



Hannes Hornischer Papers Involving the Fractal AI Framework

Below are the English-language academic papers co-authored by Hannes Hornischer that utilize the **Fractal AI** framework or its core principles. For each paper, we provide the title, coauthors, year, publication venue, a link to the full text, and a brief summary of how Fractal AI is referenced or applied.

Structural Transition in the Collective Behavior of Cognitive Agents (2019)

- **Coauthors:** Stephan Herminghaus, Marco G. Mazza
- **Year:** 2019
- **Publication:** *Scientific Reports* **9**, 12477 (2019)
- **Full text:** [Nature Scientific Reports](#) (Open Access)
- **Summary:** This paper introduces a minimal model of “cognitive” agents and shows a phase transition in their collective behavior. The agents make decisions by **maximizing the number of future options** available – i.e. they explore trajectories that keep future possibilities as open as possible ¹. This decision rule is essentially the same principle underpinning Fractal AI, even though the Fractal AI 2018 arXiv paper is not explicitly cited here. The authors assume that an intelligent agent “will seek to maximize its number of future options to move” ¹ and frame this in terms of maximizing information/entropy in the agent’s cognitive map ². In other words, the agents behave according to a *future state maximization* strategy very similar to Fractal AI’s approach of exploring forward to preserve future choices. This principle is used to derive an “entropic force” driving the agents’ motion. By applying this Fractal-AI-like framework, the study finds emergent structured patterns and draws parallels to known ideas like causal entropic forces and empowerment, indicating that maximizing future state diversity leads to coordinated collective behavior ³.

Foresight Rather than Hindsight? Future State Maximization as a Computational Interpretation of Heinz von Foerster’s Ethical Imperative (2020)

- **Coauthors:** Simon Plakolb, Georg Jäger, Manfred Füllsack
- **Year:** 2020
- **Publication:** *Constructivist Foundations* **16**(1): 36–49 (2020)
- **Full text:** [Constructivist Foundations journal](#) (Open Access)
- **Summary:** This article explores the concept of **Future State Maximization (FSX)** – the idea that intelligent agents should maximize the diversity of their possible future states – and links it to Heinz von Foerster’s ethical imperative. Hornischer and colleagues explicitly discuss Fractal AI as a prime example of the FSX principle in action. They note that while approaches like **Causal Entropic Forcing**, **Fractal AI**, and **Empowerment** have some differences, “they still share a common

principle” – namely, an agent-centric drive to enlarge the space of possible future states ⁴. The paper cites the original *Fractal AI: A fragile theory of intelligence* arXiv preprint (Cerezo & Ballester 2018) as a recent implementation of this principle ⁵. In particular, Fractal AI is mentioned as a method that, instead of purely maximizing entropy, uses “*walkers*” to maximize an agent’s future reward possibilities ⁶ – a forward-looking strategy aligned with FSX. The authors conduct computational case studies (on coordination tasks) demonstrating FSX, and they use Fractal AI to illustrate how foresight-oriented strategies can outperform traditional hindsight (past data-driven) approaches. In summary, this paper positions Fractal AI as a successful application of the *foresight* paradigm (maximizing future options) in AI, and integrates it into a broader theoretical and ethical context ⁴.

Modeling of Human Group Coordination (2022)

- **Coauthors:** Paul J. Pritz, Johannes Pritz, Marco G. Mazza, Margarete Boos
- **Year:** 2022
- **Publication:** *Physical Review Research* 4, 023037 (2022)
- **Full text:** [APS Phys. Rev. Research](#) (Open Access)
- **Summary:** In this study, Hornischer et al. combine human experiments with simulations to investigate how groups coordinate. They implement two decision-making paradigms in simulation: (1) a “cognitive force” model based on **maximization of future movement options**, and (2) a multi-agent reinforcement learning model ⁷ ⁸. The cognitive force approach is directly rooted in the Fractal AI framework – it has agents choose actions that maximize their future possibilities (an information-based strategy) ⁹. The paper explicitly cites the Fractal AI theory paper (arXiv: 1803.05049) in its references ¹⁰ as one of the key sources for the future-options maximization paradigm. In practice, the authors use this Fractal-AI-like strategy to simulate human “flocking” behavior: each agent projects hypothetical paths and favors moves that preserve future choices, mirroring the Fractal AI principle of forward planning. The results show that this FSX-based model can reproduce human-like group coordination more faithfully than a conventional reward-maximizing RL approach. In fact, the **Fractal AI-style (FSX) strategy outperformed the RL agents**, achieving higher group rewards and closer alignment with actual human behavior ¹¹. Thus, this paper demonstrates an applied example of Fractal AI principles in a social coordination setting: the authors adopt the Fractal AI framework (under the name *cognitive force/Future State Maximization*) and show it yields superior coordination efficiency, thereby validating the importance of maximizing future options in intelligent agent behavior ⁹ ¹¹.

¹ ² ³ Structural transition in the collective behavior of cognitive agents | Scientific Reports
[https://www.nature.com/articles/s41598-019-48638-8?
error=cookies_not_supported&code=ab48b764-0e53-459c-8384-3a711548c2cc](https://www.nature.com/articles/s41598-019-48638-8?error=cookies_not_supported&code=ab48b764-0e53-459c-8384-3a711548c2cc)

⁴ ⁶ pure.iiasa.ac.at
https://pure.iiasa.ac.at/id/eprint/17058/1/Plakolb_Simon_YSSP_Report.pdf

⁵ Hornischer H., Plakolb S., Jäger G. & Füllsack M. (2020) Foresight Rather than Hindsight? Future State Maximization As a Computational Interpretation of Heinz von Foerster’s Ethical Imperative. *Constructivist Foundations* 16(1): 36–49
<https://constructivist.info/16/1/036.hornischer>

7 8 9 10 11 (PDF) Modeling of human group coordination

[https://www.researchgate.net/publication/359910773_Modeling_of_human_group_coordination?
_tp=eyJjb250ZXh0Ijp7InBhZ2UiOijzY2IlbnRpZmljQ29udHJpYnV0aW9ucyIsInByZXZpb3VzUGFnZSI6bnVsbH19](https://www.researchgate.net/publication/359910773_Modeling_of_human_group_coordination?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOijzY2IlbnRpZmljQ29udHJpYnV0aW9ucyIsInByZXZpb3VzUGFnZSI6bnVsbH19)