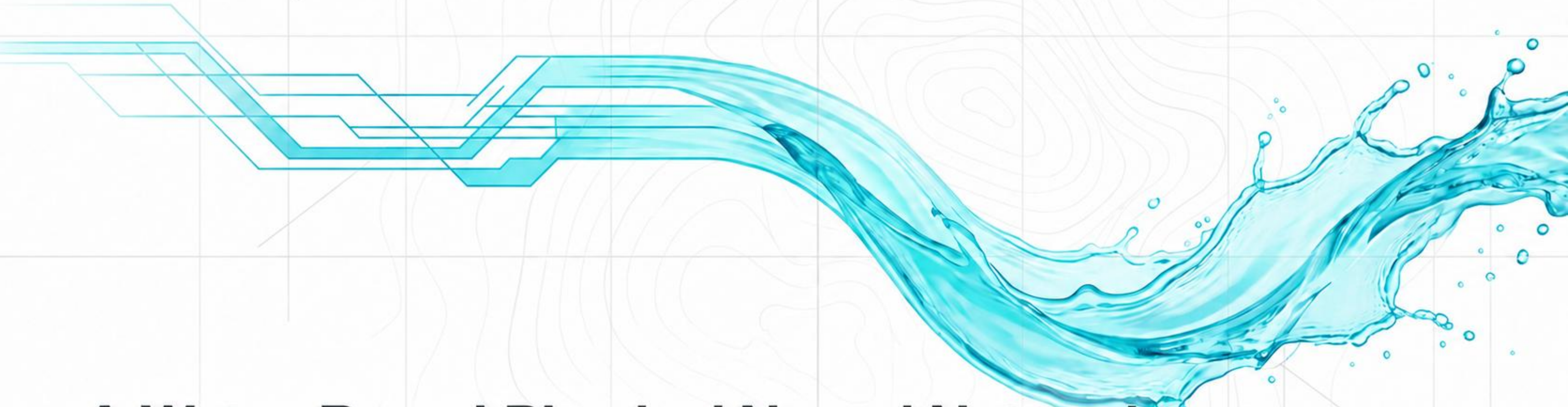


A Water-Based Physical Neural Network

Presenters: Matan Babash & Alon Elhayani

Supervisors: Hila Manor & Noa Cohen

Date: 26.05.2026

AI Changes the World

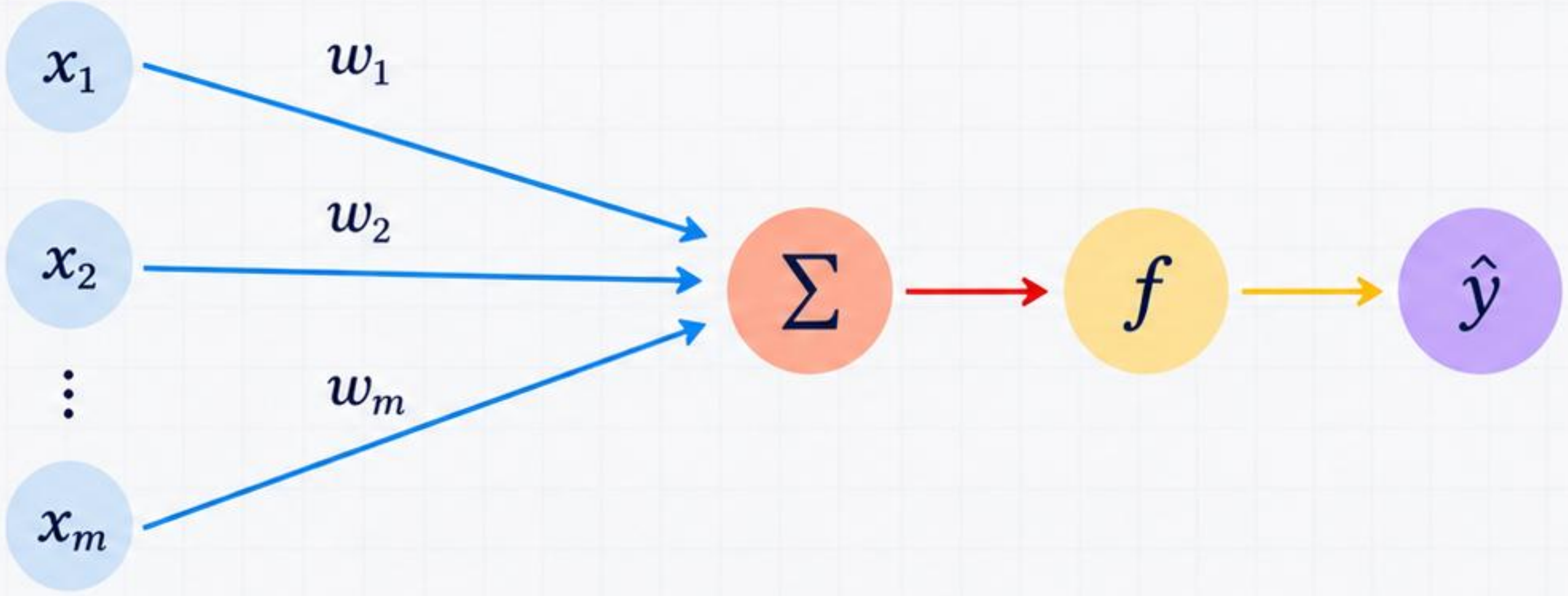
Software Development:
Smarter coding and automation.

Education:
AI as a teacher and personalized learning source.

Content Creation:
Generating ideas, writing, and designing.

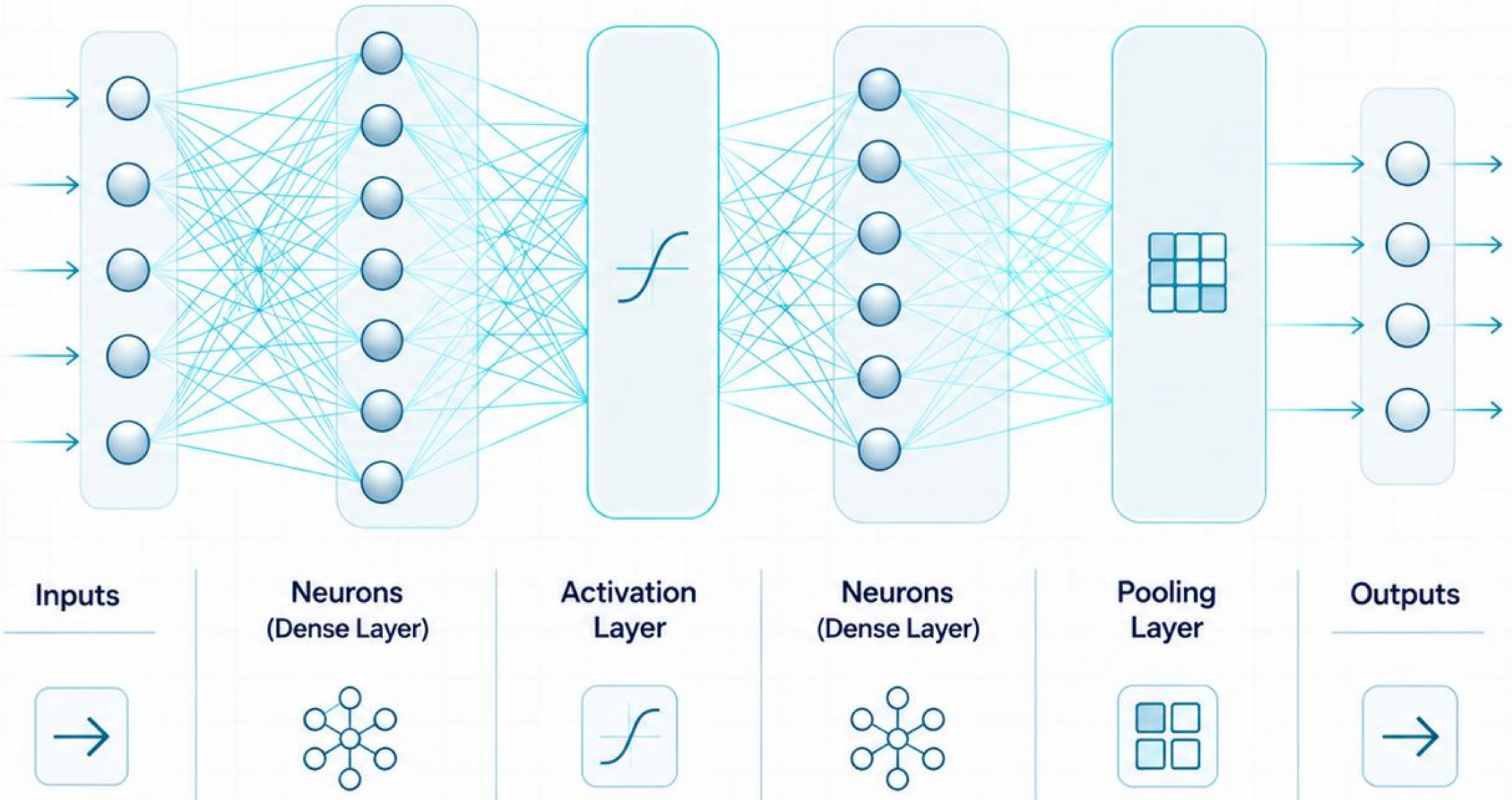
Media & Entertainment:
Creating engaging content and experiences.

