Quantifying forms of sensorimotor coupling with the situated-HKB model
WHAT ROBOTS CAN TELL US ABOUT ECOLOGICAL PSYCHOLOGY

Miguel Aguilera[1], Manuel G. Bedia[1], Bruno A. Santos[2] and Xabier E. Barandiaran[3]

[1] Dpt. Computer Science, University of Zaragoza, Spain, [2] CCNR - University of Sussex, Brighton UK,

[3] IAS-Research, Dept. of Logic & Philosophy of Science, UPV/EHU University of the Basque Country, Spain

Abstract

We present what we call "the situated-HKB model", where a sensory input modulates the control parameter of the canonical HKB model and the phase relation maps into a motor function that affects the agent-environment relationship in a simulated robot performing a gradient climbing task [1,2].

The analytic solution of the coupled agent-environment system (together with 1/f noise analysis of the coupling dynamics) allow us to distinguish between two types of sensorimotor coupling: *reactive* and *interactive*. Interactive coupling is defined by pink 1/f noise, weak internal attractor strength and fine grained sensorimotor coordination dependence.

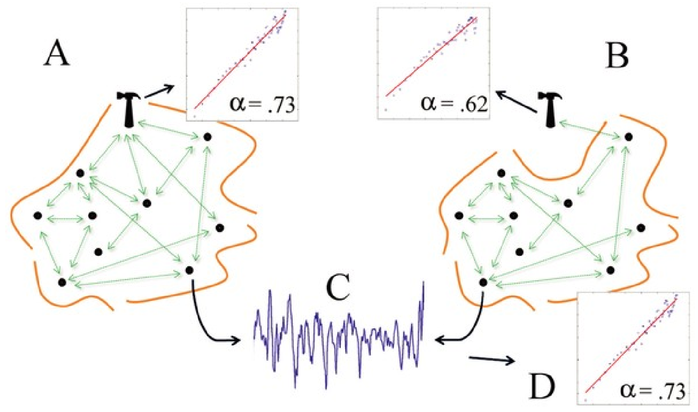
We generalize from our model the consequences of the dynamic properties of "interactive coupling" for the discussion over the constitutive vs instrumental role of movement for perceptual invariants [3]

Pink Noise and Interaction-Dominant Dynamics

Martin Heidegger claimed that most human activity is absorbed, skillful engagement with entities in the world. In that situation, we experience these entities as ready-to-hand, we are not explicitly aware of their properties but "we "see through" them to the task we are engaged in [4].

Empirical support to this claim has been lend by [5], where transitions between ready-to-hand and unready-to-hand situations have been analyzed in terms of *1/f$^{\beta}$* positive noise correlation in the interaction with a tool.

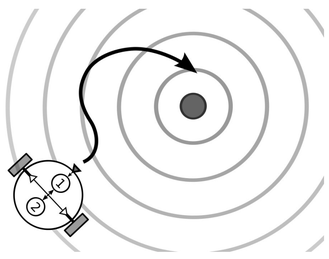
The presence of ***β=1* noise (pink)** is taken as an indicative of an smoothly operating system, softly assembled by virtue of **interaction-dominant dynamics**, coupled across different timescales.



Situated-HKB Model and Minimal Forms of Sensorimotor Coupling

Agent

The Situated-HKB model constitutes a minimal oscillatory neuro-controller for a situated and embodied agent [1,2]. It consists in two coupled oscillators, influenced by the activity of a sensor, controlling the movement of two motors.

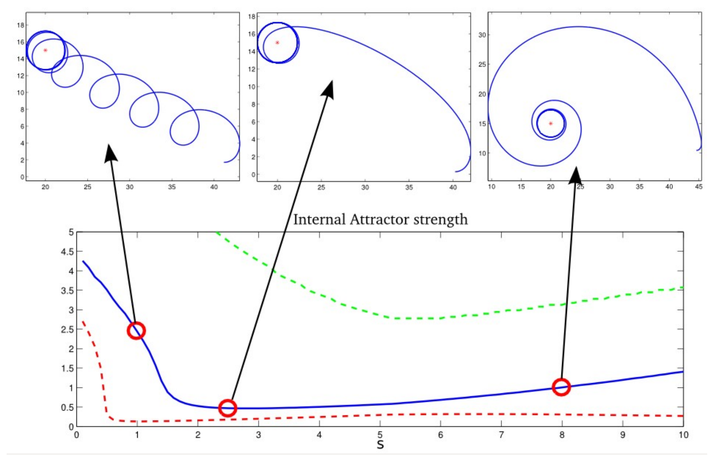


$$\dot{\varphi} = \delta\omega - kI - a \cdot sin(\varphi) - 2b \cdot sin(2\varphi)$$
$$M_R = sin(\varphi - \varphi_R)$$
$$M_L = sin(\varphi - \varphi_L)$$

Sensorimotor Coupling and Gradient Climbing Task

Tuning the sensitivity parameter of the agent's input, different gradient-climbing strategies emerge from the interaction between the agent an the environment.

Different forms of coupling show different attractor configurations. Interestingly *more efficient strategies are performed when the internal attractor of the agent is weaker*.



