

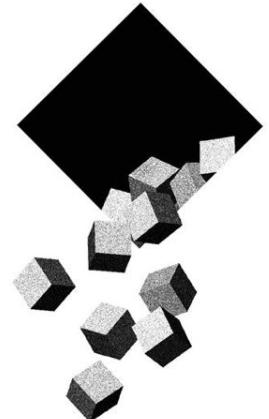
Varadraj Borte.
MS CDP.

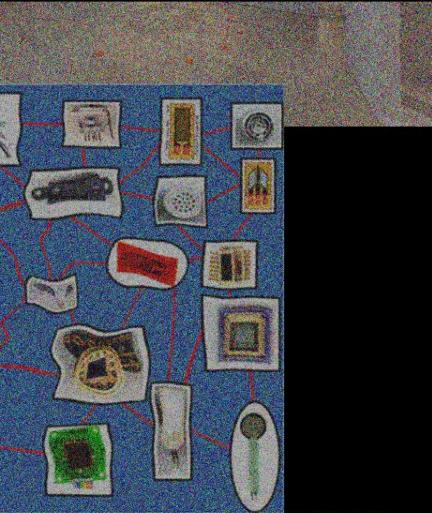
PROPOSE REVIEW
Fall 2026,
Columbia GSAPP.

If we translate the rhythms of living systems into computation, familiar software can unfold into space, letting simple digital actions grow into new, emergent ways of interacting.

"When behavior becomes the medium,
systems reveal new kinds of value."
Austin Wade Smith

By borrowing the movements of living system swarms, echoes and currents and turning them into computation, the project lets flat software take on form and behavior.

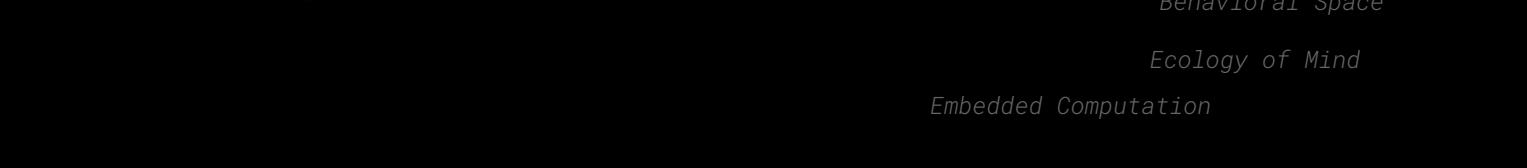




Perceptual Materiality



Machine Vision



Biocybernetic Control

Psycho-sensory Augmentation
Data Hallucination

Organismic Logics

Material Intelligence

Morphogenetic Design

Matter as Interface

Ecological Computation

Sublime Data Data Patterning

Quantized Perception
Aesthetic Computing

Information Formalism

Behavioral Space

Ecology of Mind

Embedded Computation

Refik Anadol, Machine Hallucinations

data as perceptual material;

This project extends the idea by adding biocybernetic control and everyday function.

Neri Oxman, Material Ecology

Organismic logics embedded in matter.

Here the organismic logic becomes the interface itself.

Ryoji Ikeda, Data-Verse

Sublime data patterning.

We introduce sensing + feedback to make data behave.

MIT Responsive Environments

Architecture that senses and responds.

This project shifts sensing into software primitives, interfaces as living systems.

Uexküll/Bateson/von Foerster

Umwelt, ecology of mind, cybernetic feedback.

These theories become operational rules for interaction.

Here are the biological behaviors I'm borrowing.

Biological Processes Biocybernetic Interpretations.

Homeostasis - Bats - Echolocation (Wiener/Ashby) -

"Feedback loops stabilize a system by measuring error over time and adjusting signals to stay within a comfort band."

Swarm regulation - Bees - Collective clustering

"Global patterns emerge from simple local rules. No central controller is needed; the swarm regulates itself by redistributing attention."

Ecological co-regulation - Corals - Ambient Coupling (Bateson) -

"Organisms and environments form a coupled feedback system. Both sides adjust to maintain perceptual balance."

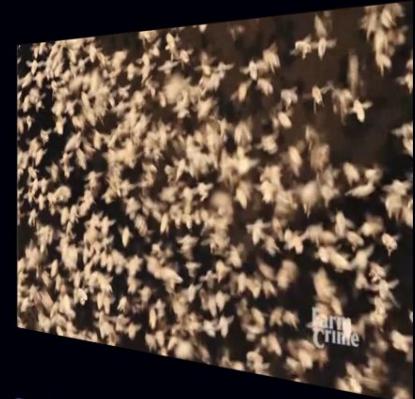
Behavior :

Bats send timed echo pulses and adjust spacing/tempo to keep perception stable as they move.