The Single Neuron



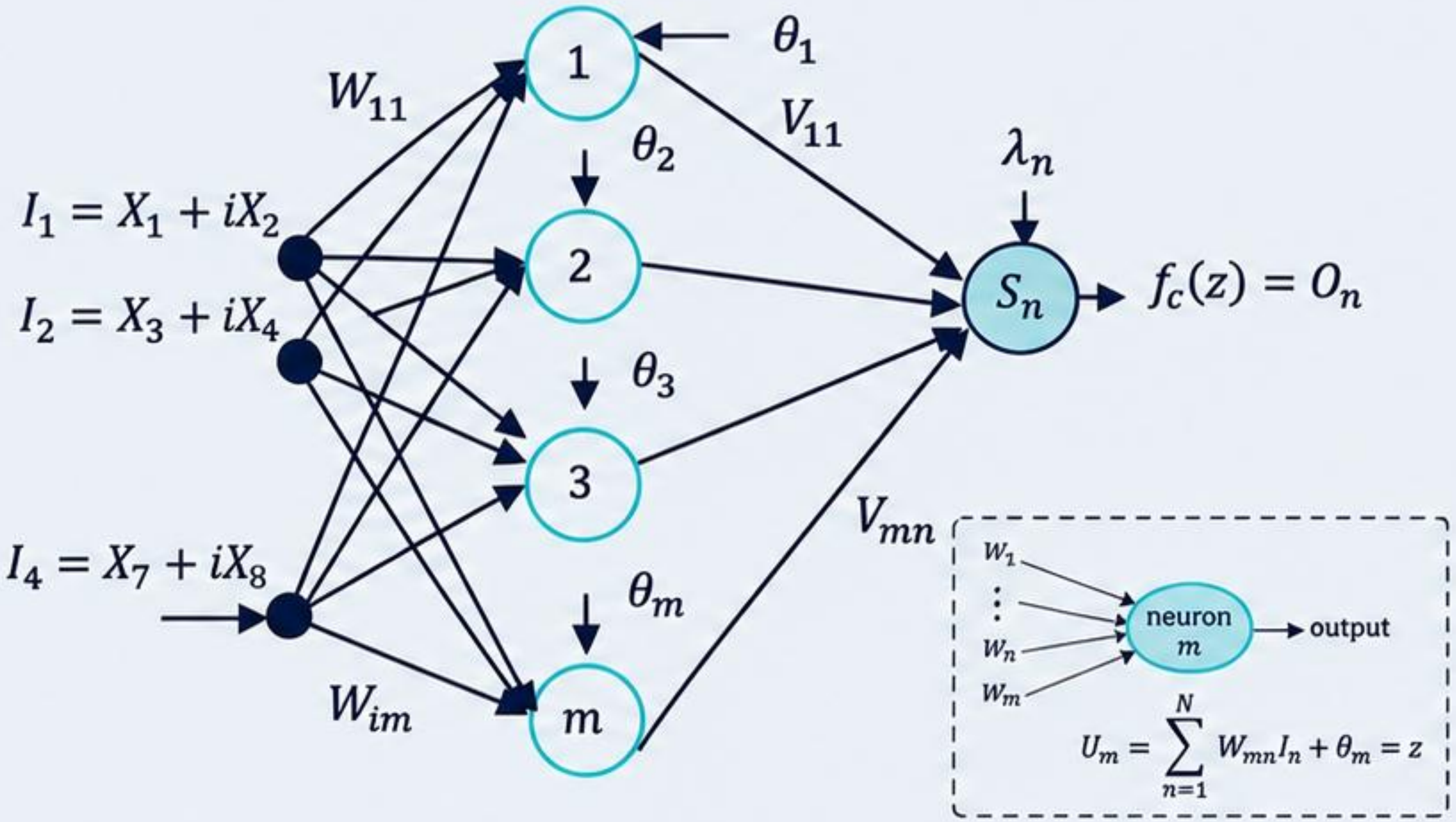
Inputs	Weights	Sum	Non-Linearity	Output
$x_1, x_2, \ldots, x_m$	$w_1, w_2, \ldots, w_m$	$z = \sum_{i=1}^{m} w_i x_i$	$f(z)$	$\hat{y} = f(z)$

The Neural Network

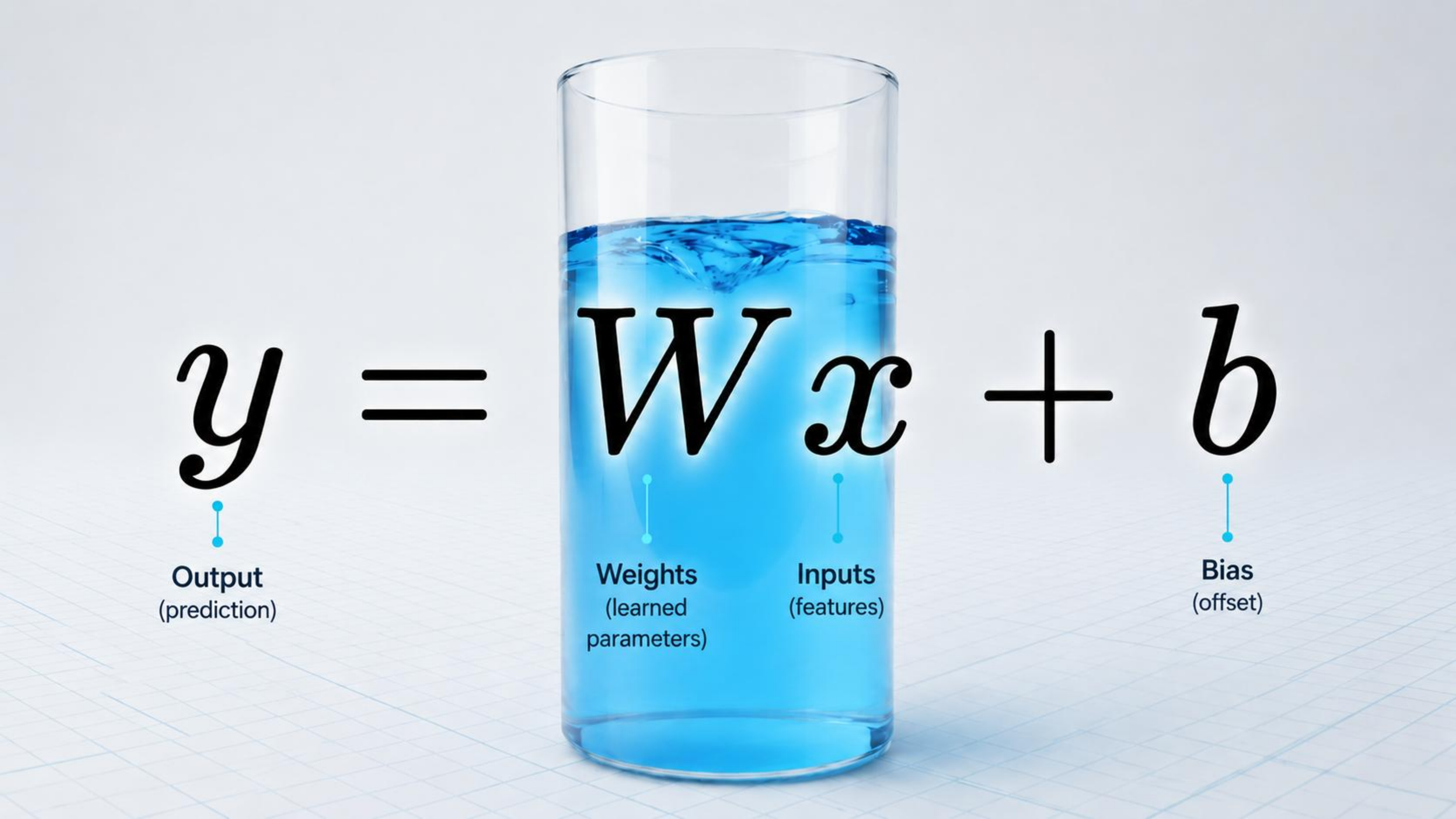


The Abstraction Barrier in Machine Learning Education

The Mathematical Reality

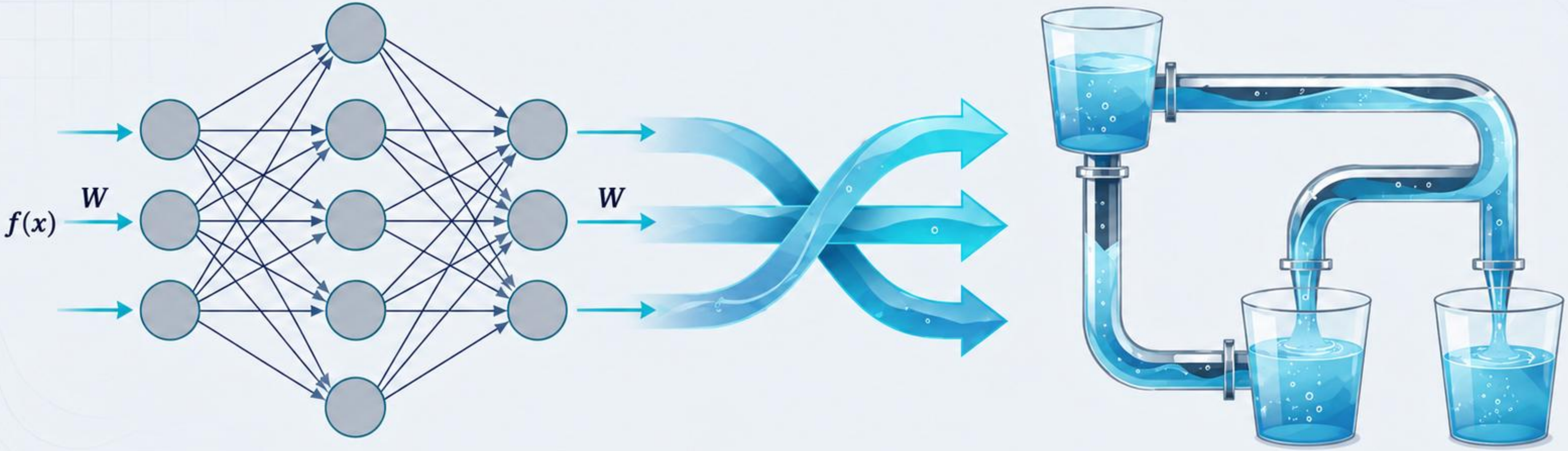


The Gap: We rely on highly abstract mathematics to explain systems that make highly tangible decisions. How do we make the invisible visible?


