# Creating and Combining Neural Networks

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# What is my research agenda with this lab?

**Goal:** Provide design principles for general, real-time autonomous perception to be fed into Soar.

Specifically, we are looking into designing neural networks for this purpose.

**Guiding questions:**

- How do we "initialize" our learning?
- How do we learn continuously?
- How do we understand and reconcile different sensory input?

**Philosophy:**

- All models are bad, but some are useful
- Reality exhibits self-similarity at different scales

# Current Projects

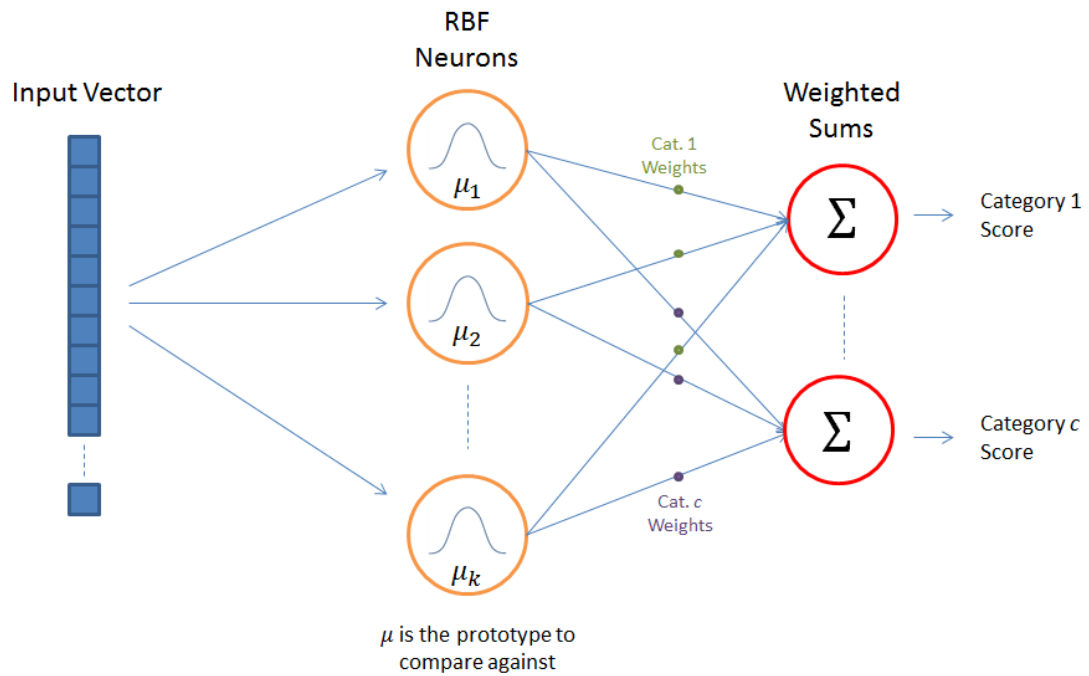
- Describing what an artificial neural network does
- Developing a methodology to allow for continuous learning while still keeping neural networks "small."
- Outline a system for combining multiple neural networks devoted to different tasks but with overlapping classification.

# What is a neural network and what is it doing?

# What is an artificial neural network?

## Definition

An **artificial neural network** is a member in a family of models that perform regression using layers of adjustable weights.

