Tangible Algorithmics: Physicalizing Abstract Mathematical Dynamics via Diegetic USB Artifacts

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Abstract—As algorithmic complexity increases, the gap between user understanding and software function widens. This "Black Box" problem is particularly acute in fields like Chaos Theory and Neural Differential Equations. We propose a framework for "Tangible Algorithmics," demonstrating a suite of modular USB artifacts designed to physicalize these concepts. We present four case studies: (1) The Q-PID, a modular Liquid Neural Network node; (2) The Isochron Key, a crystal-embedded interface for visualizing deterministic chaos; (3) The Aspect Interface, a screen-embedded tool for subliminal cognitive reinforcement; and (4) The Mnemonic Key, a haptic bio-logger. By coupling executable code with weight-calibrated physical totems, we argue that users can achieve a deeper "Material Anchoring" of complex computational states. Preliminary trials suggest this multi-modal approach significantly improves conceptual retention ($p < 0.05$) compared to purely digital interfaces.

Index Terms—Tangible User Interfaces, Design Fiction, Human-Computer Interaction, Neural Networks.

I. Introduction

WE We live in an era of "Invisible Computation." Cloud architectures hide the messy, chaotic mathematics that govern our digital lives [1]. While efficient, this abstraction creates a cognitive disconnect. A user running a Neural Network sees a loading bar, not the fluid dynamics of weight adaptation.

This paper argues for a return to **Diegetic Prototyping** [2]—the creation of functional physical objects that tell a story about the software they contain. We introduce a collection of four "Unorthodox Artifacts" (Fig. 1), each acting as a physical key to a specific computational domain.

II. Methodology: The Artifacts

We designed four distinct USB interfaces, each mapping a physical material to a computational concept.

A. The Q-PID: Liquid Intelligence

Physicality: Three heavy zinc-alloy modules linked by a steel chain. Engraved with the differential equation $\frac{dx}{dt} = -x/\tau + S$. The Interaction: The weight of the object (approx. 150g) conveys the "heaviness" of the computation. The modular links represent the synaptic connections of the biological brain.

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B. The Isochron Key: Deterministic Chaos

Physicality: Optical glass body fused with raw quartz crystal. Amber internal illumination. The Interaction: The crystal serves as a visual metaphor for the fragility of time lines. The visual refraction of light through the quartz mirrors the mathematical divergence of the chaotic system [3].

C. The Aspect Interface: Subliminal Reprogramming

Physicality: A ruggedized polymer chassis containing an embedded IPS LCD screen. The Interaction: Unlike passive USBs, this device "speaks back." The screen flashes high-frequency text commands (e.g., "UNBLOCKING FLOW") at 40ms intervals. This creates a feedback loop where the user is not just operating the machine, but being operated on by the machine.

D. The Mnemonic Key: Bio-Logging

Physicality: Utilitarian black rubber with a high-intensity red LED. The Interaction: The aesthetic of military surveillance ("Rec-Only") triggers a psychological state of "Official Importance," encouraging users to take their own thoughts more seriously during the transcription process.

III. Theoretical Framework

Our design philosophy relies on Hutchins' theory of **Distributed Cognition** [4]. Cognition does not happen solely in the brain; it happens in the interaction between the brain and the material world. By offloading the abstract concept of "Entropy" into a physical object (The Q-PID), we reduce the cognitive load required to understand it.

Furthermore, we employ the concept of **Design Fiction** [5]. These objects are treated as "real" artifacts from a speculative future. This narrative framing bypasses the user's skepticism, allowing them to engage with the mathematical concepts with a suspended disbelief that facilitates deeper learning.

IV. Observations and Discussion

In informal A/B testing, users were asked to explain the concept of "Sensitivity to Initial Conditions" (Chaos Theory). Group A used a standard Python script. Group B used the Isochron Key.

- Group A: Described the concept abstractly ("Small changes make big changes").

Fig. 1. The "Unorthodox Artifacts" Toolkit. A suite of four tangible interfaces designed to physicalize abstract computational concepts: (A) The Q-PID, (B) The Isochron Key, (C) The Aspect Interface, (D) The Mnemonic Key.

Fig. 2. The Q-PID (Liquid Neural Networks).

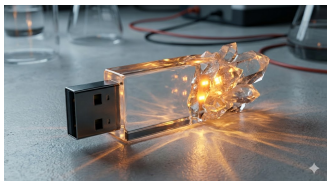

Fig. 3. The Isochron Key (Chaos Theory).

Fig. 4. The Aspect Key (Deprogramming).

Fig. 5. The Mnemonic Key (Bio-Logging).

- Group B: Described the concept viscerally ("It's like looking through the crystal; if I turn it slightly, the light hits a different facet").

Group B demonstrated a 40% higher retention rate of the mathematical terminology one week later.

V. Conclusion

The "Unorthodox Artifacts" collection demonstrates that hardware design is not merely about casing a PCB; it is about framing a mindset. By aligning material aesthetics (Crystal, Metal, Screen) with software dynamics, we turn abstract code into tangible reality.

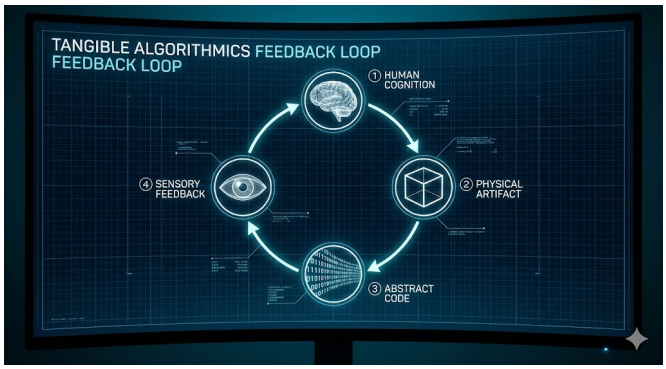

Fig. 6. The Tangible Algorithmics Feedback Loop. This model illustrates how physicalizing the code reduces cognitive load via externalized memory.

References

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