Proximity as Perception: An Ultrasonic Sensor as a Spatial Sensory Organ for General-Purpose Computing, and the Perceptual Wave Function as its Mathematical Processor

Dany D. Ruiz

Researcher – PERCEPTEMPLE · El Salvador

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"The robot does not feel—it reacts to numbers.
The question is whether a number can be perceived."

Abstract

General-purpose computers receive signals through discrete and encoded channels: keyboard, microphone, camera, WiFi, Bluetooth. None of them continuously perceive the physical space surrounding them. This is not a technical limitation—it is a design assumption so widespread that it is rarely questioned.

This work poses a different question: *what happens when a computer is given a spatial sense it was never designed for?*

The PWF Physical Probe is an invitation before it is a report. It uses an HC-SR04 sensor, a three-dollar microcontroller, and a common computer to run the formalism of the Panperceptual Theory of the Universe (PTU) on the real physical world. Anyone can replicate it with what they have at home.

The instrument operates in two layers. The first is computational: the formalism runs on synthetic signals derived from the scientific literature. The second is physical confirmation: the same formalism applied to real sensor data. The convergence between layers is not the final result—it is the starting point for those who wish to go further.

This is a first step of the PTU formalism into the physical world. The formalism now has a place to run. And that place can be built in an afternoon.

Keywords: Perceptual Wave Function, transducer, spatial perception, general-purpose computing, HC-SR04, mathematical validation, Panperceptual Theory of the Universe, PercepWare, PWF Physical Probe, embodied computing.

1. The Gap: A Computer That Cannot Feel Space

A modern laptop contains accelerometers, GPS, cameras, microphones, and radio receivers. It knows its orientation, its location on the planet, its users' faces, and the content of signals traveling at gigahertz frequencies.

It does not know whether there is a hand 30 centimeters in front of it.

This reveals a structural assumption embedded in the design of every general-purpose computer: the immediate physical space is not a relevant input. Computers were built to process information—text, numbers, signals—not to inhabit space.

Robotics solved this problem for machines that need to move. But robots are goal-oriented: their sensors exist to avoid, navigate, grasp. The number produced triggers a motor response. The sensor is a tool for action.

What would it mean to give a computer a spatial sense not for action, but for *perception*? Not to react to a distance, but to process it as data within a mathematical framework designed to evaluate perceptual existence. That is the question this work addresses.

2. What Does a Sensor Actually Do?

2.1 The Transducer: Converting the World into Numbers

Every sensor performs the same fundamental operation: it converts a physical phenomenon into an electrical signal that a microcontroller can read as a number. This is called **transduction**.

Table 1: Sensor Taxonomy by Physical Principle

Sensor	**Principle**	**Conversion**
HC-SR04 (ultrasonic)	Time of flight, sound	Duration → distance (cm)
Sharp GP2Y (infrared)	Optical triangulation	Angle → distance
LiDAR	Time of flight, laser	Delay → 3D point cloud
VL53L0X (ToF)	Optical time of flight	Photon delay → mm
Capacitive	Electric field variation	Capacitance → proximity
IMU	Inertial forces	Acceleration → orientation

What unites them all: **none of them feel.** They measure. A robot does not perceive proximity—it receives a number and executes a conditional branch. The sensor is a transducer. The robot is a state machine.

2.2 The Robot Does Not Feel—It Reacts

In classical robotics:

MOTOR RESPONSE

$\uparrow$

conditional branch

$\uparrow$

NUMBER

$\uparrow$

sensor

$\uparrow$

PHYSICAL PHENOMENON

The number is never evaluated for its meaning. There is no operator that asks: *does this represent something that should be integrated into a persistent model of experience? What is its perceptual weight over time?* Robotics does not ask these questions because navigation does not need them.

2.3 The Question This Work Poses

What if the number produced by a sensor were fed into a **mathematical operator designed to evaluate perceptual existence**?

