The Imagination Machine:
A Formal Model of Institutional Epistemology

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Abstract

Scientific institutions evolve knowledge through a recursive process: structured dialogue, selective compression and differential transmission of ideas, and empirical feedback. To model this dynamic, we introduce a formal model of institutional learning in which both reasoning procedures and evaluative procedures evolve through dialogue, compression, and environmental feedback. Monte Carlo generations of trios of dialogical agents operate over a shared corpus and evolving prompts. Each trio generates dialogue interpreted as a sample path in a representational space. Agents propose compression rules, prompt revisions, and candidate solutions to an external problem.

Compression proceeds in two stages. First, a compendium is formed from the proposed compression rules, resulting in a compression prompt. Second, a language model conditioned on the compression prompt produces a final prompt revision and proposes a solution to the problem of interest.

The subsequent generation of agents receives an external correctness signal evaluating the final solution of the previous generation, and the final prompt revisions are implemented before simulation of the subsequent generation commences.

The resulting architecture formalizes a minimal model of institutional learning in which reasoning rules and evaluative procedures co-evolve through dialogue, compression, revision, and environmental feedback.

1 Introduction

Academic institutions operate through a recursive process:

1. researchers generate hypotheses through dialogue and simultaneously contribute to institutional procedures
2. institutions filter, compress, and differentially transmit generated ideas
3. empirical feedback guides future research and institutional development

Two forms of structure evolve simultaneously:

- **reasoning**: the ideas and conceptual frameworks under discussion
- **evaluation**: the procedures by which ideas are summarized, reviewed, and judged

We formalize this process as a recursive system of dialogue, compression, and feedback operating across generations of interacting agents. The framework can be interpreted both as a theoretical model of institutional learning and as a potential architecture for multi-agent reasoning systems.

Contribution. We introduce a formal model of institutional learning in which both reasoning procedures and evaluative procedures evolve through dialogical exploration, compression, and feedback. The resulting dynamics define a stochastic process over institutional states.

Note on related work. The authors are aware that related work exists across several relevant literatures, including prompt optimization, multi-agent large language model systems, evolutionary approaches to prompt search, and institutional learning. A fuller literature review situating this contribution within those bodies of work will appear in a revised version.

2 Basic Objects

Definition 1 (Corpus). *Let W denote a shared corpus of writings available to all agents.*

Definition 2 (Representational Space). *Let $\mathcal{R}$ denote a representational space of possible dialogues.*

Definition 3 (External Problem). *Let $\mathcal{Q}$ denote an external problem to which generations propose solutions.*

Two prompts evolve over time.

Definition 4 (Reasoning Prompt). *R_g denotes the reasoning prompt at generation g.*

Definition 5 (Compression Prompt). *C_g denotes the compression prompt governing summarization.*

3 Monte Carlo Dialogical Trios

At generation g we instantiate a population

$$\mathcal{M}_g = \{T_g^{(1)}, \ldots, T_g^{(N_g)}\}$$

of dialogical trios.

Each trio

$$T_g^{(k)} = \{a_{g,1}^{(k)}, a_{g,2}^{(k)}, a_{g,3}^{(k)}\}$$

is initialized with

$$(W, R_g, C_g, \mathcal{Q})$$

and generates a dialogue.

Definition 6 (Dialogue Sample Path). *The dialogue produced by trio $T_g^{(k)}$ is*

$$D_g^{(k)} \in \mathcal{R}.$$

Dialogue trajectories are interpreted as sample paths through the representational space.

4 Agent Outputs

Each agent $a_{g,i}^{(k)}$ produces three outputs:

1. reasoning revision proposal
$$(A_{g,i}^{R,k}, F_{g,i}^{R,k})$$

2. compression prompt revision proposal
$$(A_{g,i}^{C,k}, F_{g,i}^{C,k})$$

3. candidate solution
$$S_{g,i}^k$$

Here A denotes additions to a prompt and F denotes proposed removals (forgetting).

5 Two-Stage Compression

Compression proceeds in two stages.

The two stages separate the accumulation of institutional memory from the compression of that institutional record into transmitted reasoning and evaluation procedures.

5.1 Stage 1: Compendium Construction

Collect proposed additions to the compression prompt:

$$\mathcal{A}_g = \left\{ A_{g,i}^{C,k} \;\middle|\; 1 \le k \le N_g,\; 1 \le i \le 3 \right\}.$$

Construct the compendium:

$$\widetilde{C}_g = \mathrm{Gather}(C_g, \mathcal{A}_g).$$

The Gather operation aggregates proposed additions without semantic compression, functioning as an append-only institutional memory within a generation; subtraction from the compression prompt occurs after compression and before transmission to the subsequent Monte Carlo generation.