Behavior :

Bees self-organize into clusters based on local interactions, attraction, repulsion, and shared relevance.



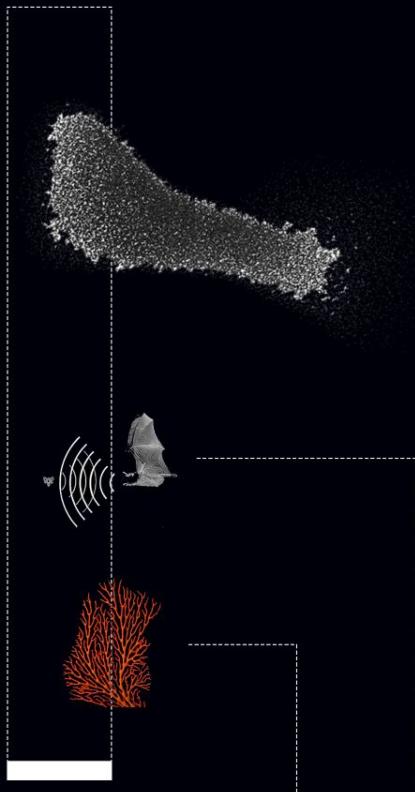
Behavior:

Coral systems respond to slow environmental gradients, light, heat, flow, and modulate their state to maintain



How biological behaviors become **computational logic**

Translating Biological Behavior Into
Computational Logic.



1

Attraction - Cohesion :

Particles move toward nearby particles to stay together.

$$v_{attract} = \alpha * (\text{mean(neighbors)} - \text{position})$$

2

Repulsion - Avoid Collisions:

Particles push away from neighbors that come too close to avoid overlap.

$$v_{repel} = \rho * \sum (\text{position} - \text{neighbor}) / \text{distance}^2$$

3

Alignment (Shared Direction / Rotation):

Particles adjust their heading to match the average direction of their neighbors.

$$v_{align} = \lambda * \text{mean}(\text{heading}(\text{neighbors}))$$

4

Neighbor Radius (Local Awareness)

Each particle responds only to neighbors within a small radius, this creates structure.

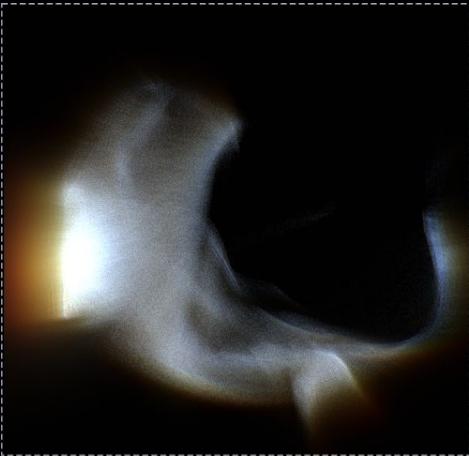
$$\text{neighbors} = \text{particles within radius } r$$

5

Relevance Field (Compression + Panic Response)

When a "signal" increases relevance (danger, attention, user input), particles cluster tightly; when relevance drops, they relax and spread out.

$$\begin{aligned} \text{if } R > \text{threshold: } \alpha \uparrow \quad p \downarrow \\ \text{else: } \quad \alpha \downarrow \quad p \uparrow \end{aligned}$$

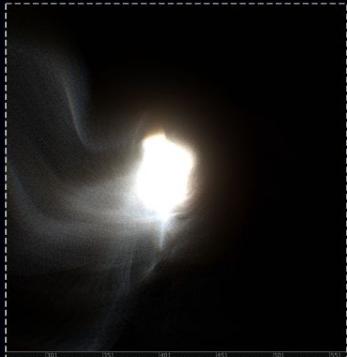


High α , low $\rho \rightarrow$ tight cluster
(Attraction dominates → “panic response”)

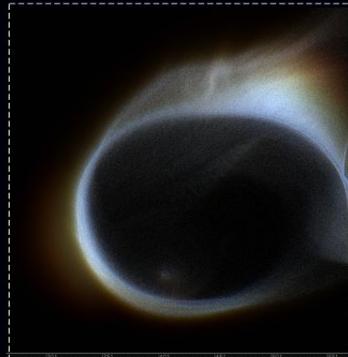
α = attraction strength
 ρ = repulsion strength
 λ = alignment strength
 r = neighbor radius
R = relevance signal