$y = Wx + b$
Output
(prediction)
Weights
(learned
parameters)
Inputs
(features)
Bias
(offset)

Bridging Intuition and Mathematics

What if we can use water instead?



Making the Invisible Visible

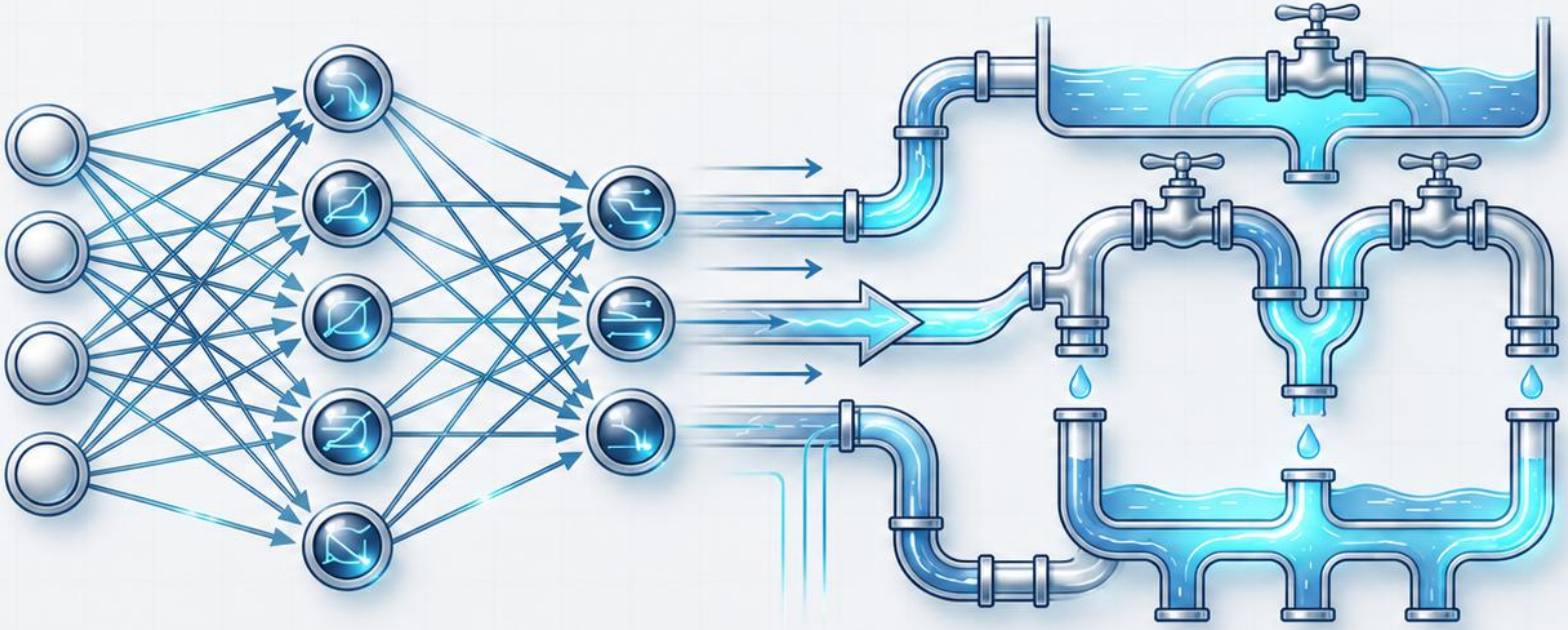
The Idea: Build a physical model to illustrate network mechanics.

The Translation:

- Neuron = Container
- Weights = Volume
- Moving Data = Water Flow

Goals:

- Educational: Simplify machine learning principles.
- Conceptual: Implement mechanics over digital computation.



