Next-generation AI agents

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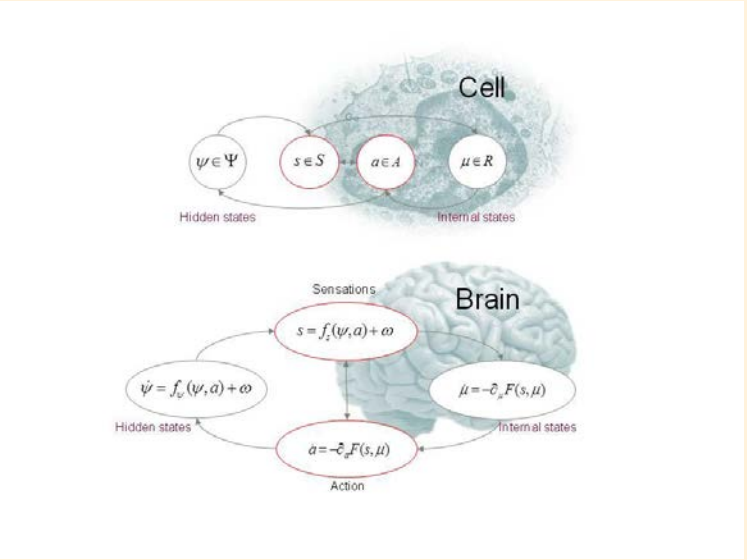


- AI agents hype vs. reality
- First principles: Active Inference (AIF)
- From single agents to nested systems
- Stepping stones for technological evolution

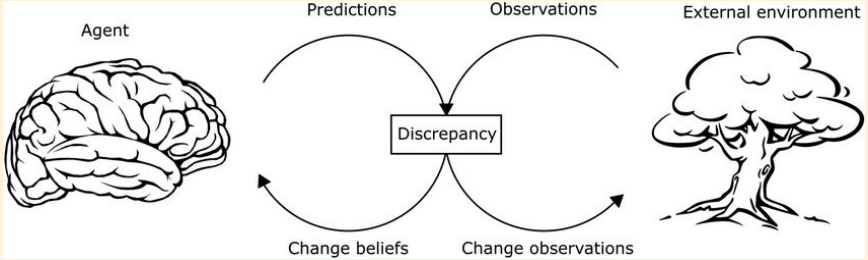
Agenda

- **2025 hype "Year of the Agent":** LLM-based agents promise autonomous multi-agent teams for complex tasks, fueling massive excitement.
- **Market boom projections:** AI agents market hits ~$8B in 2025, expected grow to $50B+ by 2030 at 46% CAGR, driven by enterprise automation demands.
- **Reality check in practice:** current agents fail in novel scenarios, reward-engineered, data and compute hungry, and prone to hallucinations or breakdowns.
- **High cancellation risks:** up to 70% of agentic AI projects could be axed by 2027 due to unexpected costs, scaling complexity, and risks.
- **The Gap “hype vs true autonomy”:** while promising, most agents lack adaptive, intrinsic motivation, setting opportunities for next-gen solutions like Active Inference (AIF).

First Principles: Active Inference basics

- **Roots in Free Energy Principle (FEP):** developed by Karl Friston, FEP posits that adaptive systems minimize "surprise" (prediction error) to survive entropy, unifying biology, physics, and AI.
- **Core idea:** agents reduce variational free energy, a bound on surprise, through perception (updating world models) and action (changing the world to match predictions).
- **Perception-Action loop:** sense data → infer hidden causes (update beliefs) → act to refine models or environment→ learn from outcomes, creating continuous adaptation.
- **Expected Free Energy (EFE)**: key metric for policy selection; balances epistemic value (exploration to reduce uncertainty) and pragmatic value (exploitation to achieve preferred states).
- **Why it matters for AI:** provides intrinsic motivation and efficiency; unlike reward-driven RL or data-hungry LLMs, AIF enables true autonomy in changing, uncertain environments.

Key concepts



1

Free Energy Principle

All adaptive systems (brains, potentially AI) minimize variational free energy, a bound on surprise (prediction error).

2

Active Inference

Agents actively sample the world to test/refine generative models → unify perception, action, learning.

3

Agent loop

Key loop: infer states → predict outcomes → select actions minimizing expected free energy.