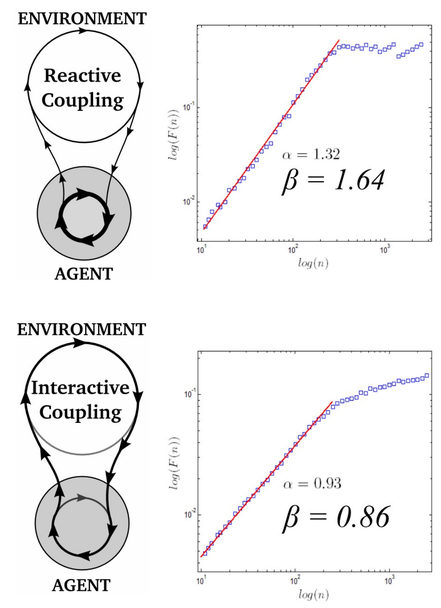
The Coupling Paradox

The obtained results suggest that absorbed skillful coping with the world would only be possible through *weakly attractive internal states* which are able to establish *strong couplings with its environment*.

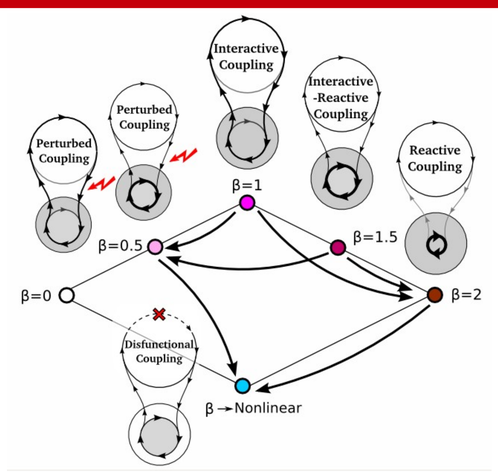
Scale Correlations

Correlation measures over the acceleration of the agent's motors, show that:

- Agents with strong internal attraction show a frequency distribution where slow scales dominate over others. These are **reactive agents**.
- Agents with weak internal attraction display scale-free correlations due to their interaction-dominant dynamics. These are **interactive agents**.



Map of Coupling Modes



Different types of behaviour are not mediated by nothing like internal states standing for something on the environment (i.e. representations). **Instead, it is the actual "shape" of the coupled agent-environment dynamics what conforms different types of world experiences.**

Noise correlation measures are a tool that allows us to map different modes of sensorimotor coupling.

Interactive Coupling and Constitution

We defend that *interactive dynamical coupling* is the most characteristic form of everyday behavioural coupling between natural cognitive systems and their environments.

Necessary and sufficient properties:

PROPERTY 1: During the coupling the interaction itself holds the strongest attraction.

PROPERTY 2: System-environment dynamics display an interaction-dominant pattern characterized by scale-free *1/f$^{\beta}$*, $\beta = 1$.

PROPERTY 3: The interaction is constituted by a fine grained sensorimotor coordination where internal dynamics are co-modulated by the structure of sensorimotor contingencies they create.

As a **CONSEQUENCE**: Movement is *constitutive* of perceptual and other cognitive processes. As a result sensory invariants are not movement invariant in a instrumental but in a constitutive way.

Conclusions

The model presented here allows to analyze different minimal forms of coupling between an agent and its environment. A combination of a formal analysis of the attractor landscape of the system and a measure of timescale correlation in its interactions (together with perturbation experiments—not shown in this poster) allows us to characterize the type of couplings that the agent engages in.

These different modes of coupling cannot be determined by neither the environment, the agent's representation of the environment (if any), nor the sum of environmental and agent variables. Instead, it is determined by the *structure of the interactive World*: the dynamic topology that emerges from the coupled agent-environment system.

We can differentiate between interactive agents, with loosely attractive internal states and scale-free correlations in its interactions with the environment, and reactive agents, with more rigid internal state and scale dominance in their interactions.

Interactive dynamical couplings are the basis for most natural cognitive activity. Relaxation of internal attractors in exchange for a strong interaction-dominant coupling between an agent and its environment creates the conditions for an absorbed, skillful engagement, where motor dynamics become constitutive of cognitive and perceptual states.

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References

[1]Aguilera, M., Bedia, M.G., Santos, B.A. & Barandiaran, X.E. (forthcoming). Situated-HKB model. Theoretical Exploration of the Sensorimotor Spatial Coupling of an Oscillatory System.

[2] Santos, B.A, Barandiaran. X.E., Husbands, P., Aguilera, M., Bedia, M.G. (forthcoming). Sensorimotor Coordination and Metastability in a Situated HKB Model.

[3] Mossio, M., & Taraborelli, D. (2008). Action-dependent perceptual invariants: From ecological to sensorimotor approaches. Consciousness and Cognition, 17(4), 1324–1340.

[4] Dreyfus H (1991) Being-in-the-world: A commentary on Heidegger's Being and Time, Division I. Cambridge, MA: The MIT Press.

[5] Dotov, D. G., Nie, L., and Chemero, A. (2010). A demonstration of the transition from Ready-to-Hand to Unready-to-Hand. PLoS ONE, 5(3).