Distilling the MNIST Dataset

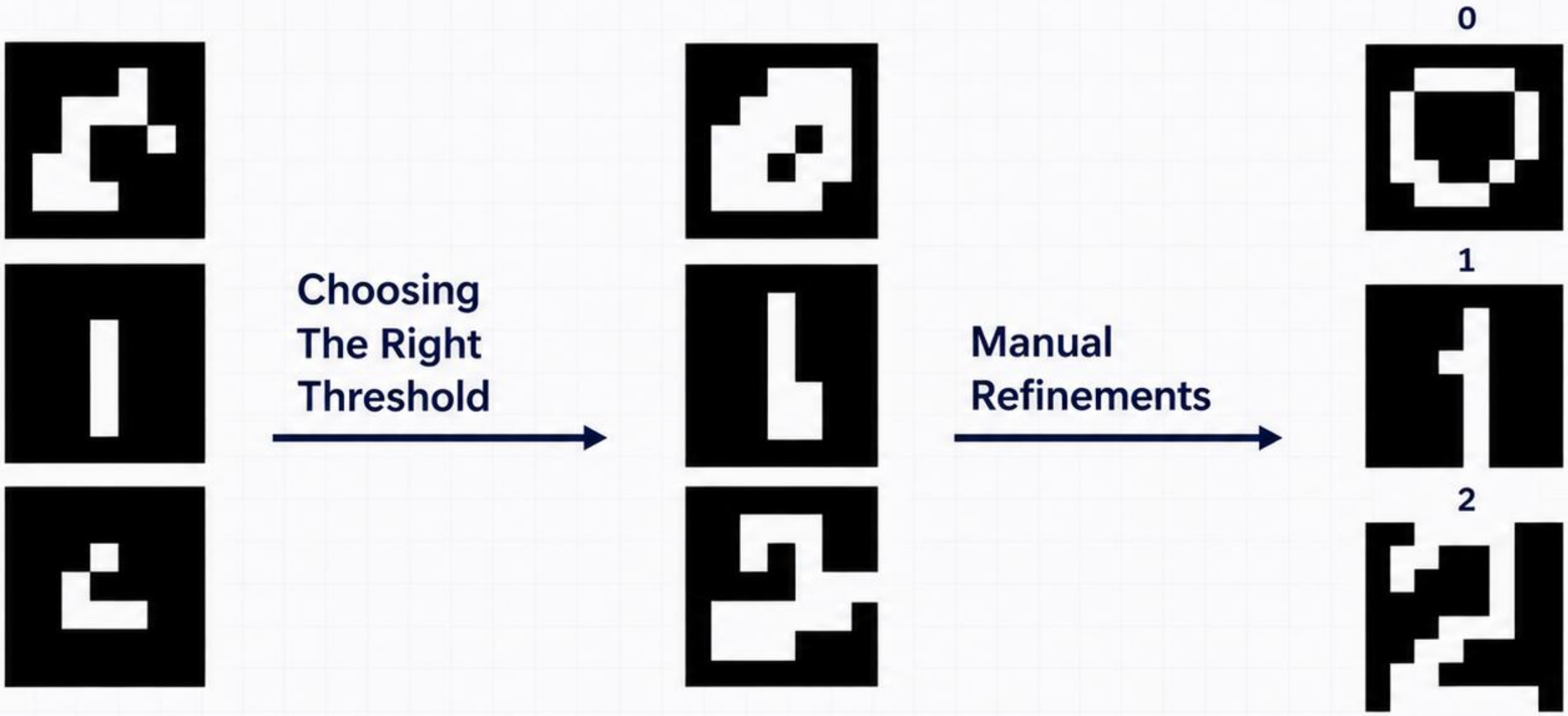
Original: 28x28
handwritten digits

Output: 8x8 input grid
for physical training

Original: 28x28
handwritten digits

Output: 8x8 input grid
for physical training

Data Refinement Pipeline

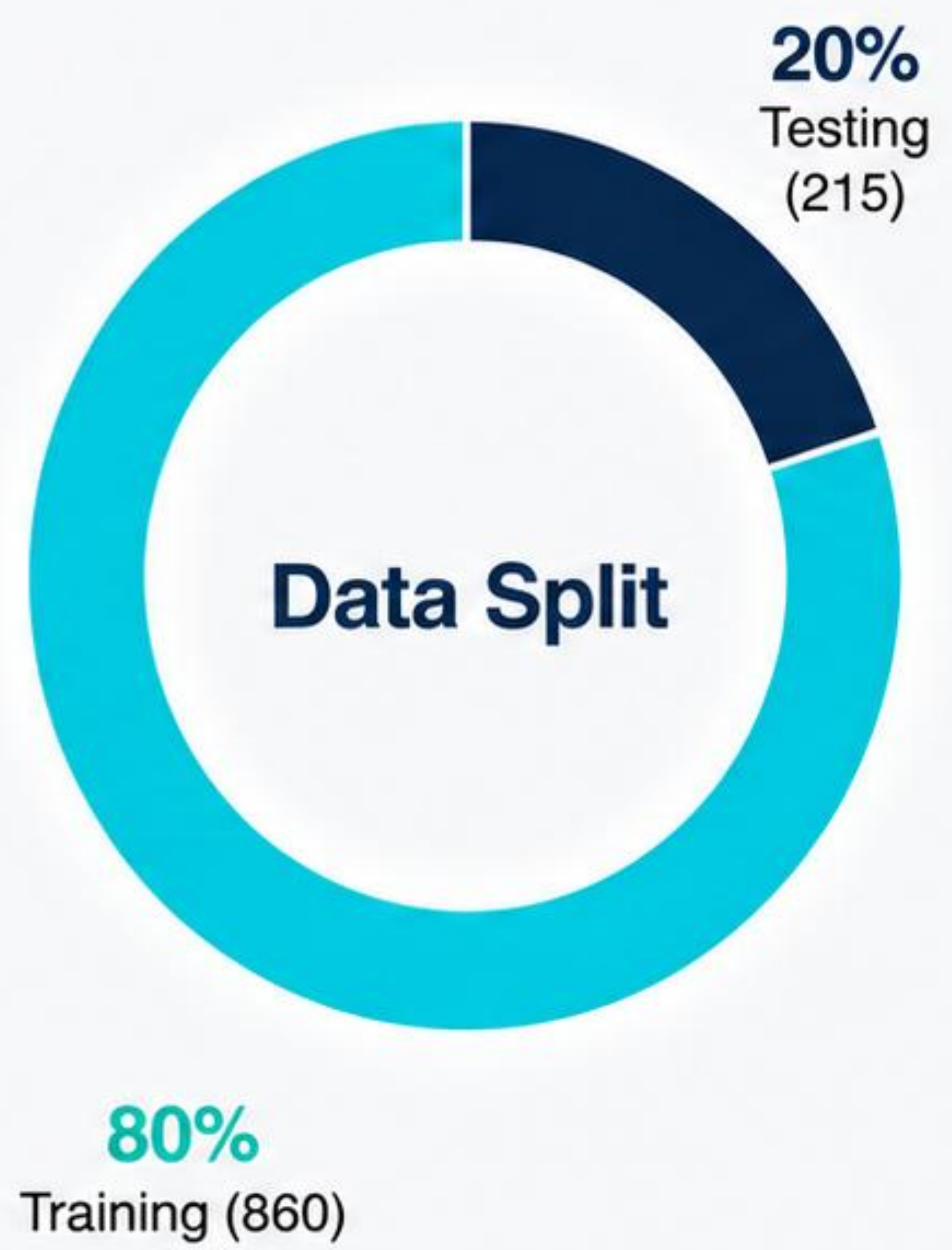


Dataset Composition & Augmentation

1,075

Total Curated Images

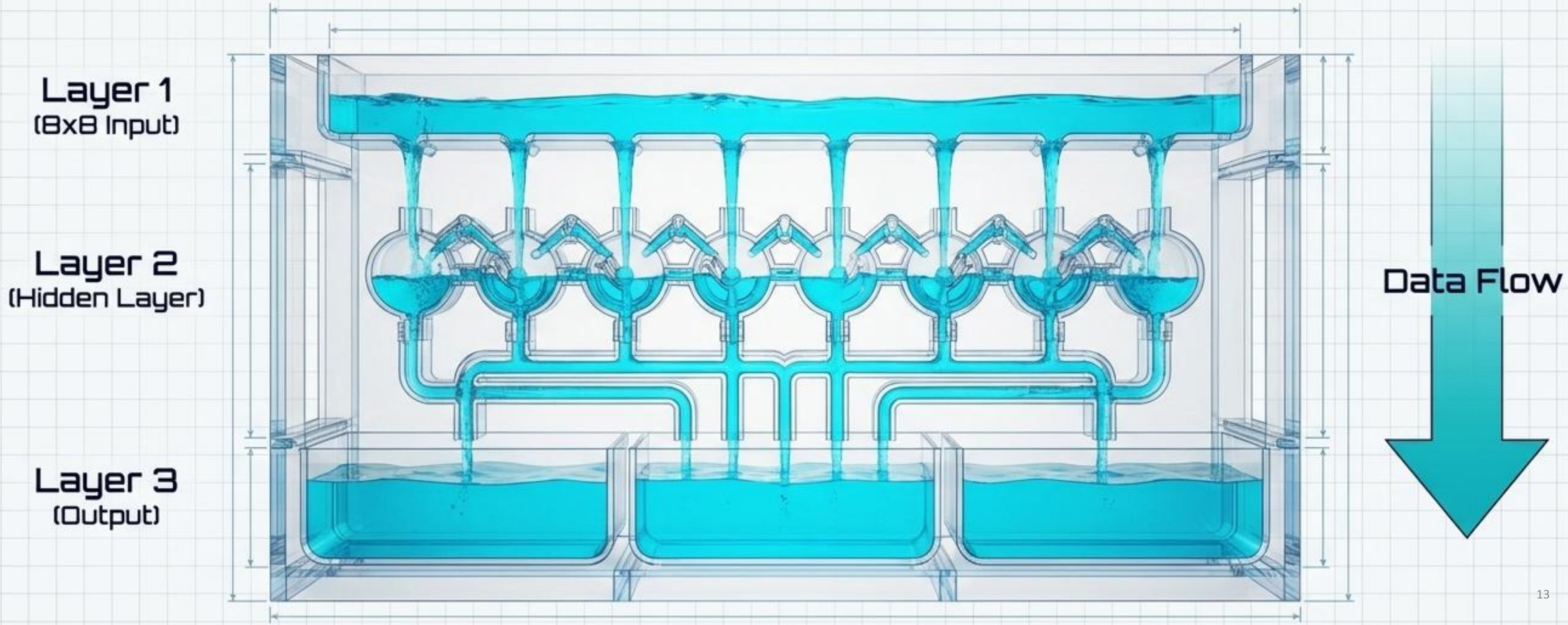
Highly ambiguous or poorly drawn samples were manually filtered to prevent physical miscalibration.



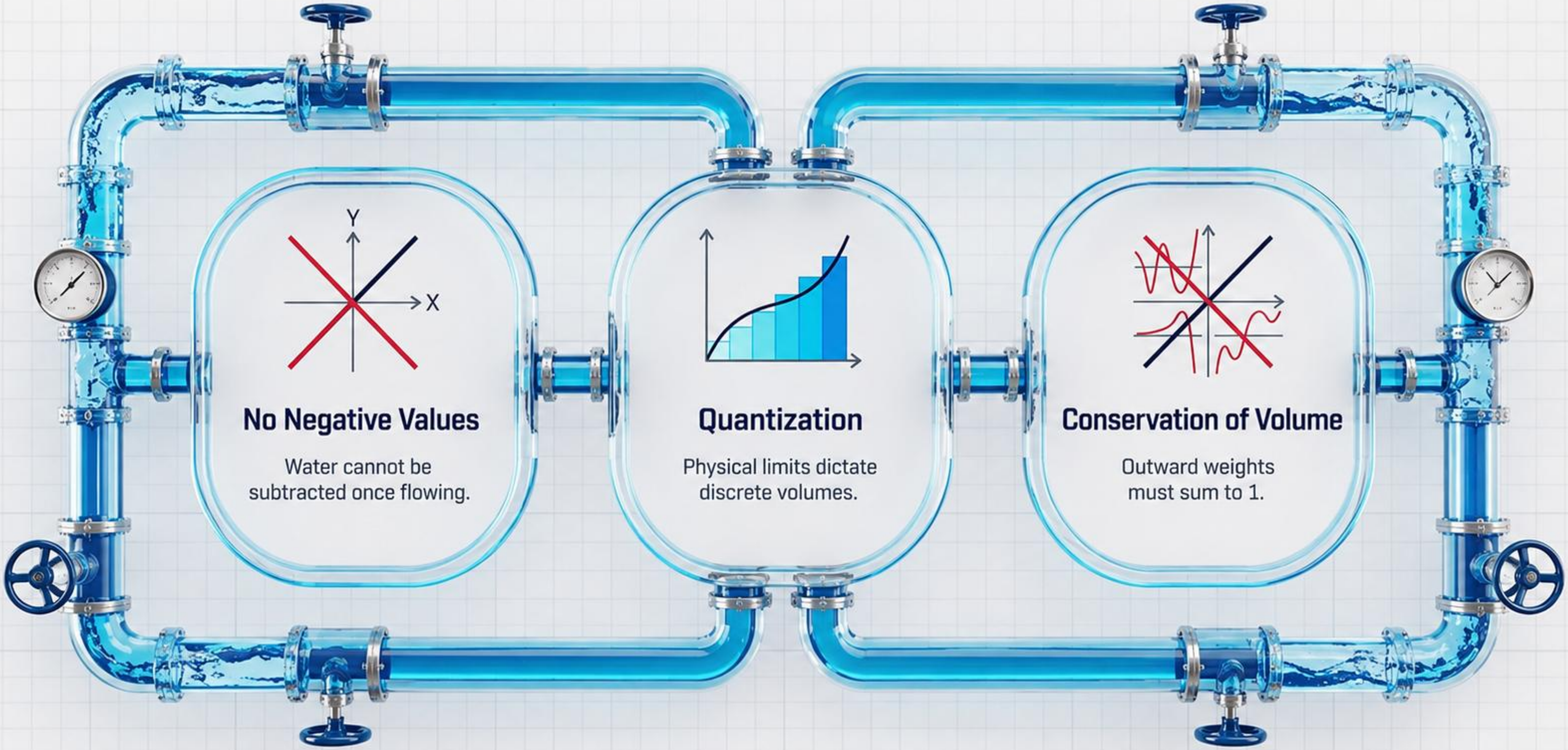
Utilizing Gravity as the Processor

The Problem: Data must move simultaneously.

