oscillator*

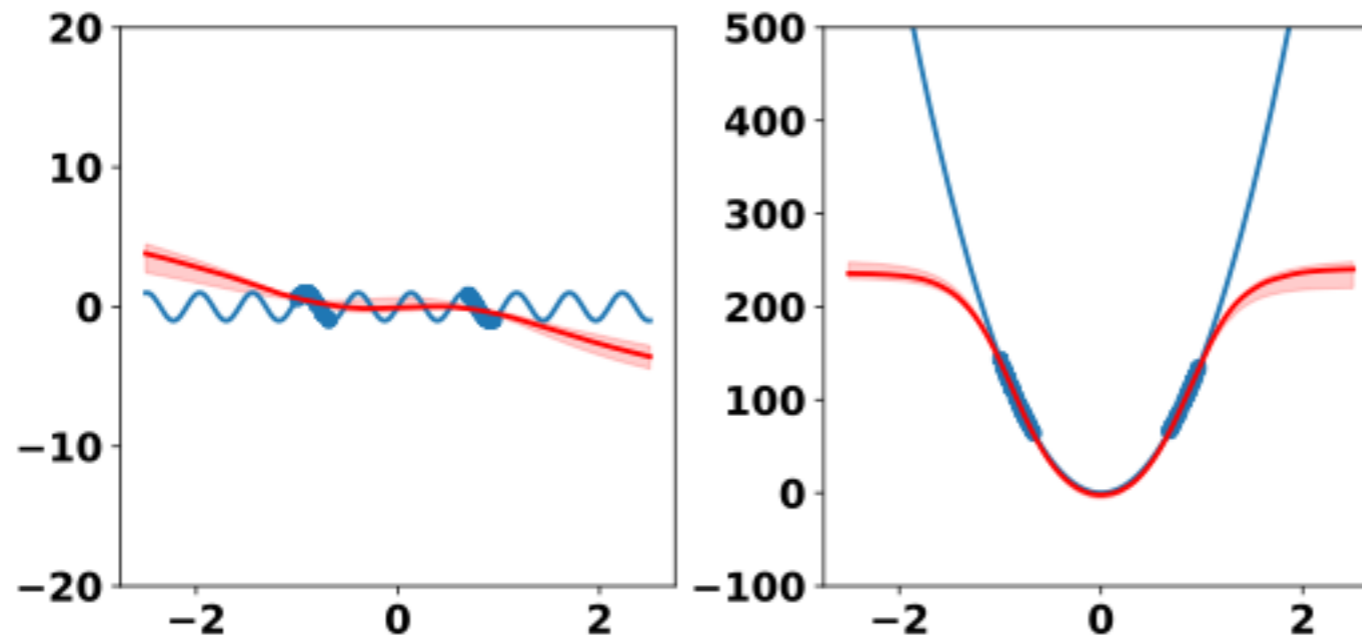


*Blackbody*

**Extrapolation is ill-defined.  
Identifying periodicity helps**

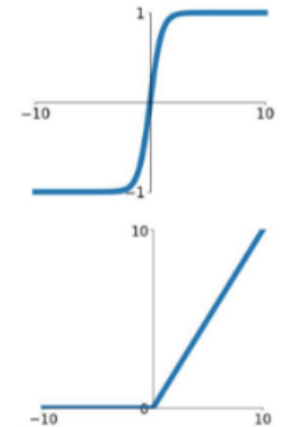
# Existing Activation Functions

Tanh



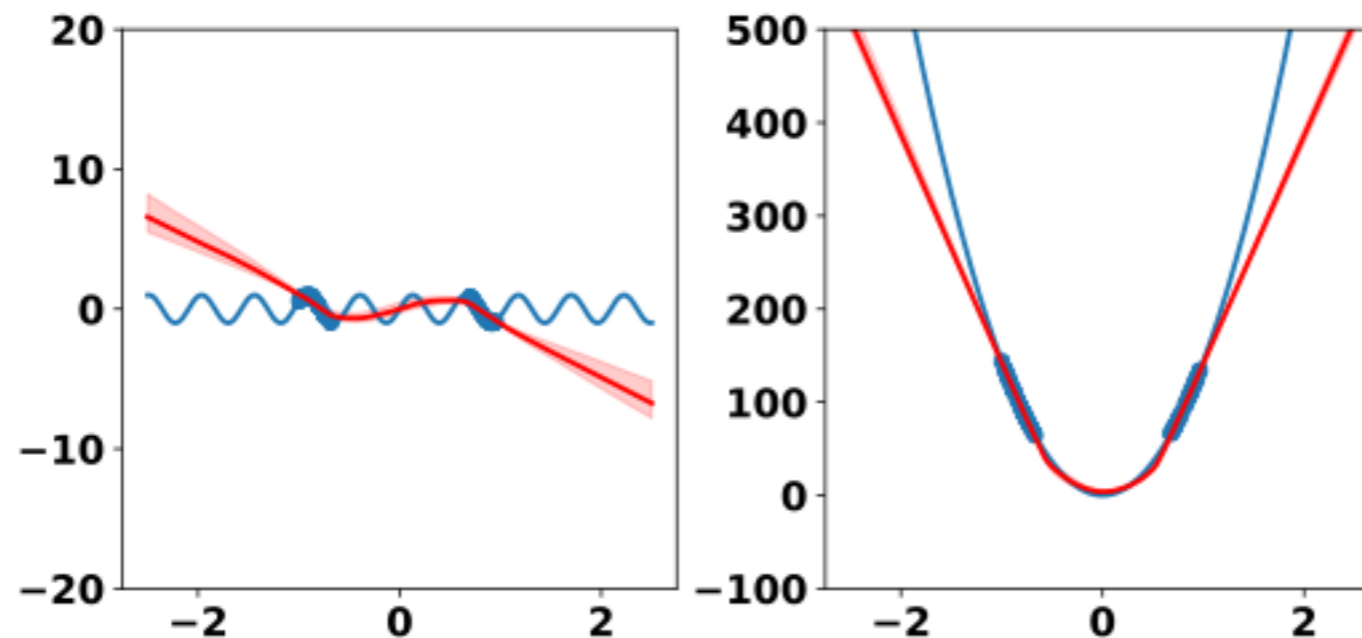
- Ground Truth
- Sampled Input
- NN prediction