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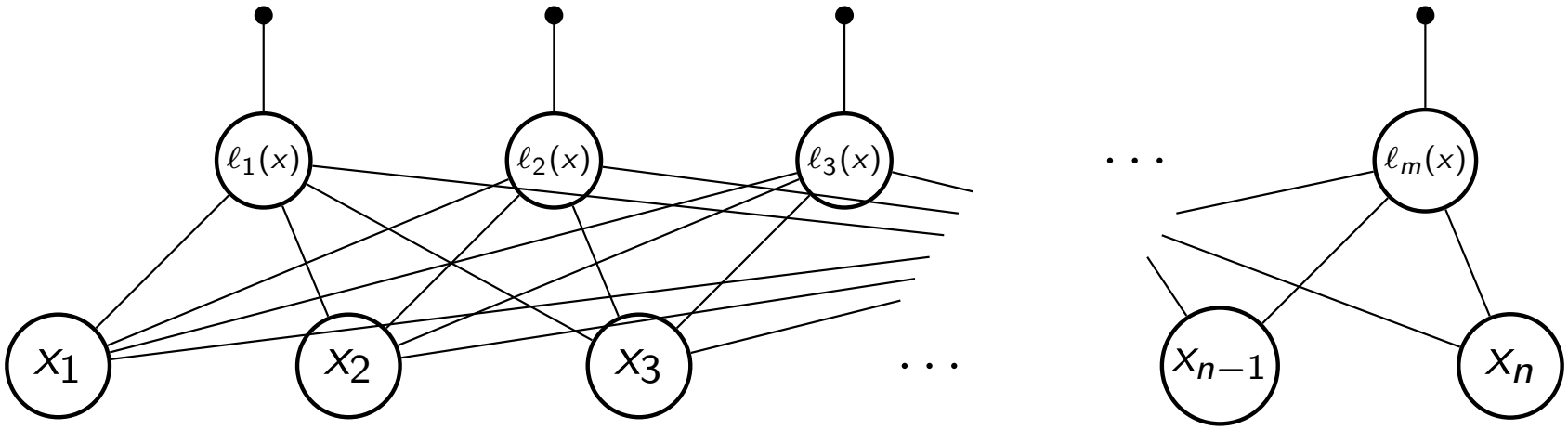
[1] Image taken from http://mccormickml.com/

# What is a neural network layer?

$$F(\vec{x}) = \sum_{i=1}^{n} v_i \varphi(w_i^T \vec{x} + b_i)$$




$\varphi$ is called the **transfer function**. For the layer to be a universal approximator (i.e., can approximate continuous functions over $\mathbb{R}^n$), $\varphi$ must be

continuous and "discriminatory"