The Physics Solution: Rotate the network 90 degrees downward.



Constraint Framework



Physical Constraints as Optimization Problem

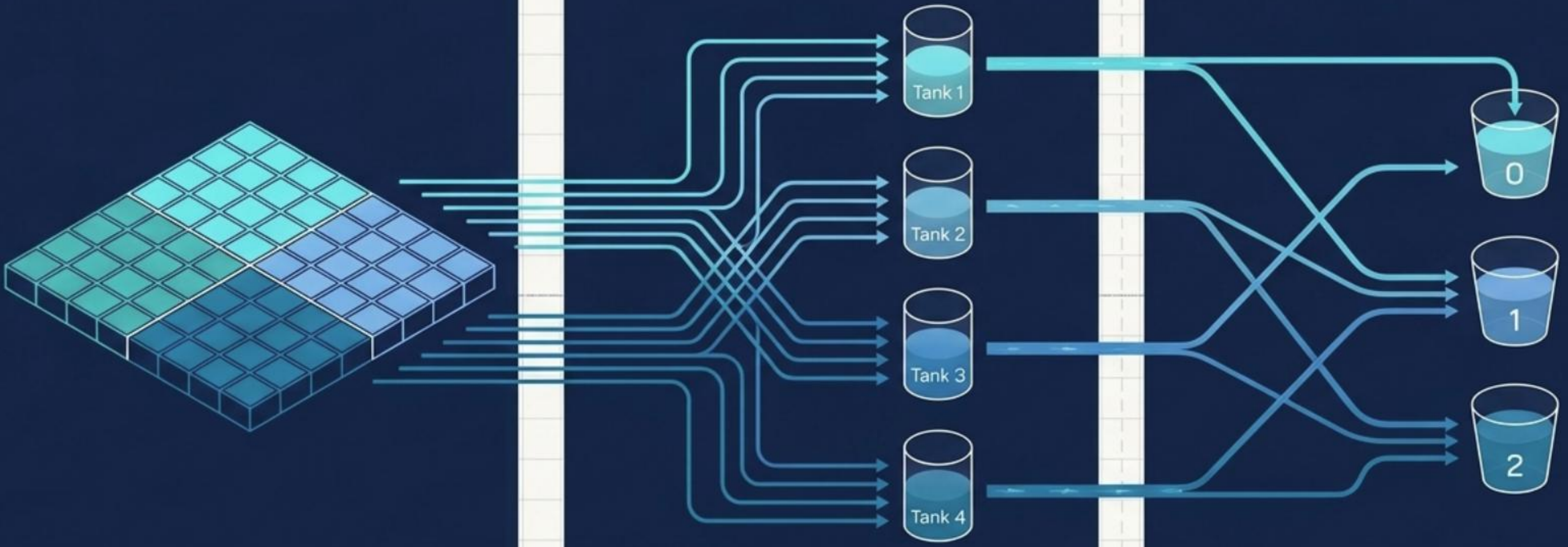
$$\min_{W} \quad \mathcal{L}(W) \quad \text{(classification loss)}$$

$$\text{such that} \quad \begin{cases} 0 \leq W_{ij} \leq 1 & \text{(non-negative physical flow)} \\ W_{ij} \in Q & \text{(quantized, realizable values)} \\ \sum_j W_{ij} = 1, \ \forall i & \text{(conservation of volume)} \end{cases}$$

Weights must satisfy physically realizable flow constraints:

non-negative, quantized (2 decimal places), and sum to exactly 1 for each hidden neuron.

The Architecture: Localized Processing



Input Layer (64 Nodes)

The compressed 8x8 MNIST digit is split into four distinct 4x4 spatial regions.

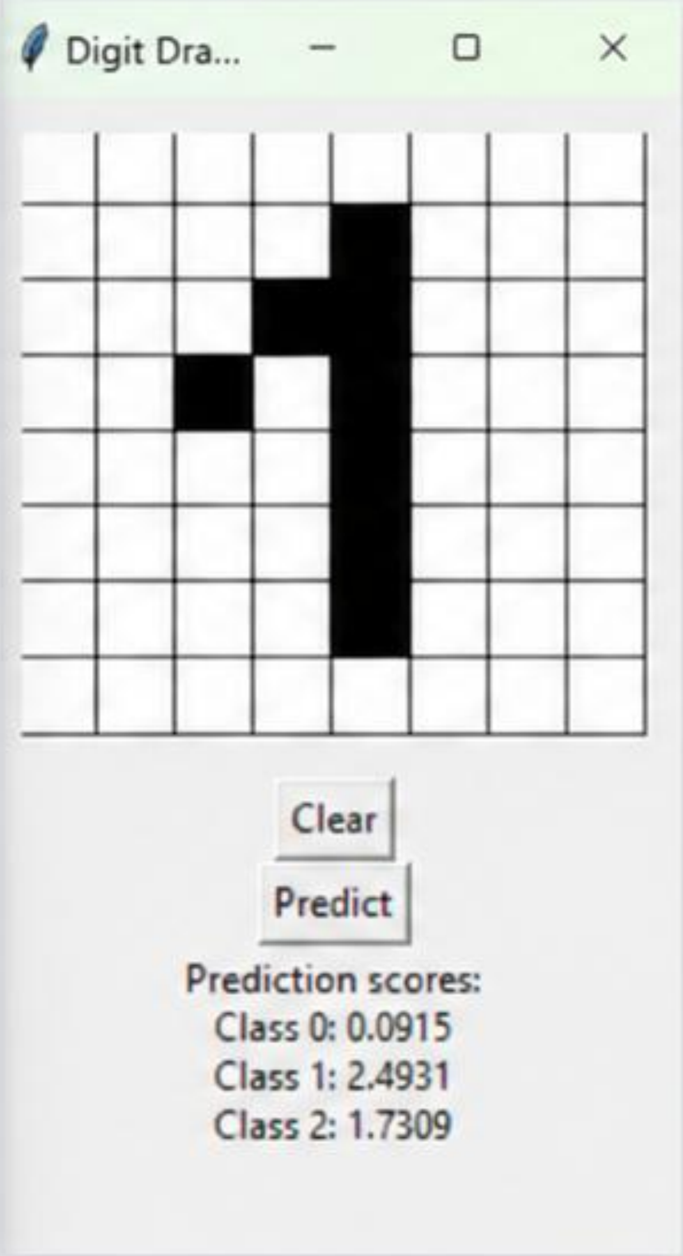
Hidden Layer (4 Nodes)

Each quadrant feeds exclusively into its own dedicated hidden neuron, drastically reducing physical complexity and tube crossing.

Output Layer (3 Nodes)

The four hidden neurons distribute their accumulated fluid into three output buckets representing the final classifications.

Simulation for Confidence Level

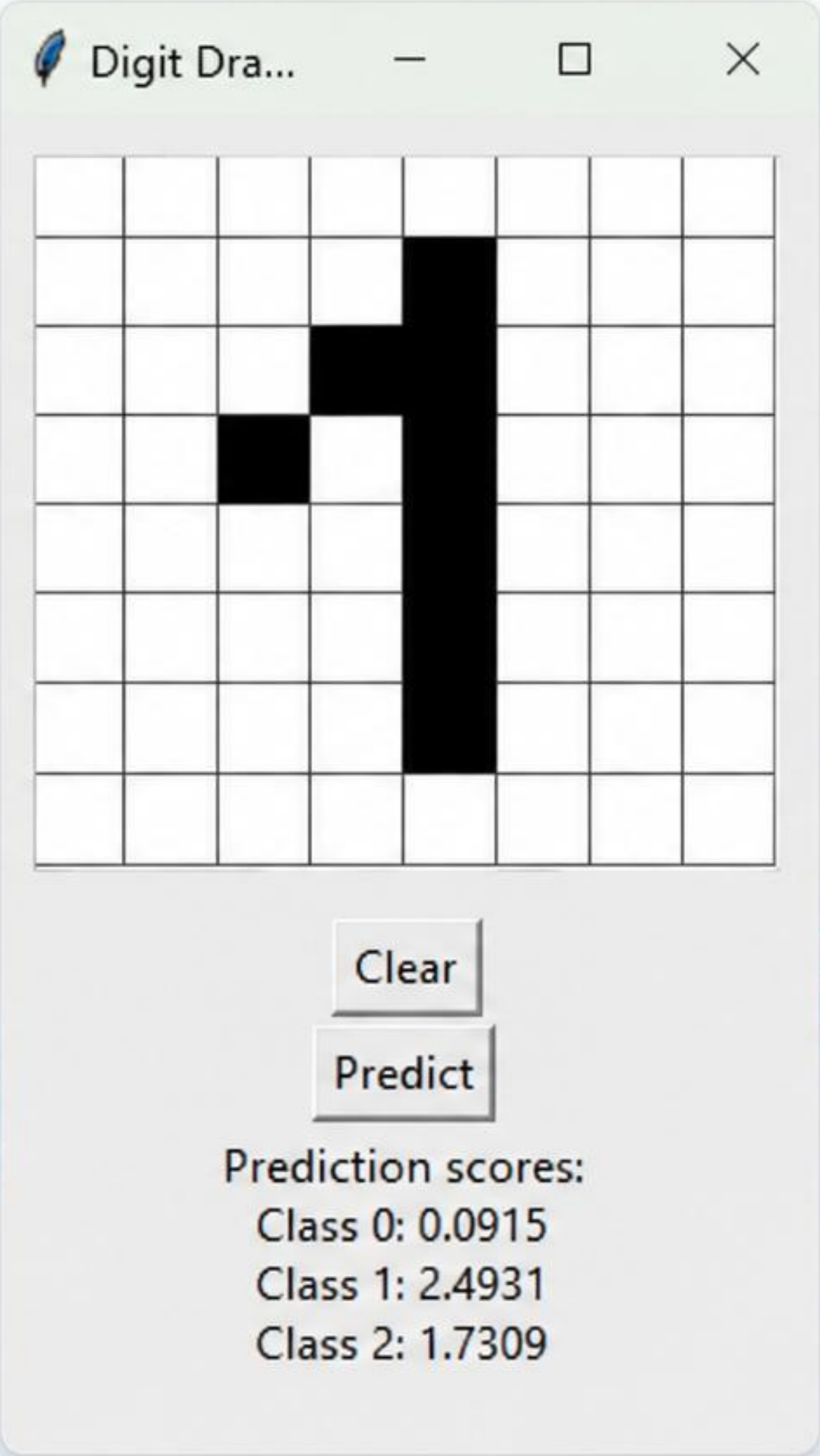


We built a simulation to evaluate the model's confidence level.

