Decentralized Autonomous Narrative Networks (DANN): A Multi-Model Approach to Reinforcement Learning

Paul Lowndes
ZeroTrust@NSHkr.com

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Abstract

[Previous abstract remains the same]

1 Introduction

The proliferation of artificial intelligence systems and their increasing role in shaping information flows has created new challenges in understanding and managing narrative dynamics in digital spaces. Traditional multi-agent reinforcement learning (MARL) approaches often fail to capture the nuanced interplay between agents' beliefs, knowledge, and the narratives they construct and propagate. This paper introduces Decentralized Autonomous Narrative Networks (DANN), a framework that explicitly models these dynamics through a combination of embedding spaces, belief systems, and narrative evolution mechanisms.

2 Framework Overview

2.1 Core Components

We begin by defining the fundamental mathematical structures that underpin the DANN framework:

Definition 1 (Embedding Space)**.** *The global embedding space E_G is a metric space (E_G, d) where:*

- $d : E_G \times E_G \to \mathbb{R}_{\geq 0}$ *is a distance function*
- *For all $x, y \in E_G$: $d(x, y) = 0 \iff x = y$ (identity)*
- *For all $x, y \in E_G$: $d(x, y) = d(y, x)$ (symmetry)*
- *For all $x, y, z \in E_G$: $d(x, z) \leq d(x, y) + d(y, z)$ (triangle inequality)*

Definition 2 (Agent Space)**.** *For each agent a_i, its local embedding space $E_i \subseteq E_G$ is equipped with:*

- *Knowledge set $K_{i,t} \subset E_i$ at time t*

- *Belief set* $B_{i,t} \subset E_i$ *at time* t
- *Narrative sequence* $N_{i,t} = (c_{i,1}, c_{i,2}, \ldots, c_{i,T}) \in E_i^T$

where $K_{i,t} \subseteq B_{i,t}$ *(knowledge is a subset of beliefs).*

3 Mathematical Framework

3.1 Veracity Function Properties

The veracity function $V : E_G \to [0, 1]$ satisfies:

Property 1 (Veracity Axioms)**.** *For all* $x, y \in E_G$*:*

- $V(x) = 1 \iff x \in T$ *(truth region)*
- $\|x - y\| \leq \epsilon \implies |V(x) - V(y)| \leq \delta$ *(continuity)*
- $V(x) = 0 \implies x$ *is maximally inconsistent with truth*

3.2 Narrative Dynamics

Definition 3 (Narrative Divergence)**.** *The divergence* D *between narratives satisfies:*

$$D(N_{i,t}, N_{j,t}) = \sum_{k=1}^{T} w(c_{i,k}) \cdot d(c_{i,k}, c_{j,k}) \tag{1}$$

where $w(c) = f(V(c))$ *for some monotonic function* $f : [0, 1] \to [0, 1]$.

3.3 Agent Interaction Mechanisms

3.3.1 Knowledge Propagation

Knowledge updates follow:

$$K_{i,t+1} = K_{i,t} \cup \{e \in E_i \mid V(e, T) > \tau_K \wedge \exists j : e \in K_{j,t}\} \tag{2}$$

where τ_K is the knowledge acceptance threshold.

3.3.2 Belief Evolution

Belief updates incorporate both knowledge and social influence:

$$B_{i,t+1} = f_B(B_{i,t}, K_{i,t+1}, \sum_{j \neq i} \alpha_{ij} B_{j,t}) \tag{3}$$

where α_{ij} represents the influence weight of agent j on agent i.

4 Learning Mechanisms

4.1 Narrative-Based Reward

The reward function combines environmental and narrative quality:

$$R_i(s_t, a_t, s_{t+1}) = \alpha \cdot R_{\text{env}}(s_t, a_t, s_{t+1}) + \beta \cdot Q(N_{i,t+1}) \tag{4}$$

where:

- $Q(N) = \gamma_1 C(N) + \gamma_2 V_{\text{avg}}(N) + \gamma_3 I(N)$
- $C(N)$ measures narrative coherence
- $V_{\text{avg}}(N)$ is the average veracity
- $I(N)$ measures narrative influence

4.2 Agent-Switching Mechanism

The switching function is defined as:

$$S_i(t) = \arg\max_j \{Q(M_{i,j}, N_{i,t}, \text{Context}_t) + \lambda H(j)\} \tag{5}$$

where:

- $H(j)$ is an entropy term promoting exploration
- λ balances exploitation vs. exploration
- Context_t includes environmental and social factors

5 Discussion and Future Work

[This section would discuss implications, limitations, and future research directions]