# What does "discriminatory" mean?

## Definition

We say that $\varphi$ is **discriminatory** if for a measure $\mu \in M(I_m)$

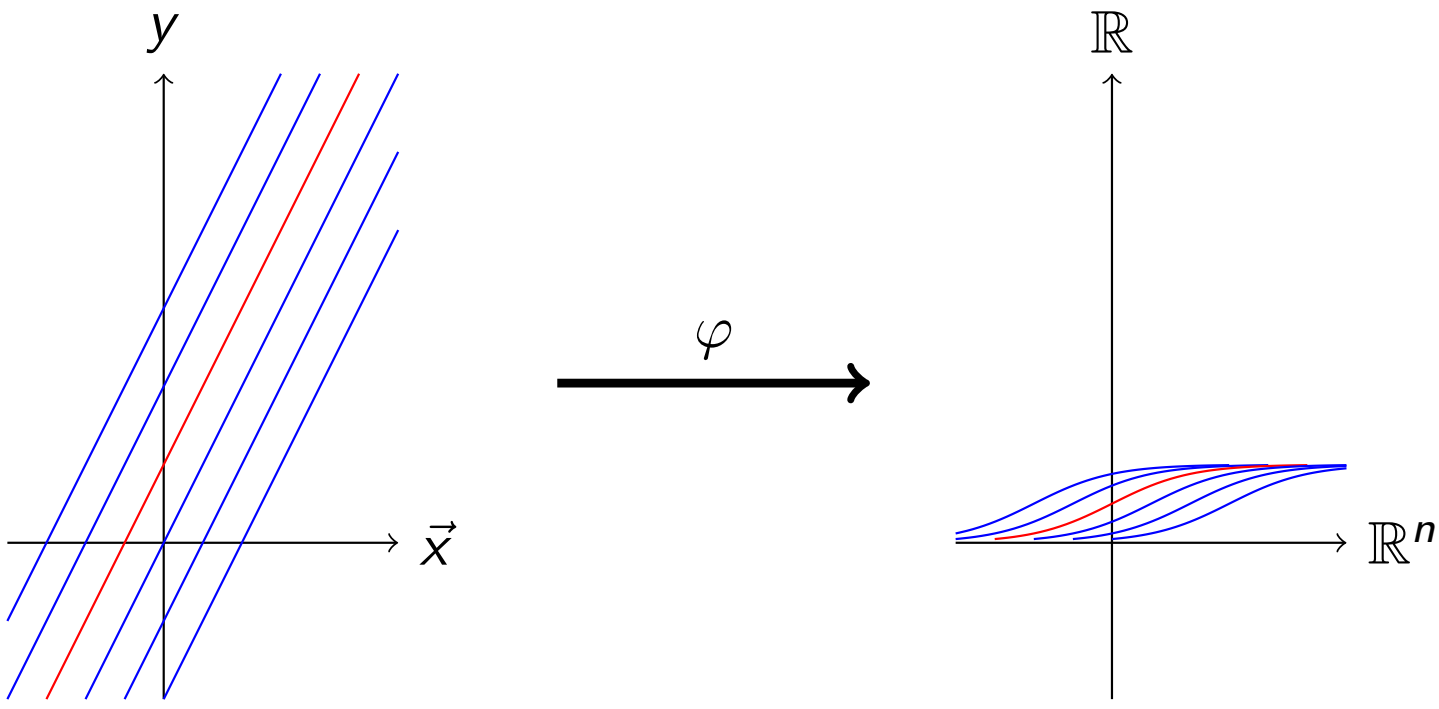
$$\int_{I_m} \varphi(w^T x + b) d\mu(x) = 0 \tag{1}$$

for all $w \in \mathbb{R}^n$ and $b \in \mathbb{R}$ implies that $\mu = 0$.

This definition is essentially a consequence of the proof. [2]

[2] See Cybenko, G. Approximation by superpositions of a sigmoial function. *Math. Control Signals Systems*. 1989. 303-314.

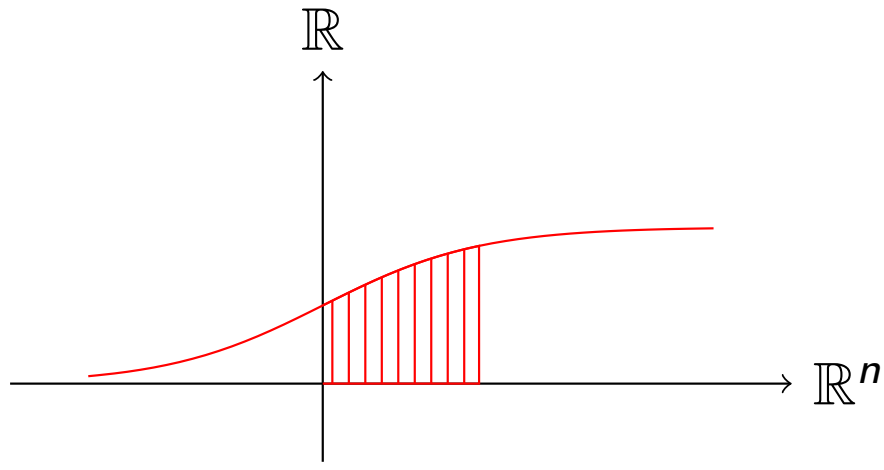
# What is a layer actually doing?




The **red function** might be chosen by a particular choice of $w$ and $b$.

# What is a layer actually doing?

$$F(\vec{x}) = \sum_{i=1}^{n} v_i \varphi(w_i^T \vec{x} + b_i) \xrightarrow{N \to \infty} \int_{I_m} \varphi(w^T x + b) d\mu(x)$$




Why is this approximating an integral?
And why a nontraditional measure?