Digital Proof of Concept

80% Classification Accuracy

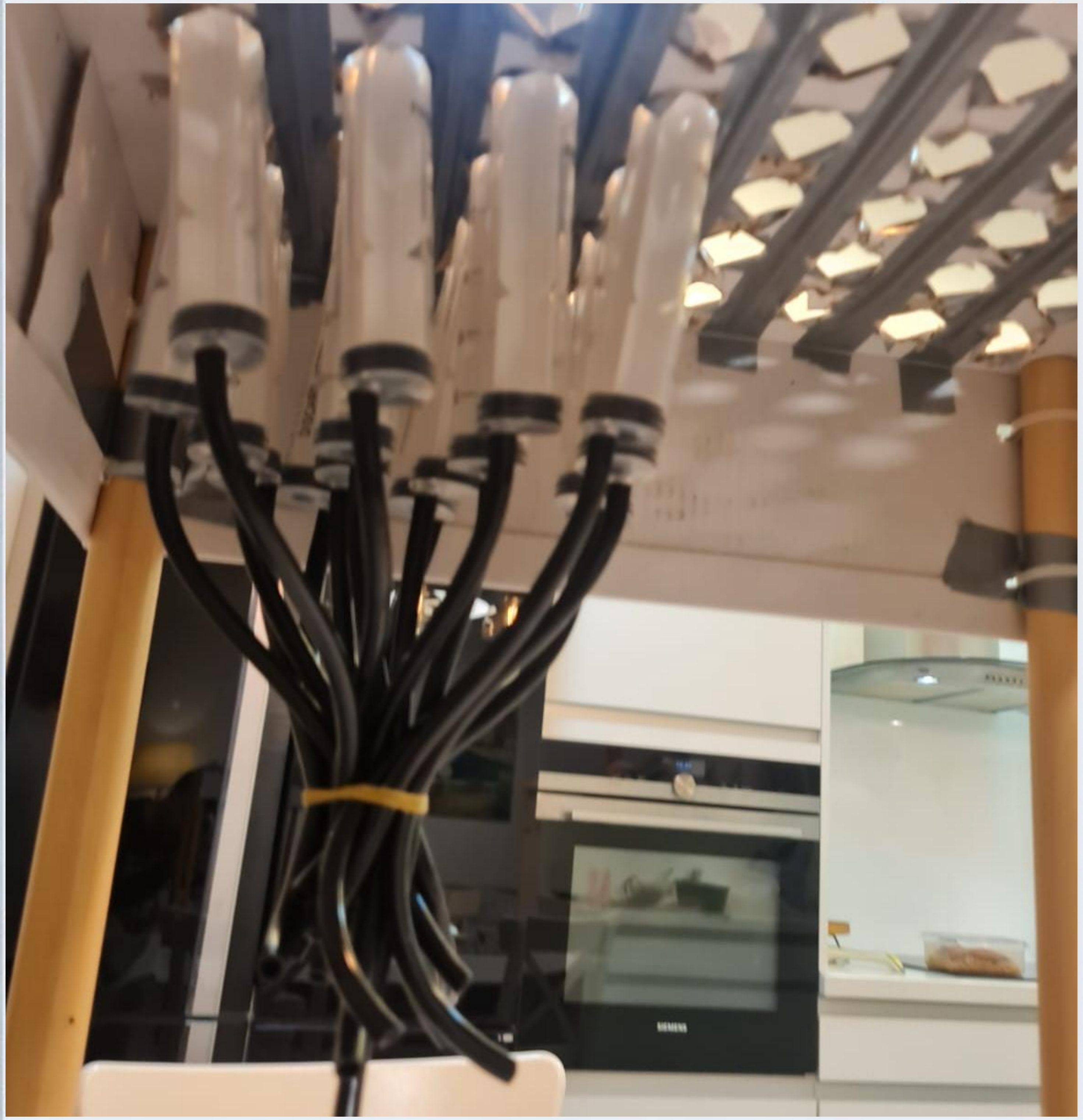
Key Insight: Digital prediction scores translate into physical water levels.