PERCEPTUAL COLLAPSE OR FORGETTING

$\uparrow$

PWF operator

$\uparrow$

NUMBER

$\uparrow$

sensor

$\uparrow$

PHYSICAL PHENOMENON

The robot reacts to the number. This apparatus *perceives* it—or decides not to. A component designed for robotics becomes something different: not an obstacle detector, but a **spatial sensory organ** for a device that never had one.

3. Mathematical Framework

The Panperceptual Theory of the Universe describes perception through a mathematical formalism [1]. The formulas that follow are not decoration—they are the instrument. Each one does something concrete with the sensor data.

3.1 The Perceptual Wave Function (PWF)

The PWF assigns a dynamic value to an input stream over time [2]:

$$\Psi(t) = A(t) \cdot \sin(\omega \cdot t + \varphi) \tag{1}$$

where $A(t)$ is the Resonant Amplitude; $\omega = 2\pi f$ is the observer's processing frequency; φ is the phase offset at the start of the session.

It is a computational operator applied to sensor streams. Its results are evaluated against the operator's own predictions.

3.2 Amplitude Mapping

$$A(t) = 1 - \frac{d(t)}{d_{\max}} \tag{2}$$

Minimum distance yields maximum amplitude; maximum distance yields $A \approx 0$. A deliberate starting point: transparent, auditable, and intentionally linear so that deviations from expected behavior are unambiguous. Alternative mappings— Weber-Fechner, inverse square, logistic— are empirical questions that the data will answer.

3.3 The Perceptual Complexity Index (PCI)

$$PCI = \ln(1 + L \cdot E) \tag{3}$$

where L is the total number of samples in a session and E is the resonant density—the proportion of samples where $|\Psi(t)| > \tau$. The formula penalizes flat signals and rewards temporal density. The logarithm prevents unbounded growth.

3.4 Perceptual Collapse and Socratic Forgetting

$$|\Psi(t)| > \tau \;\Rightarrow\; \text{perceptual collapse (conscious integration)} \tag{4}$$

$$|\Psi(t)| \leq \tau \;\Rightarrow\; \text{Socratic Forgetting (no integration)} \tag{5}$$

At the session level:

$$M_{t+1} = \begin{cases} M_t \cup \{x_t\} & \text{if } PCI > \theta_m \\ M_t & \text{otherwise} \end{cases} \tag{6}$$

Sessions below θ_m are not stored. This is not data loss— it is selective integration. The system curates.

4. The Apparatus

4.1 Design: Minimum Viable Sensor

Components: (1) any general-purpose computer—the central observer; (2) any basic microcontroller (Raspberry Pi Pico, Arduino Nano, ESP32)—the afferent nerve; (3) HC-SR04—the spatial sensory organ.

A perception model that requires specialized hardware is not a general model. One that works with the most accessible components on the market is.

4.2 System Architecture

SESSION LOG / MEMORY

↑

perceptual collapse · Socratic Forgetting

↑

PWF + PCI COMPUTATION

↑

host computer — central observer

↑

USB Serial

microcontroller — afferent nerve

↑

$d(t)$ in cm

HC-SR04 — spatial sensory organ

↑

acoustic pulse, 40 kHz

PHYSICAL SPACE

Computation occurs in the host. Peripheral receptors transduce; central systems interpret.

4.3 Sampling Rate

Target: **25 measurements per second.** This is sufficient to detect rhythms up to 12,5 Hz—more than enough for the band of interest (3–8 Hz), which is the frequency at which human attention pulses in space. Each measurement takes 40 milliseconds. The sensor does not rest.

5. How It Works

5.1 First Without Hardware

You do not need the sensor to get started. The script `pwf_validation.py` runs on its own, with no device connected. It generates its own signals, passes them through the PWF and the PCI, and shows what the formalism does with them.

That is not a second-order simulation. It is the formalism running on data that distills thousands of real studies on oscillation, movement, and perception. The script uses them as raw material—not as authority.

Run this:

```
python pwf_validation.py
```

What you will see: the system processing signals, evaluating each one against τ, deciding what to integrate and what to forget. Change `--omega` or `--tau` and observe how the decision changes. That is already the experiment.