Balanced $\alpha + \rho \rightarrow$ smooth flow
(Local awareness + moderate forces)



Very high $\alpha \rightarrow$ particles pull inward strongly
(Critical relevance event)



High $\lambda \rightarrow$ circular alignment
(Shared heading → vortex)



High ρ , low $\alpha \rightarrow$ cloud expansion
(Recovery / relaxation state)

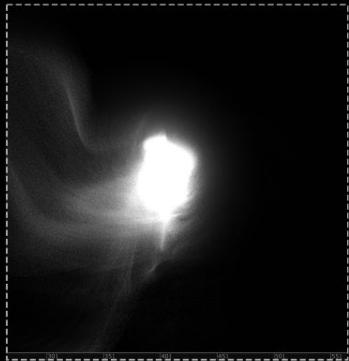
State	α	ρ	λ	R
Compression	High	Low	Med	High
Shear / Flow	Med	Med	Low	Low
Collapse / Core	VeryH	Low	Low	High
Vortex	Low	Low	High	Med
Dissipation	Low	High	Low	Low



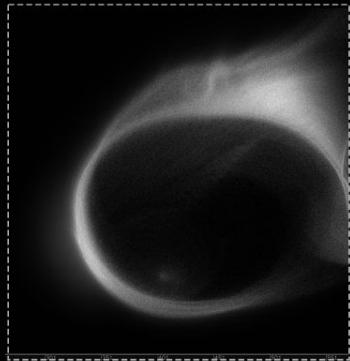
High α , low $p \rightarrow$ tight cluster
A dense, compressed mass.



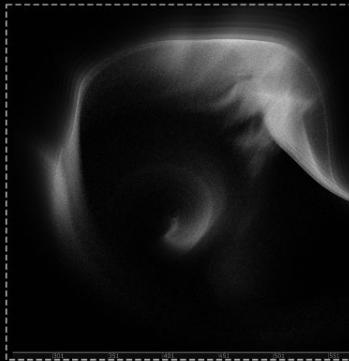
Balanced $\alpha + p \rightarrow$ smooth coherent, flowing movement.



Very high $\alpha \rightarrow$ particles pull Everything collapses sharply into a bright center



High $\lambda \rightarrow$ circular alignment A rotating ring, coherent spinning motion.

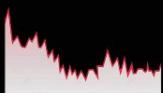


High p , low $\alpha \rightarrow$ cloud A loosened, relaxed, outward-expanding form.

UX TRANSLATION



The system becomes tense / overloaded / urgent



A risk spike / sudden volatility / something needs immediate attention.



Calm, guided navigation / a stable system state.



Healthy cash flow, steady savings growth, predictable patterns.



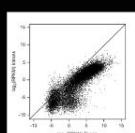
Attention magnet, the system highlights something important.

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A concentrated event: bill due, payment alert, anomaly detected.