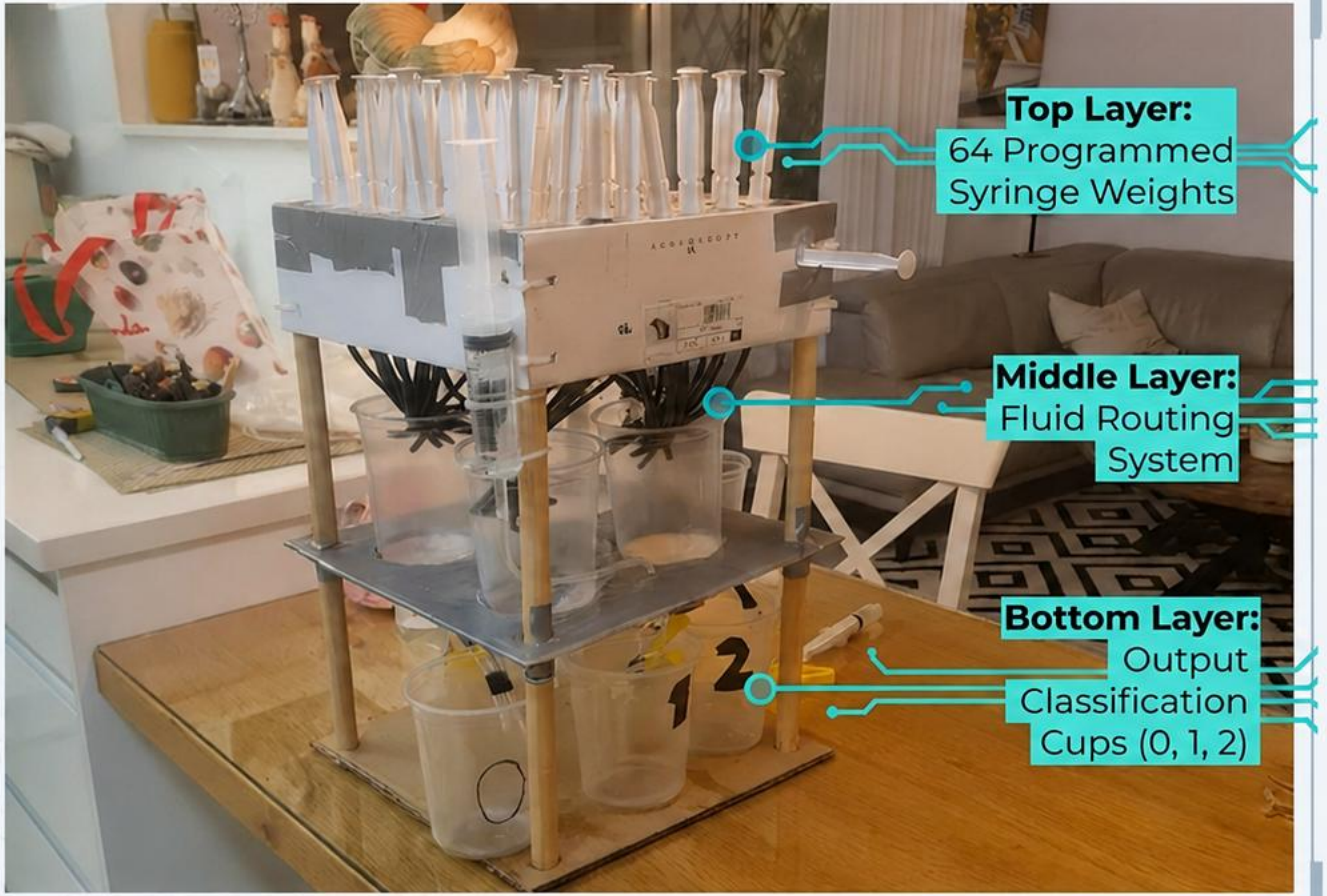
The Prototype

The Input Matrix: 64-Neuron Initialization

The Input Matrix: 64-Neuron Initialization

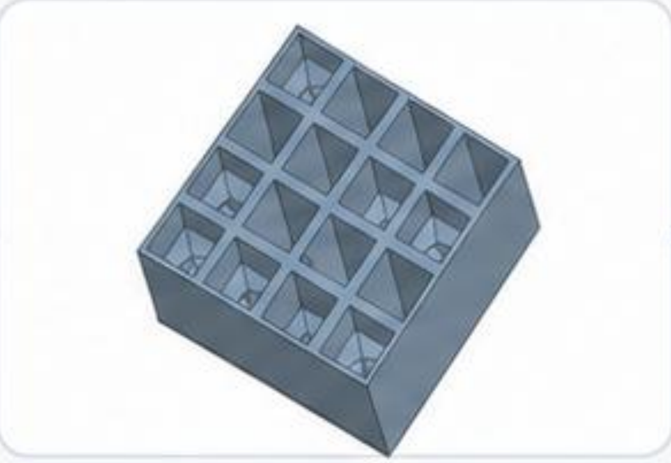


The prototype : a water based neural network



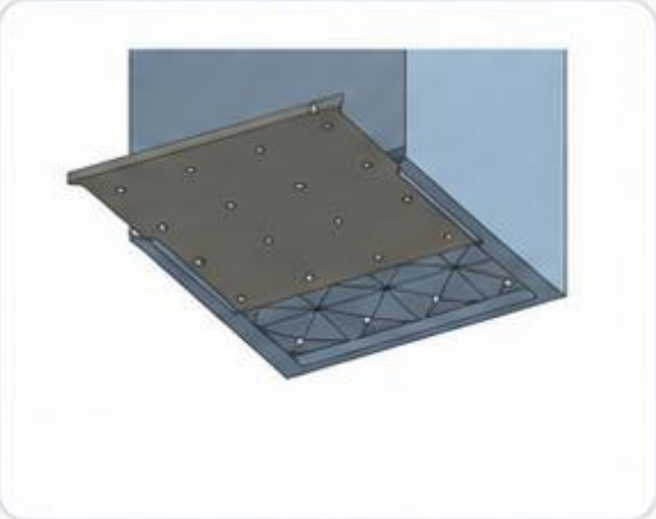

SUGARDADDY
1
2
DRIP DRIVE: See How Sugar is Measured!
A Unique and Force
Gravity and Force