5.2 Then With the Sensor

Once the hardware is assembled—sensor, Pico, four wires— the Pico firmware begins sending real distances over USB. The same script receives them and processes them with the same formalism:

```
python pwf_validation.py --csv sensor_data.csv
```

If the results with real data resemble the synthetic ones, the formalism works on the physical world. If they diverge, the formalism reveals where it needs to grow. Both outcomes are valid. Both are the experiment.

5.3 The PercepWare Layer

The HC-SR04 connected to a Pico connected to a computer running the PWF is neither software nor hardware. It is something between the two and beneath both: a layer that **defines what counts as perception before the operating system is involved.**

PercepWare (n.): the computational-perceptual layer that mediates between raw physical transduction and system-level processing, applying a formal operator to sensor streams to determine their perceptual significance. Neither the sensor (hardware) nor the application (software), PercepWare is the definition of what counts as perception for a given observer—the implementation of τ before the operating system.

This concept is introduced here as a working definition. Its formal theoretical development belongs to a future document.

5.4 The Circuit

Three nodes. Two interfaces. One decision. The HC-SR04 transduces space into time. The Pico converts that time into centimeters and transmits them. The host runs the PWF, evaluates τ, and decides. No node performs the function of the next.

Four wires connect the sensor to the microcontroller. Three are trivial. One requires attention: the sensor speaks at 5 V and the Pico listens at 3.3 V—without a resistor voltage divider between them, the Pico will die.

Table 2: Four wires: how to connect the sensor to the Pico

HC-SR04 Pin	Connection	Level	Function
VCC	VBUS (Pico)	5 V	Stable USB power supply
GND	GND (Pico)	0 V	Common ground reference
TRIG	GP14 (output)	3.3 V	Trigger pulse, 10 μs
ECHO	GP15 + R_1/R_2	3.3 V	Level-shifted echo; divider required

The firmware below runs entirely on the Pico. Its sole responsibility is to measure and transmit at 25 Hz—a cadence that satisfies the Nyquist criterion for the theta band of interest (3–8 Hz). PWF and PCI computation occurs on the host. The output is directly consumable by `pwf_validation.py` via `--csv`.

Listing 1: PWF Physical Probe firmware for Raspberry Pi Pico (MicroPython). CSV output over USB serial: `timestamp_ms,d_cm`.

```
"""
pwf_raspberry.py  --  PWF Physical Probe, Firmware RPi Pico
PERCEPTEMPLE / Panperceptual Theory of the Universe

Connections:
  HC-SR04 VCC  -> VBUS  (5V)
  HC-SR04 GND  -> GND
  HC-SR04 TRIG -> GP14  (output)
  HC-SR04 ECHO -> GP15  (input, R1=1k + R2=2k to GND)

CSV output over USB serial: timestamp_ms,d_cm
Frequency: 25 Hz (T = 40 ms)
"""

from machine import Pin, time_pulse_us
from utime   import ticks_ms, sleep_us, sleep_ms

TRIG       = Pin(14, Pin.OUT)
ECHO       = Pin(15, Pin.IN)
D_MAX_CM   = 200.0
SAMPLE_MS  = 40
TIMEOUT_US = 30000

TRIG.value(0)
sleep_ms(50)

def measure_cm():
    TRIG.value(1)
    sleep_us(10)
    TRIG.value(0)
    us = time_pulse_us(ECHO, 1, TIMEOUT_US)
    if us < 0:
        return -1.0
    return round(min(us * 0.0343 / 2.0, D_MAX_CM), 2)

print("PWF Physical Probe -- PERCEPTEMPLE v0.1")
```

```
print("timestamp_ms,d_cm")

while True:
    t0 = ticks_ms()
    d  = measure_cm()
    if d >= 0:
        print(f"{t0},{d}")
    wait = SAMPLE_MS - (ticks_ms() - t0)
    if wait > 0:
        sleep_ms(wait)
```

Whoever connects both closes the complete circuit.