**tanh**  
 $\tanh(x)$



**ReLU**  
 $\max(0, x)$

ReLU



**Neural Network adopts  
extrapolation properties  
of activation function.**

# We propose: Snake

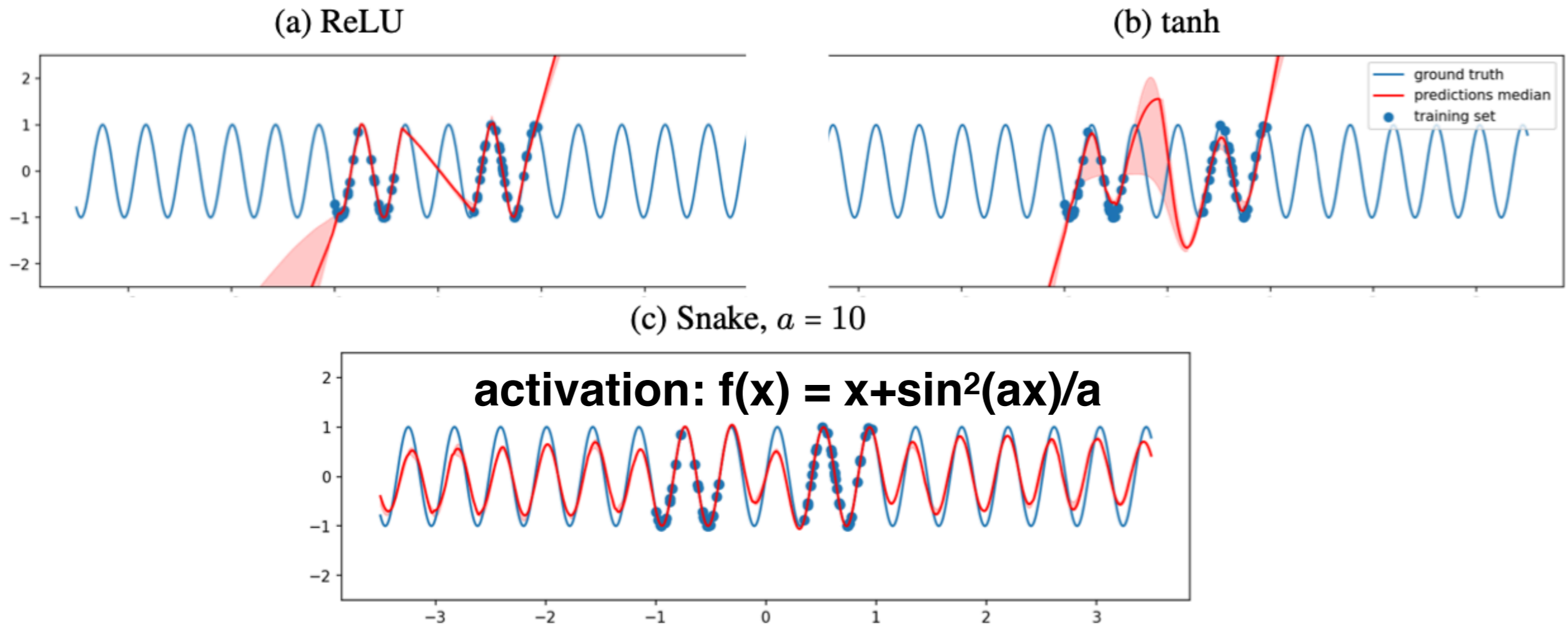


Figure 4: Regressing a simple sin function with tanh, ReLU, and Snake as activation functions.