# What is a layer actually doing?

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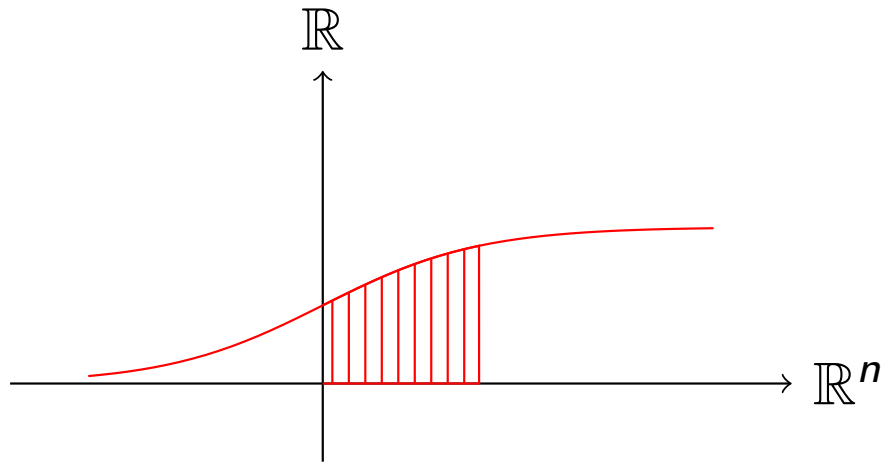
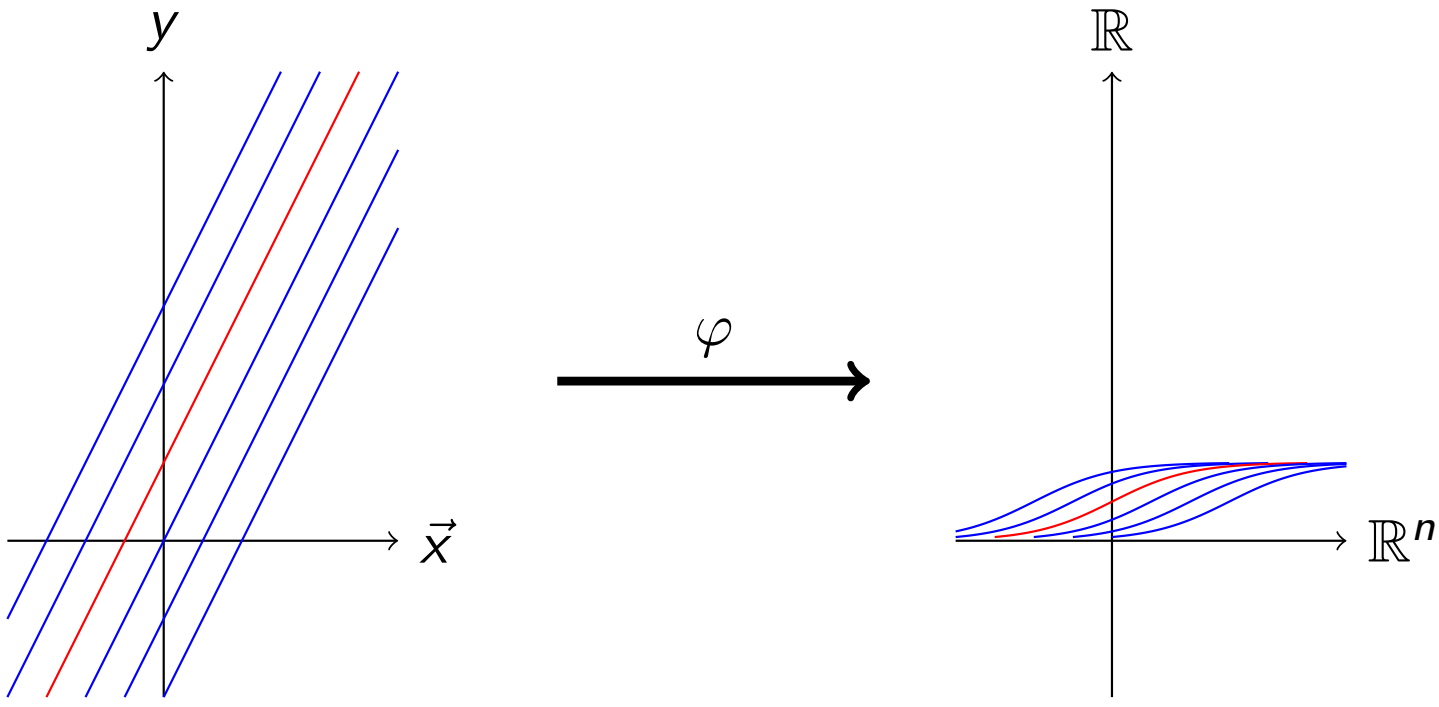