5.2 Stage 2: Summarization

Define

$$\mathcal{R}_g = \left\{ (A_{g,i}^{R,k}, F_{g,i}^{R,k}) \;\middle|\; 1 \le k \le N_g,\; 1 \le i \le 3 \right\},$$

$$\mathcal{C}_g = \left\{ (A_{g,i}^{C,k}, F_{g,i}^{C,k}) \;\middle|\; 1 \le k \le N_g,\; 1 \le i \le 3 \right\},$$

and

$$\mathcal{S}_g = \left\{ S_{g,i}^k \mid 1 \le k \le N_g,\ 1 \le i \le 3 \right\}.$$

Let Γ denote a language model conditioned on the compendium.

Using compendium $\widetilde{C}_g$, compute

$$\Gamma_g^{\widetilde{C}_g}(\mathcal{R}_g, \mathcal{C}_g, \mathcal{S}_g) = (A_g^R, F_g^R, A_g^C, F_g^C, \widetilde{S}_g).$$

Here $\widetilde{S}_g$ denotes the summarized solution proposed by generation g.

6 Generational Feedback

The summarized solution $\widetilde{S}_g$ is evaluated against the external problem $\mathcal{Q}$.

The environment returns a feedback signal

$$Y_g \in \mathcal{Y}$$

representing the correctness or quality of the proposed solution.

7 Prompt Updates

Reasoning and compression prompts evolve separately but in a coupled manner.

7.1 Compression Update

$$C_{g+1} = \widetilde{C}_g \setminus F_g^C.$$

7.2 Reasoning Update

$$R_{g+1} = (R_g \setminus F_g^R) \oplus A_g^R \oplus C_{g+1} \oplus Y_g.$$

Both layers evolve through inheritance, forgetting, and structural addition. If the prompt length exceeds a threshold M, tokens are removed according to a first-in-first-out (FIFO) policy.

8 Algorithmic Overview

The imagination machine evolves prompts across generations through dialogue, compression, and feedback. One generational step proceeds as follows.

1. Initialize a population of dialogical trios using prompts (R_g, C_g) and shared corpus W. For example, the population may be a collection of trios of instances of a language model with pseudo-randomly sampled temperature parameters.

2. Each trio generates a dialogue $D_g^{(k)}$ and agents propose reasoning revisions, compression prompt revisions, and candidate solutions.

3. Aggregate proposed compression prompt additions and construct the compendium $\widetilde{C}_g = \text{Gather}(C_g, \mathcal{A}_g)$.

4. Use the language model Γ conditioned on $\widetilde{C}_g$ to summarize revisions and candidate solutions.

5. Evaluate the summarized solution $\widetilde{S}_g$ against the external problem $\mathcal{Q}$ and obtain feedback signal Y_g.

6. Update reasoning and compression prompts to obtain (R_{g+1}, C_{g+1}).

9 Stochastic Institutional Dynamics

The evolution of the system can be interpreted as a stochastic process.

Definition 7 (Institutional State). *Let*

$$X_g := (R_g, C_g)$$

denote the institutional state at generation g.

Dialogue generation, summarization, and feedback introduce randomness through sampling processes and Monte Carlo population dynamics.

Definition 8 (Generational Transition Kernel). *Let*

$$K(\cdot \mid X_g, W, \mathcal{Q})$$

denote the conditional probability law governing the next institutional state given the current state, corpus, and external problem.

Thus institutional evolution may be written

$$X_{g+1} \sim K(\cdot \mid X_g, W, \mathcal{Q}).$$

10 Interpretation

Dialogue trajectories

$$D_g^{(k)}$$

represent sample paths through representational space. The Monte Carlo population approximates a distribution over such trajectories.

Compression extracts shared structure across dialogues, while external feedback guides the evolution of reasoning.

The resulting architecture formalizes institutional learning: ideas evolve through dialogue to solve problems while evaluative procedures operate through selective compression and transmission of corpora of recorded symbols; the processes co-evolve continually.

11 Conclusion

The imagination machine evolves two interacting structures:

- reasoning prompts governing intellectual exploration
- compression prompts governing institutional evaluation

Dialogue generates trajectories, compression extracts inheritable structure, forgetting prevents uncontrolled growth, and feedback from external problems guides institutional learning across generations.