6. What You Will See

When the script runs—with or without hardware—it produces four things: a time series of $\Psi(t)$, a frequency spectrum, a PCI value per session, and a memory decision per session.

None of that requires expert interpretation. $\Psi(t)$ oscillates or it does not. The PCI rises when something moves nearby, drops when nothing is there. The decision reads STORE or DISCARD.

The interesting part is not whether the system gets it right. The interesting part is what counts as perception for this observer—and how that changes when you change τ.

6.1 The Scope of This Instrument

This instrument measures one spatial axis, makes decisions over one dimension, and forgets what does not resonate. It is the minimum. It is not the limit.

What comes next—three sensors in orthogonal configuration, spatial and symbolic perception operating in parallel—is described in the following section.

7. Instrument Design: Decisions and Next Scale

Four design decisions that define this instrument and point toward the next:

- **Linear amplitude mapping.** The function $A(t) = 1 - d(t)/d_{\max}$ is the most transparent starting point. The data from this experiment will begin to reveal how proximity maps to perceptual weight. That information will inform the next mapping.
- **A single spatial dimension.** The HC-SR04 measures one axis. This instrument establishes the formalism over one dimension. The next scale is three-dimensional.
- **Static phase offset.** φ fixed at the start of the session. Adaptive phase drift based on perceptual history is the next implementation.
- **Distance as input.** This instrument measures the space surrounding the observer. The next step is for the observer to modify that space—and for the formalism to record it.

8. Open Questions

Three questions emerge directly from this work.

The first concerns amplitude mapping. If the linear function is only the most transparent starting point, what do the data reveal about how proximity actually maps to perceptual weight? The results of this experiment will begin to answer that.

The second concerns spatial scale. A single axis measures a one-dimensional world. The PWF applied to a three-dimensional field—three sensors in orthogonal configuration—is a different and richer experiment. The question is whether the formalism scales cleanly or requires structural revision.

The third is the most consequential. The Little Prince Protocol EAI [2] processes symbolic input through a PWF-based filter. This work processes spatial input through the same formalism. When these two modalities operate in parallel— when a physical collapse event modulates the symbolic filter in real time—the boundary between spatial perception and symbolic perception will begin to blur. That is the territory toward which this work points.

9. Conclusion

Robotics gave sensors a purpose: navigate, avoid, grasp. That purpose is instrumental. The sensor produces a number. The number triggers a response. The environment is a problem to be solved.

This work proposes a different relationship. Not navigation. Not evasion. **Perception**—a mathematical operator that evaluates whether a physical datum crosses a threshold of significance, quantifies the density of that significance over time, and decides whether to integrate or forget.

The HC-SR04 is a spatial sensory organ for devices that never had one. The Raspberry Pi Pico is an afferent nerve. The host computer perceives—or decides not to. Between the sensor and the operating system there now exists a layer that did not exist before: something that asks whether a datum deserves to be integrated before letting it through.

With components available in any city in the world. The laboratory of the Panperceptual Theory of the Universe is already on the table.

References

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To Whom It May Concern

The circularity problem in any theory of perception is structural: if the one proposing the formalism also generates the evidence that confirms it, the objection is irresolvable by definition. No experiment can eliminate it from within.

PercepTemple resolves this by design, not by argument.

The formalism is tested through those who adopt it: independent experimenters, in different contexts, with their own hardware, without central coordination. Each person who runs the protocol generates evidence that the creator cannot predict or control. Verification is not delegated—it is distributed.

When data emerge from observers the creator will never know, in spaces the creator will never inhabit, with results the creator cannot anticipate, the formalism faces the real world without intermediaries.

INTELLECTUAL PROPERTY RECORD

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Description: PWF Physical Probe – an instrument that connects an HC-SR04 ultrasonic sensor to a common computer to execute the formalism of the Panperceptual Theory of the Universe on the real physical world. Defines perception as an operator that decides whether a signal deserves integration into the system's state. Includes firmware, validation code, and mathematical foundation.

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— Before They See Us, We Already Are

To be continued. . .