This is changing the weights of the derivatives of y!

# So... What is "discriminatory"?




We can prove that a discriminatory function must be injective (i.e. each line maps to a unique function).

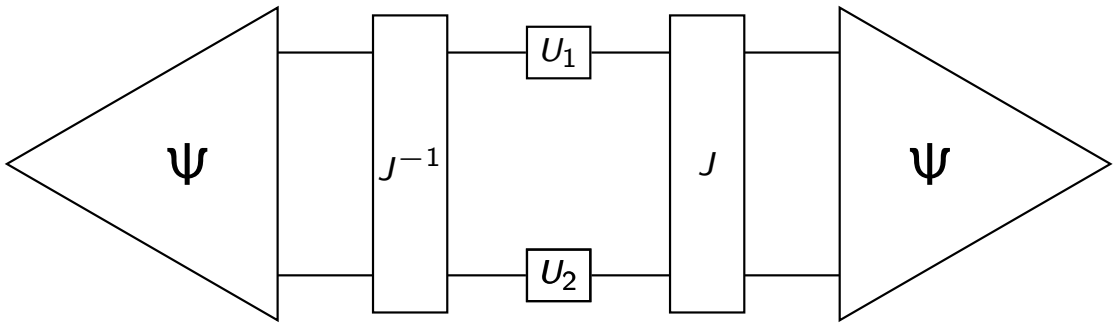
# Why analyze the details of the process?

# We want to guide the design neural networks without directly programming them.

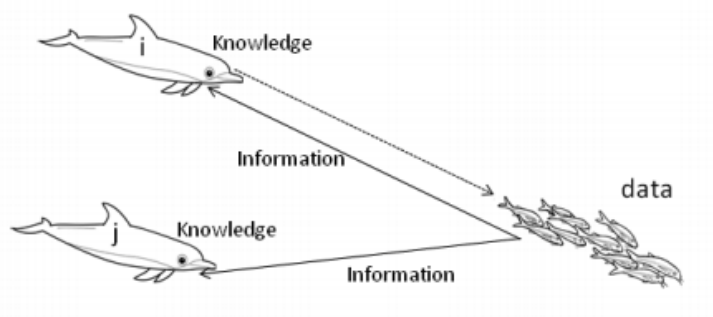
- To want live, autonomous learning; we can't manually write code.
- Organic learning organisms learn continuously. We don't want to distinguish training from implementation.
- We need
  - a set of sufficiently generic but small neural networks,
  - a good metric on the space of neural networks, and
  - rules for growth and shrinking.*
- These needs can be used to define rules for competitive games between neural networks that push the networks to converge.
- This could be a method for an autonomous agent to initiate learning or adjust a seemingly known perception task.

# Once we have many, different neural networks, how can we combine them?

- An autonomy also requires many, different perception tasks that run in parallel.
- The current plan is to entangle of the outputs.




- While this quantum process sounds arbitrary, it turns out to model herd movements well—especially echolocating herds since they share more information. [3]




[3] See Lusseau, D. Quantum-like perception entanglement leads to advantageous collective decisions. ArXiv 1308.0668.