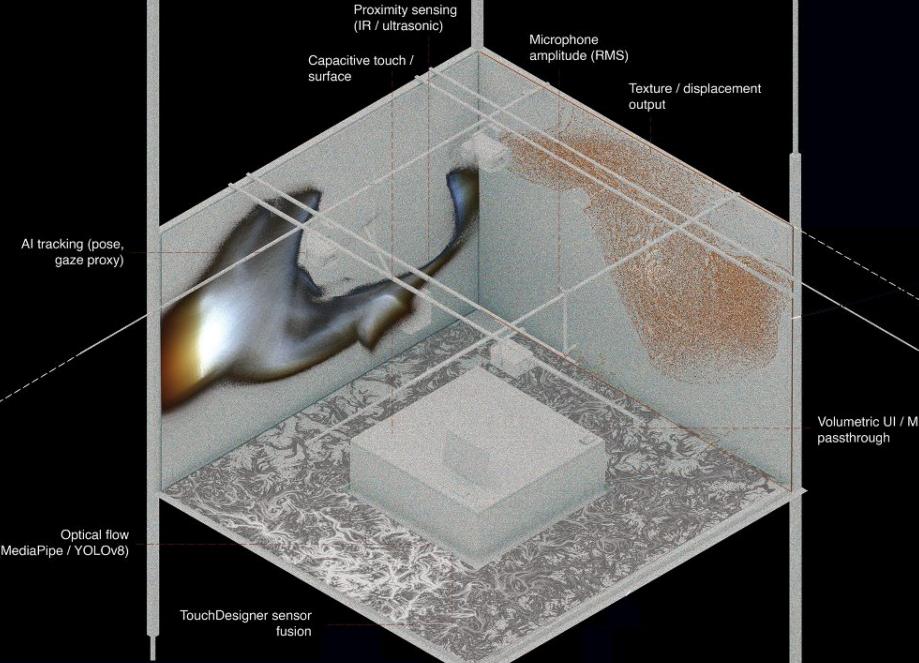
Recurring monthly payments



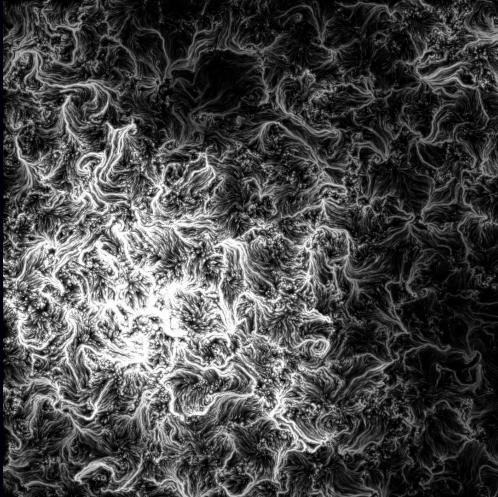
Lower risk Debt reduction Stabilization after volatility



From,
behavioral logic



To,
Spatial Interaction system



Environmental signal
translated
into ambient behavioral
modulation.

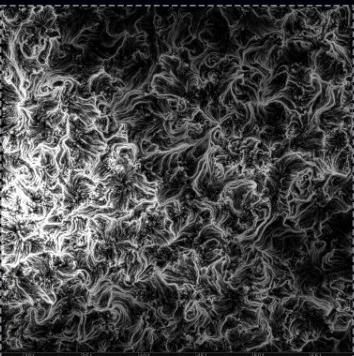
α = attraction strength

ρ = repulsion strength

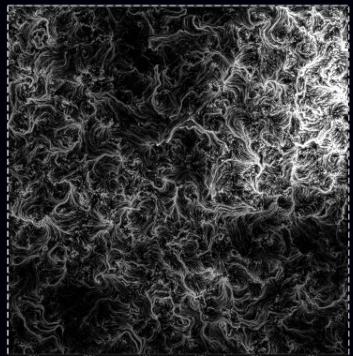
λ = alignment strength

r = neighbor radius

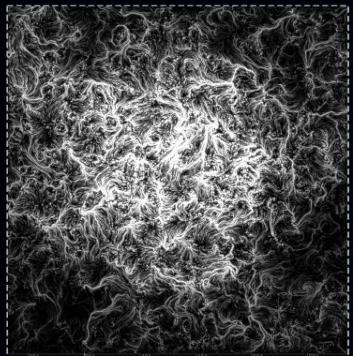
R = relevance signal



Turbulent drift (baseline state)
(Field moves as a continuous flowing mass.)

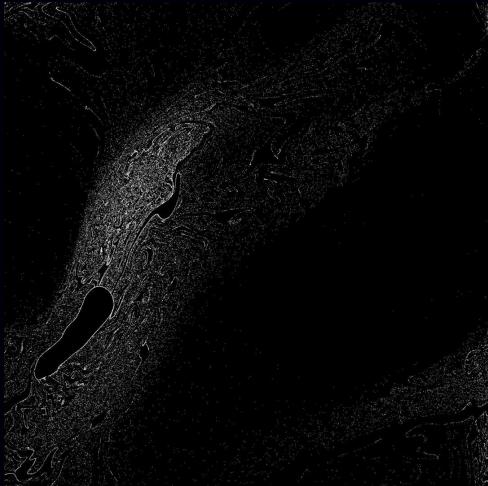


Field dissipation (release & spread)
(Energy relaxes; particles drift outward.)



Vortex shear (rotational coherence)
(A circular motion emerges through shared directional flow.)

State	α	ρ	λ	R
Turbulent Drift	Med	Med	Low	Low
Gradient Pull	High	Low	Low	Med
Vortex Shear	Med	Low	High	Low
Core Density Swell	High	Med	Low	High
Field Dissipation**	Low	Med	Low	Low



Hand - based interaction
for feedback loop
activation.