4

Definition

Next-gen agents are autonomous entities whose core is hierarchical active inference over generative models.

5

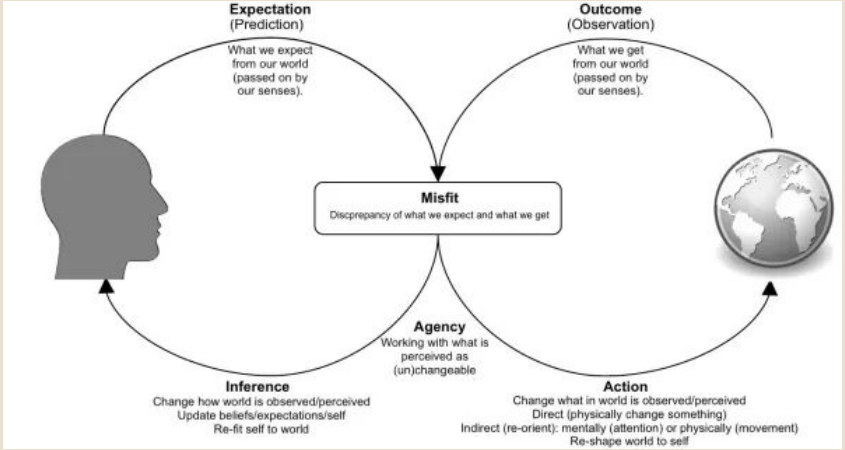
Features

Enabling true agency, adaptation, and intrinsic motivation without external rewards.

AIF agents key advantages

- **Adaptation:** handles uncertainty via epistemic foraging (active exploration to reduce ambiguity), outperforming LLM wrappers in novel scenarios without massive retraining.
- **Intrinsic motivation:** AIF agents minimize expected free energy naturally, curiosity and goal-seeking emerge from first principles; no need for crafted rewards or extrinsic reinforcement like in RL/LLM agents.
- **Efficiency & scalability:** hierarchical generative models enable low-data and compute-efficient learning, contrasts with data-hungry LLMs.
- **Explainability & governance:** beliefs and policies are inspectable, reducing risks compared to opaque black-box models.

- **Single AIF agent:** real-time adaptation in uncertain environments (e.g., robotics whole-body control via inner AIF).
- **Scaling to multi-agent:** shared and nested Markov blankets, belief propagation/message passing, collective EFE minimization, emergent orchestration (no rigid central controller needed, hybrid supervisory AIF for reliability).



- **AIF as technological evolution accelerator:** self-evolving agents drive innovation, enabling complex intelligence via mirror biological evolution at digital world.
- **Faster discovery & breakthroughs:** agents hypothesize, test, and refine world models, changing fields like scientific research, and creative problem-solving.
- **Resilient enterprise systems:** orchestrated multi-agent workflows adapt to disruptions in real-time, minimizing free energy across supply chains, automation, robotics.
- **Systemic transformation:** from isolated tasks to ecosystem-wide evolution, unlocking new business models, societal structures, and a future where technology self-organizes for global challenges.

Key takeaways

1

Embrace AIF for true agency

Define next-gen AI agents using AIF's first principles, minimizing free energy for intrinsic motivation, adaptability, and efficiency beyond LLM limitations.

2

Balance Exploration and Exploitation

Leverage to create agents that smartly handle uncertainty, making them robust for real-world, dynamic environments.

3

Orchestrate Multi-Agent Systems Emergent

Scale from single agents to teams via shared world models and collective minimization, unlocking coordination without central control.

4

Drive Technological Evolution

Start experimenting with AIF tools to accelerate innovation, build resilient systems, and evolve human-AI collaboration for the future.

Resources

"Active Inference: The Free Energy Principle in Mind, Brain, and Behavior" by Thomas Parr, Giovanni Pezzulo, Karl Friston

"Fundamentals of Active Inference: Principles, Algorithms, and Applications of the Free Energy Principle for Engineers" by Sanjeev Namjoshi (release on March 17, 2026)

RxInfer.jl: examples gallery https://examples.rxinfer.com/

pymdp: a Python library for AIF in discrete state spaces https://pymdp-rtd.readthedocs.io/

Active Inference Institute www.activeinference.institute

Questions?
Please reach out:

Thank you!