**Snake can capture and therefore extrapolate the periodic data.**

# Applications: Body Temperature

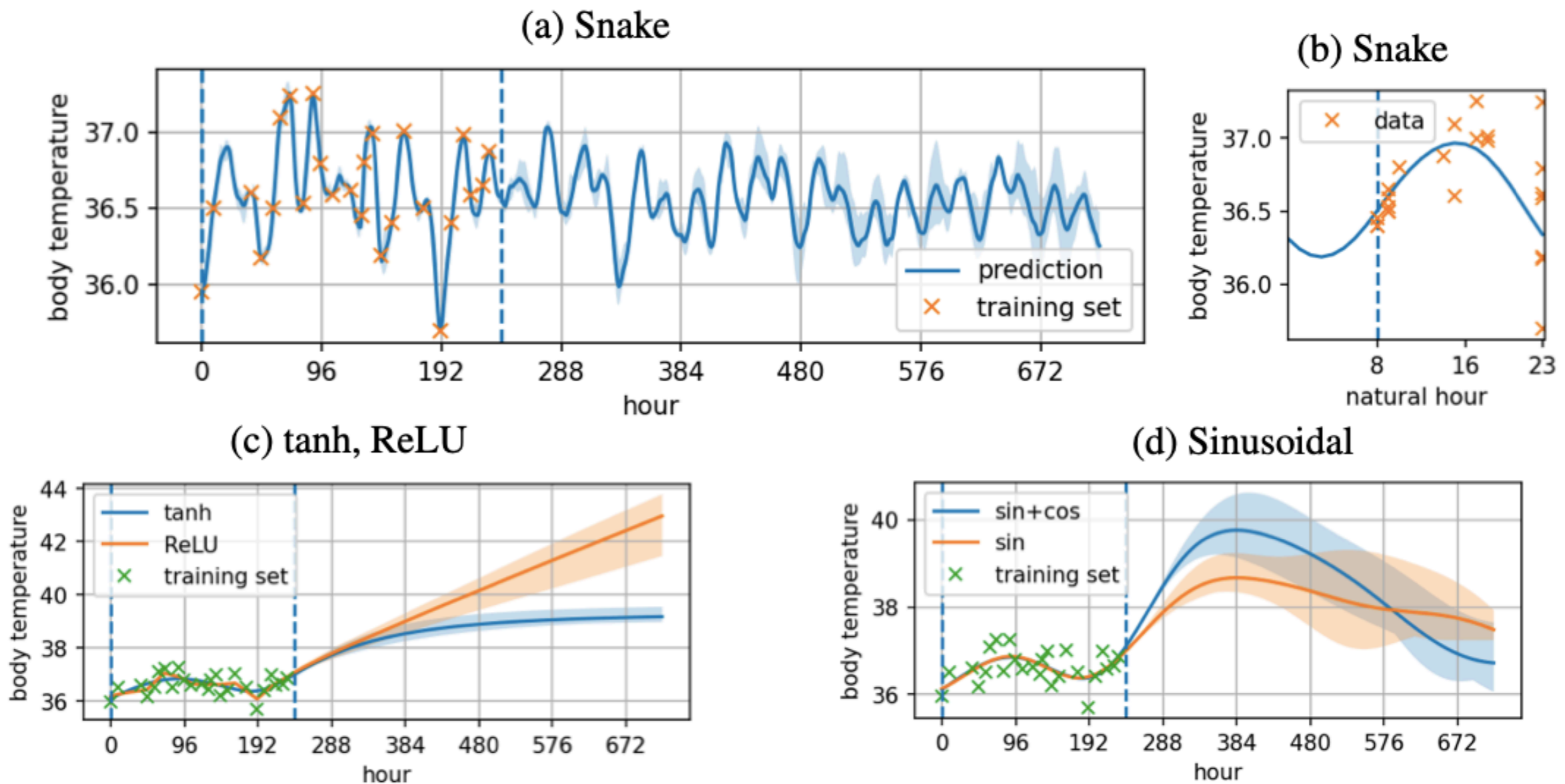
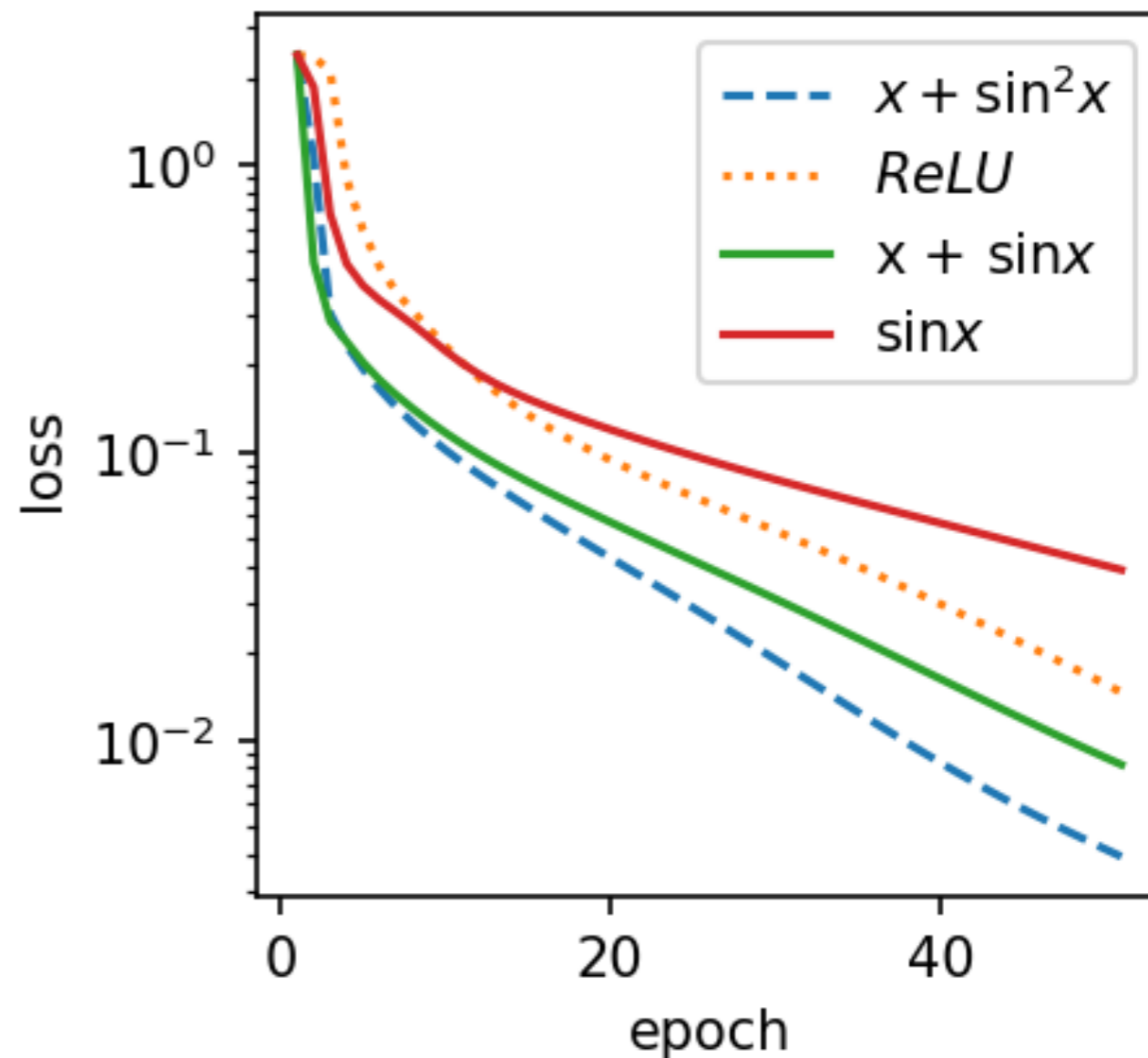
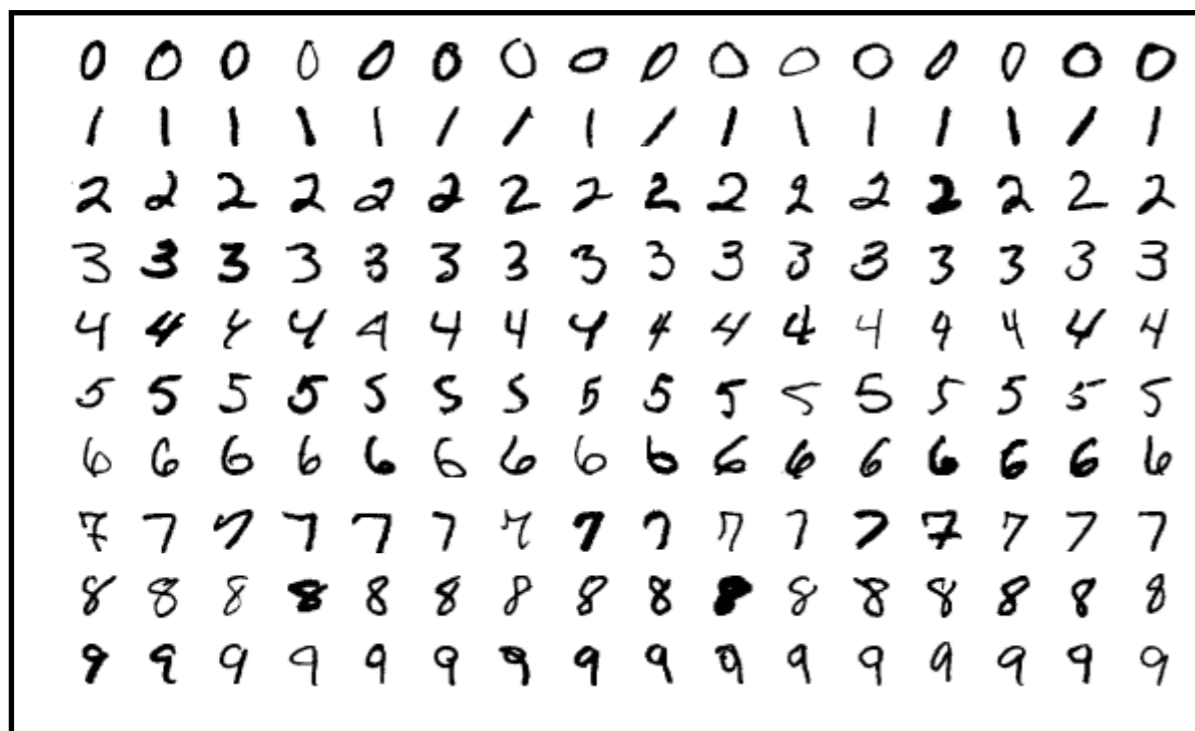