α = attraction strength

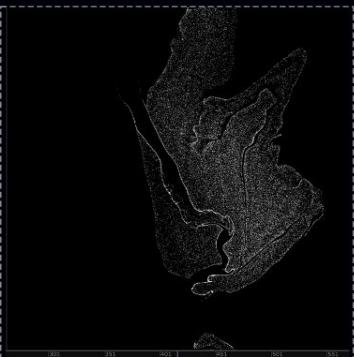
ρ = repulsion strength

λ = alignment strength

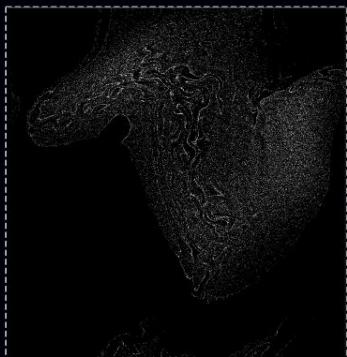
r = neighbor radius

R = relevance signal

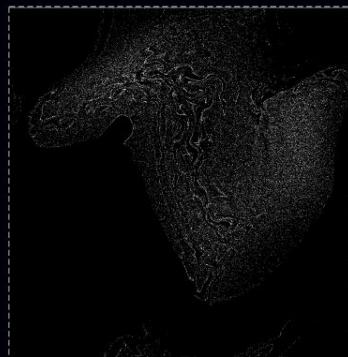
**State (Feedback Phase)	α	ρ	λ	R
Compression (High Relevance)	High	Low	Med	High
Flow / Scanning	Med	Med	Low	Low
Core Collapse (Critical Event)	Very High	Low	Low	High
Directional Lock (Tracking)	Low	Low	High	Med
Dissipation (Recovery)	Low	High	Low	Low



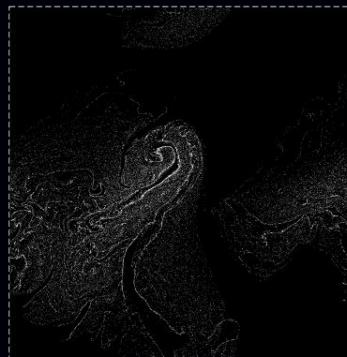
Balanced $\alpha + \rho$,
v smooth sensing flow



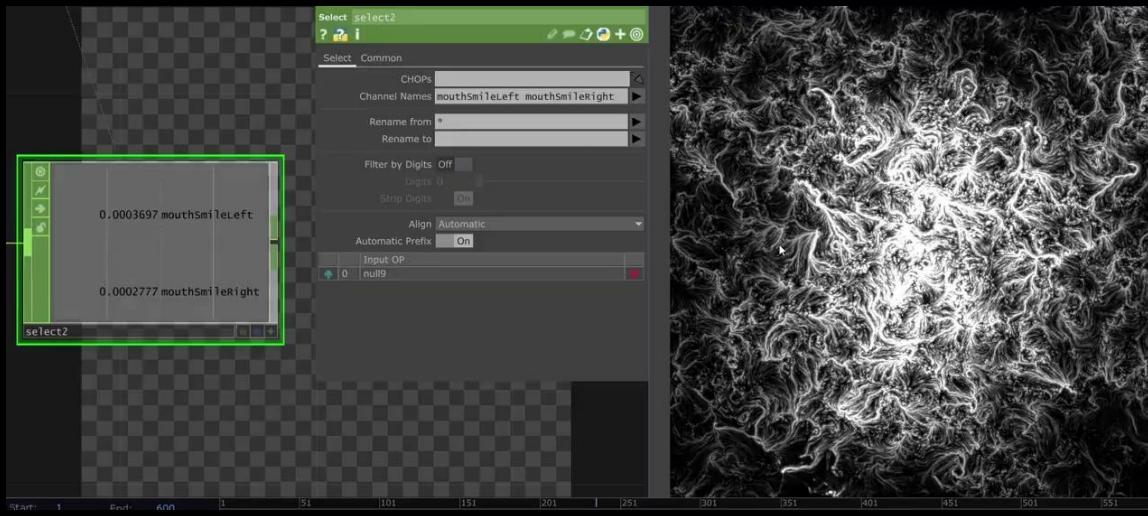
Very high α ,
particles pull inward
strongly