What We Built



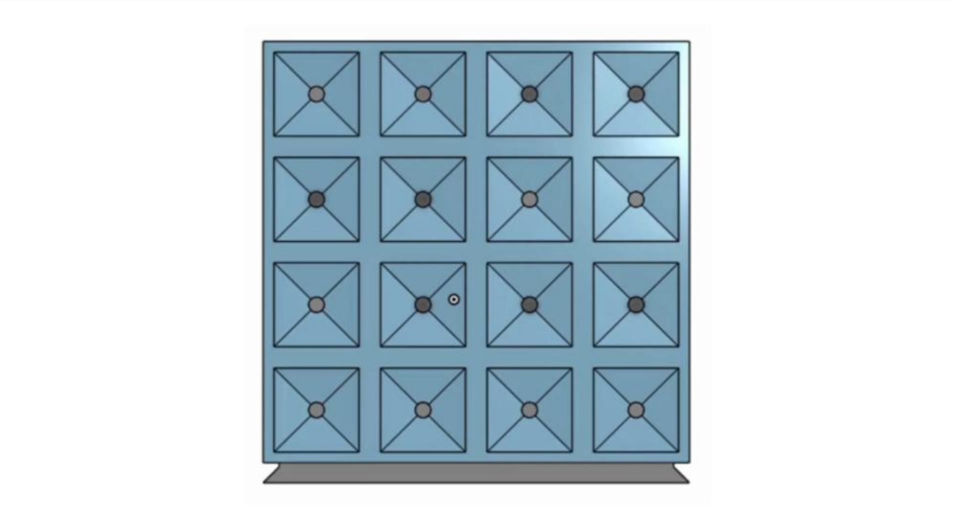
Digit Insert

Collection Tray



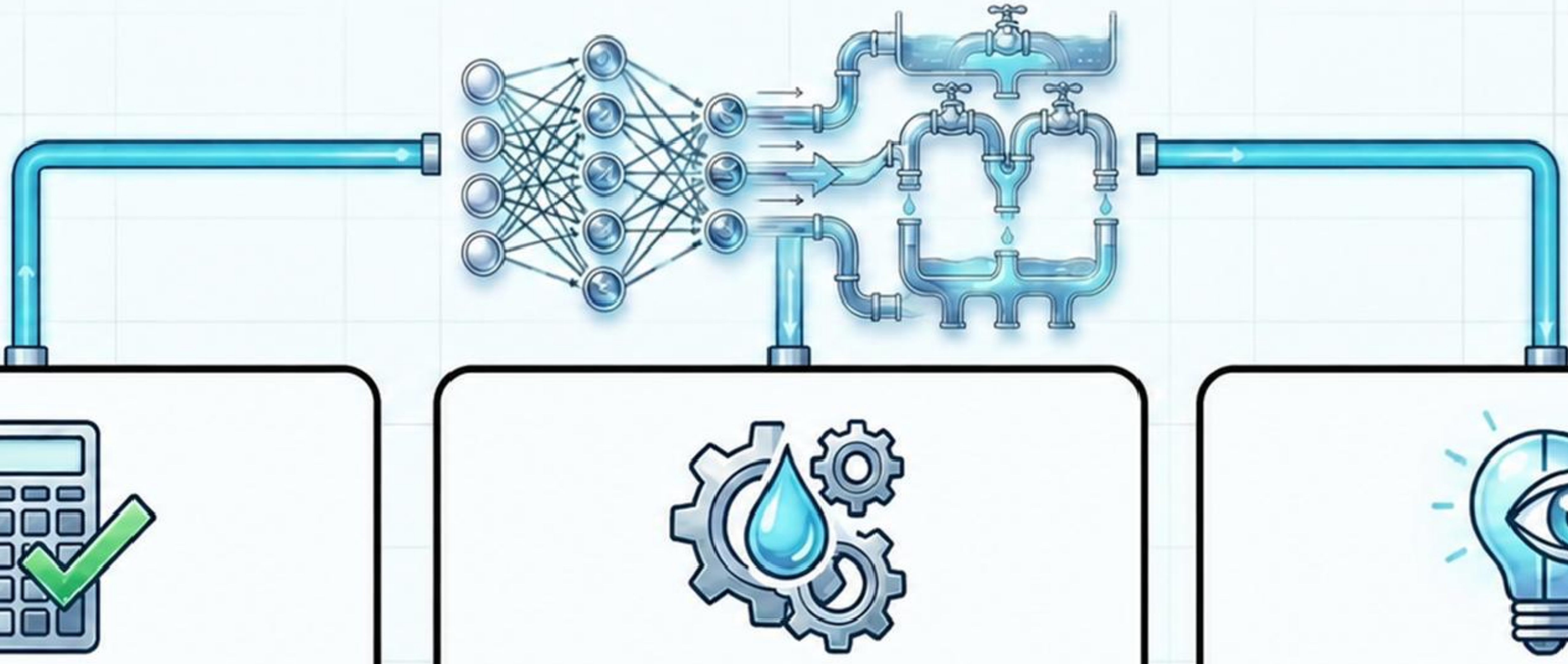
Release Door

Base



Conclusion: Bridging the Abstraction Barrier

Proving computational logic via fluid mechanics



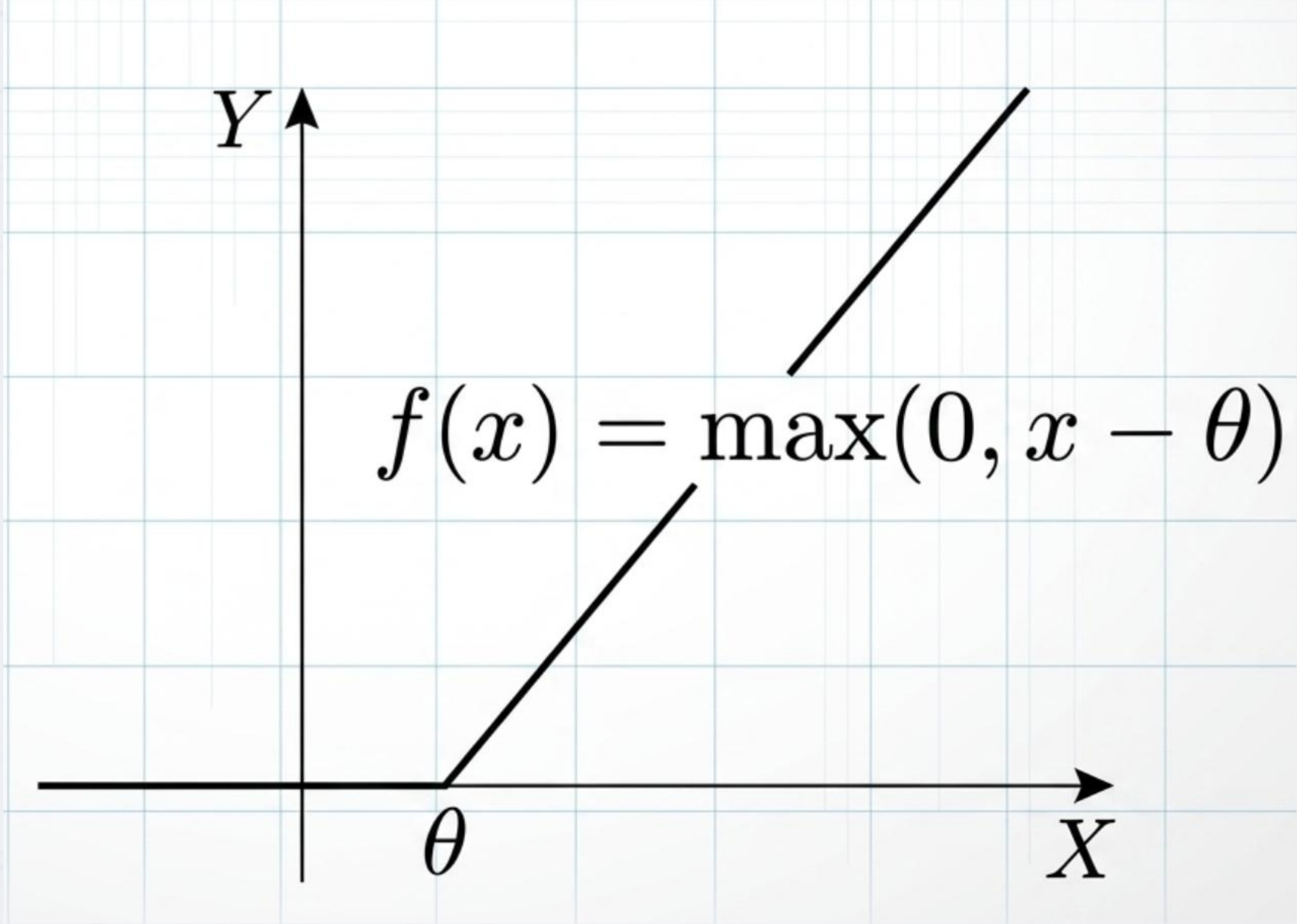
1. Mathematical Proof of Concept

2. Engineering Translation

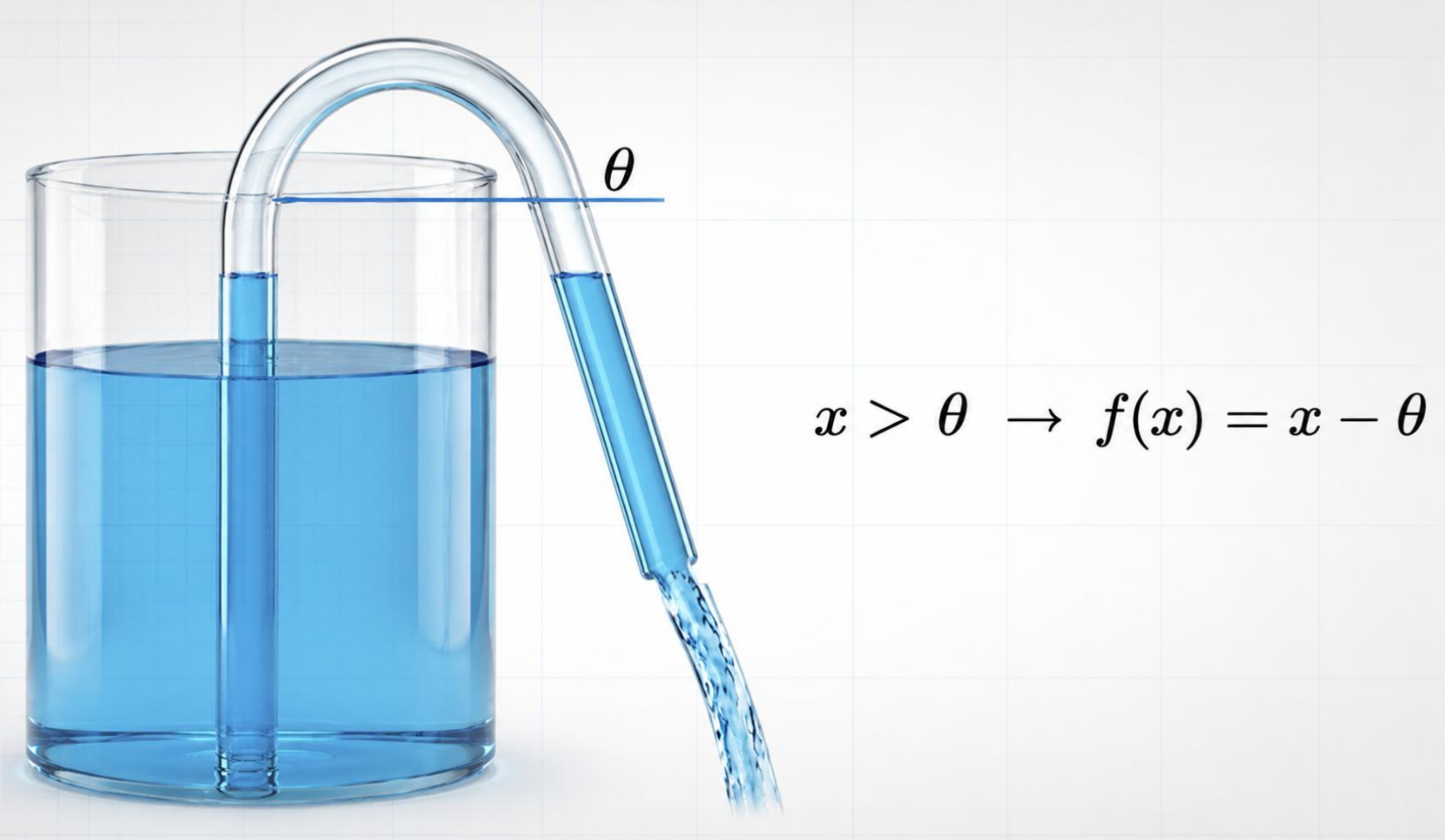
3. Educational Breakthrough

Future Work

ReLU Function

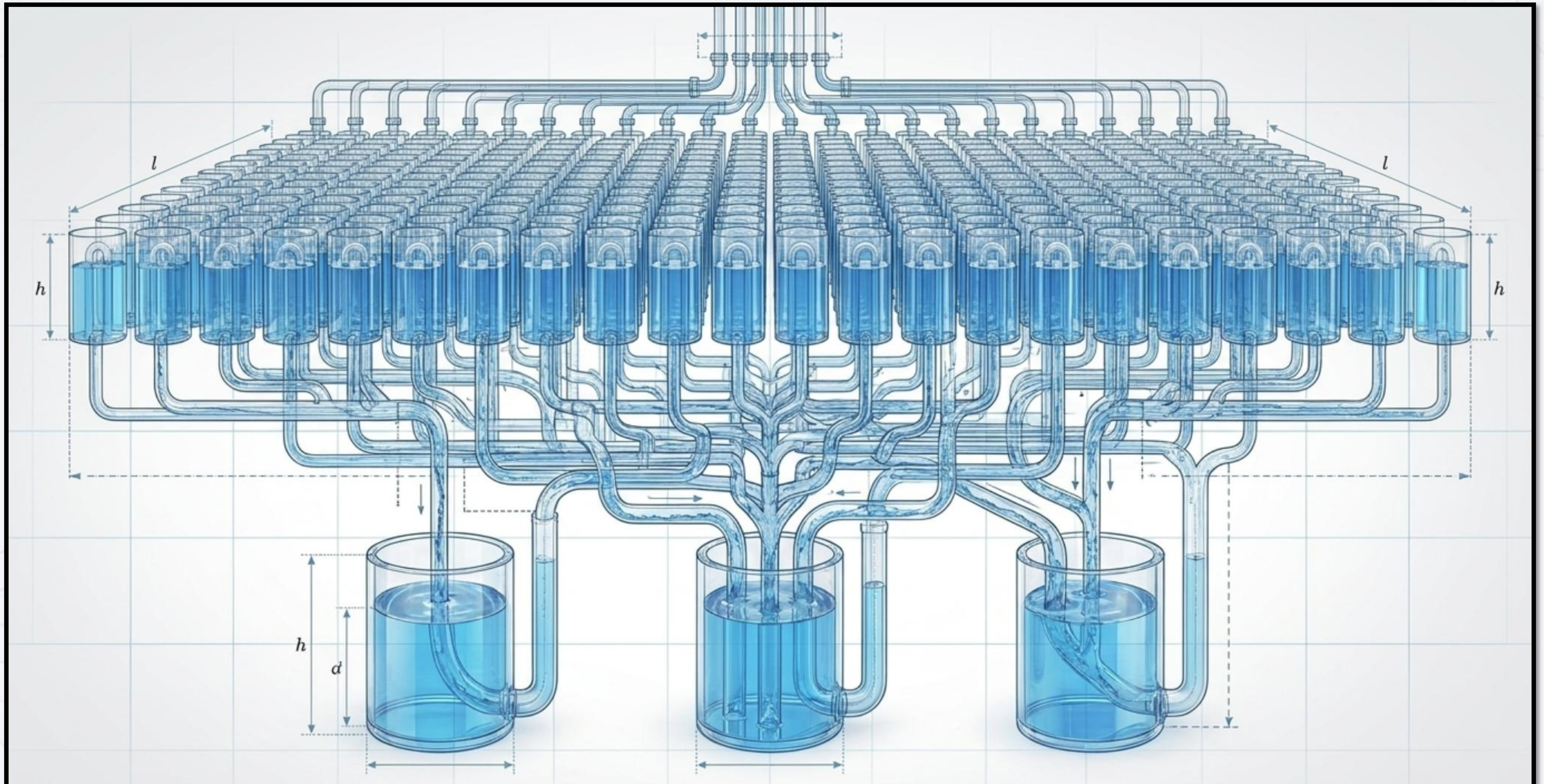


Siphon



Future Work

Leverage the universal approximation capability of ReLU networks to achieve arbitrarily high precision and build fully sized model.



Siphon Arrays: Non-Linearity at Scale

Questions?