Figure 8: Prediction of human body temperature. (a) Snake; (b) Averaged temperature prediction in a circadian cycle (i.e. as a function of the natural hours in a day); (c) tanh and ReLU; (d) sinusoidal activations.

# Applications: MNIST



Snake can also be used on "classical" computer vision tasks.

# Conclusion & Summary

- ▶ We propose a **new activation function** to model and extrapolate periodic data:  $x + \sin^2(x)$  ("Snake").
- ▶ Minimises **inductive bias**.
- ▶ Can be applied to all kind of **semi-periodic data** and image classification tasks.



**Edward Dixon** @EdwardDixon3 · Jun 23

I made a thing! I was so intrigued by this paper that I wrote a [@PyTorch](#) implementation of their snake (trainable!) activation function and turned it into a [#Python3](#) package: [github.com/EdwardDixon/sn...](https://github.com/EdwardDixon/sn...) Can this critter improve [#DeepLearning](#) for [#audio](#)? Watch this space...



**Edward Dixon** @EdwardDixon3 · Jun 22

"Neural Networks Fail to Learn Periodic Functions and How to Fix It". Physicists Liu Ziyin, Tilman Hartwig and Masahito Ueda propose snake:  $x + \sin^2(x)$ . Great explanation of this design, e.g. why sine alone fails. Very interesting results, recommended. [arxiv.org/abs/2006.08195](https://arxiv.org/abs/2006.08195)