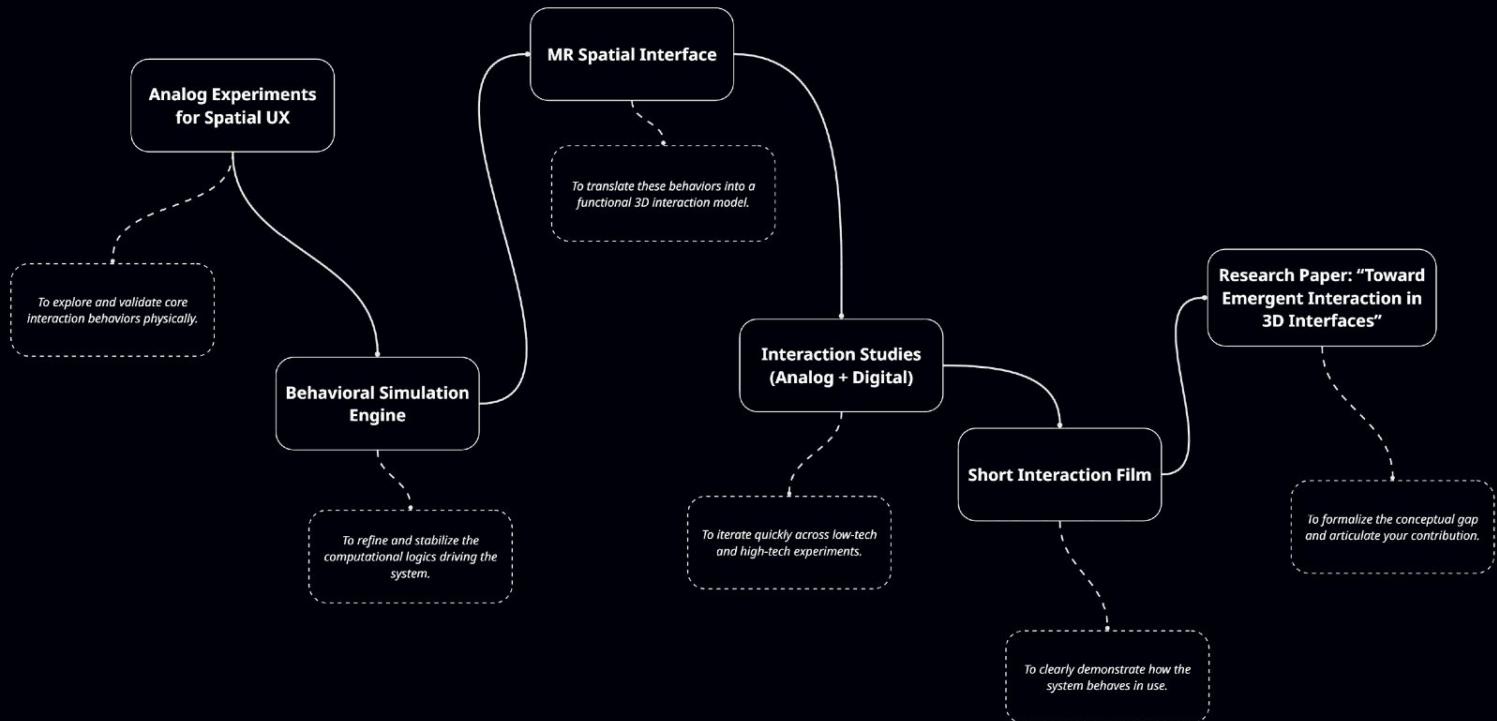
High λ ,
vcircular alignment



High ρ , low α ,
cloud expansion



Roadmap ahead.



Biological + Cybernetic Foundations

Wiener, Norbert. *Cybernetics: Or Control and Communication in the Animal and the Machine*. MIT Press, 1948.

Ashby, W. Ross. *An Introduction to Cybernetics*. Chapman & Hall, 1956.

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Sumpter, David. *Collective Animal Behavior*. Princeton University Press, 2010.

Animal Behaviors Referenced

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Ambient Coupling & Co-Regulation:

Rinkevich, Baruch. "Coral resilience, stress responses, and regenerative behavior." *Marine Biology*, 2014.

Computation, Interaction, & Systems Theory

Hiroshi Ishii. "Radical Atoms and Tangible Bits." MIT Media Lab.

Elias, Tega. Work on ambient spatial interfaces (spatial UI references).

Benjamin Bratton. *The Stack: On Software and Sovereignty*. MIT Press, 2016.

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Which behavior has the strongest potential to push further?

Where should I focus next: simulation refinement, analog tests, or MR prototype?

Should the narrative be more concise, focusing on the interaction system rather than the financial frame?

What conceptual gap should I address to make this publishable?