MAGS: Learning LLMS

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Humans vs LLMs

- Lack of Agency
  - Figure, Tesla, etc...
- Lack of True Understanding, Reasoning, Novelty
  - ???
- **Lack of Memory, Learning, and World Model**
  - **Our Goal**

Motivation & Problem

Memory and Learning

- LLMs cannot **learn and remember**
  - Test-time emulation with context windows is not viable
    - Quadratic scaling
    - Attention decay and ephemeral context
    - Stateless session
  - Retrieval Augmented Generation (RAG) can add information
    - But rigid, one way static transfer of knowledge
    - Cannot reconcile new or conflicting information permanently

Motivation & Problem

SoTA / Literature

- CAMELoT, MIT+IBM
  - Added Memory Blocks To Remember Information
  - Fixed Memory Size, Overwrites Past Memory, No relationships between memory, No reconciliation
- Continual Learning
  - Catastrophic Forgetting, Expensive, Very Slow, not optimal
  - Google Titans (RMTs): Updates Attention loses fine details, and slow + 2M token max
- AriGraph
  - Adding Dynamic Graph-Based RAG
  - LLM has no representation of memory, only adds information (no updating+consolidating), no importance of different episodes, memory not connection across episodes

Motivation & Problem

Technical Approach

M	A	G	S
Memory	**Augmented**	**Graph**	**Scaling**
Episodic and Semantic Memory Blocks (RAG) along with Long-term vs Working Memory Supports separation of general knowledge, experience, and importance.	Compatible with any vanilla frozen LLM. Fine-tuned for engram+recall steps, so LLM can interact with memory. LLM can query knowledge before answering and store novel experiences and learnings.	Liquid Knowledge Graphs, that can add+remove nodes, change edge weights, consolidate and forget knowledge. Replicates human Hebbian Plasticity, Neurogenesis, and Synaptic Pruning.	Allows for context scaling limited by memory constraints rather than attention decay. Similar time inference. Chat History is part of Working memory, so agents are more modular.

Technical Approach

Structure

Knowledge broken down into Long-Term (important info), and Working Memory (chat history). Memory is moved from Working to Long-Term based on usage, ‘surprise’, or importance.

Recall

Anchor Nodes selected from query, BFS over decaying edge weights. SCCs consolidated. Can also query for connection between nodes.

Engram

Updates nodes and edge weights based on query importance. Can add or update information.

Validation

Custom game with nonsensical rules (so mode cannot reason). LLM can store newfound experiences, rule changes, surprising things, general game rules, etc...

Validation Examples

Mathematical Formulation - GRPO

Let $\pi_\phi(a|s)$ be the policy with parameters ϕ and $\pi_{\phi_{\text{old}}}(a|s)$ be the policy before the update. Define the probability ratio:

$$r_t(\phi) = \frac{\pi_\phi(a_t|s_t)}{\pi_{\phi_{\text{old}}}(a_t|s_t)}.$$

Let A_t be the advantage estimate at time t and define the group-relative advantage as:

$$\hat{A}_t^{\text{GRPO}} = A_t - \frac{1}{|\mathcal{G}(t)|} \sum_{t' \in \mathcal{G}(t)} A_{t'},$$

where $\mathcal{G}(t)$ is the set of experiences in the group corresponding to time t.

Then the GRPO objective is:

$$L^{\text{GRPO}}(\phi) = \mathbb{E}_t \left[\min \left(r_t(\phi)\, \hat{A}_t^{\text{GRPO}},\ \text{clip}\left(r_t(\phi),\, 1-\epsilon,\, 1+\epsilon\right)\, \hat{A}_t^{\text{GRPO}} \right) \right],$$

where ϵ is a hyperparameter that limits the extent of policy updates.

Mathematical Formulation - MAGS

$$\min_{\theta,\phi,\psi} \mathcal{L} = \mathbb{E}_{(x,y)\sim\mathcal{D}} \left[\ell\Big(f_\theta\Big(x, g_\phi\big(M(x;\psi)\big)\Big), y\Big)\right] - \lambda\, \mathbb{E}_{x\sim\mathcal{D}} \left[R\Big(M(x;\psi), g_\phi\big(M(x;\psi)\big)\Big)\right] + \mu\, \mathcal{L}_{\text{graph}}\Big(M(x;\psi)\Big) + \nu\, \mathcal{R}(\theta,\phi,\psi).$$

We define our objective as a composite loss that jointly optimizes the language model's prediction accuracy, memory retrieval/reinforcement, and dynamic graph structure regularization. Let:

- θ denote the parameters of the underlying LLM.
- ϕ denote the parameters governing the memory retrieval and update module.
- ψ denote the parameters controlling the dynamic graph (i.e., Liquid Knowledge Graph) structure.
- $\mathcal{D} = \{(x, y)\}$ be the dataset of input–output pairs.
- $M(x;\psi)$ be the memory representation extracted from input x (including both episodic and semantic components).
- $g_\phi\big(M(x;\psi)\big)$ be the memory retrieval function that selects relevant memory nodes.
- $f_\theta(\cdot)$ be the generative function of the LLM augmented with the retrieved memory.
- $\ell(\cdot,\cdot)$ be a standard prediction loss (e.g., cross-entropy).

1. **Prediction Loss Term:**

$$\mathbb{E}_{(x,y)\sim\mathcal{D}} \left[\ell\Big(f_\theta\Big(x, g_\phi\big(M(x;\psi)\big)\Big), y\Big)\right]$$

ensures that the model's predictions are accurate given the input and the augmented memory.

2. **Memory Reward Term:**

$$-\lambda\, \mathbb{E}_{x\sim\mathcal{D}} \left[R\Big(M(x;\psi), g_\phi\big(M(x;\psi)\big)\Big)\right]$$

where $R(\cdot)$ is a reinforcement signal (e.g., derived from Group Relative Policy Optimization) that rewards effective memory recall and engram updates. The hyperparameter λ balances its influence.

3. **Graph Regularization Term:**

$$\mu\, \mathcal{L}_{\text{graph}}\Big(M(x;\psi)\Big)$$

is a penalty term (which may include terms for edge density, conflict resolution, and pruning cost) to maintain an efficient, sparse, and interpretable Liquid Knowledge Graph. The hyperparameter μ regulates its strength.

4. **Regularization Term:**

$$\nu\, \mathcal{R}(\theta,\phi,\psi)$$

is a composite regularization term (including, for example, L_2 norms, memory capacity constraints, and complexity penalties) that ensures the overall system remains computationally feasible and stable. The hyperparameter ν controls its weight.

Results

Include GIF / Examples

5 Models

- Llama 3.2 1B, Llama 3.2 3B, Gemma 3 1B, Gemma 3 4B, Llama 3.2 11B (never converged).
- Tried using reasoning models / CoT (Qwen SmallThinker 3B), started talking about syrup in the middle

750 Steps

For training with PPO / GRPO. Evaluated with 100 Examples. Examples generated with multi-shot in-context learning with GPT-4o

Model	Score (F1)
Llama 3.2 1B	41%
Llama 3.2 3B	61%
Gemma 3 1B	52%
Gemma 3 4B	68%
Llama 3.2 11B (never converged)	N/A

Results

Include Pic of Finished Graph

Tried two types of schemas

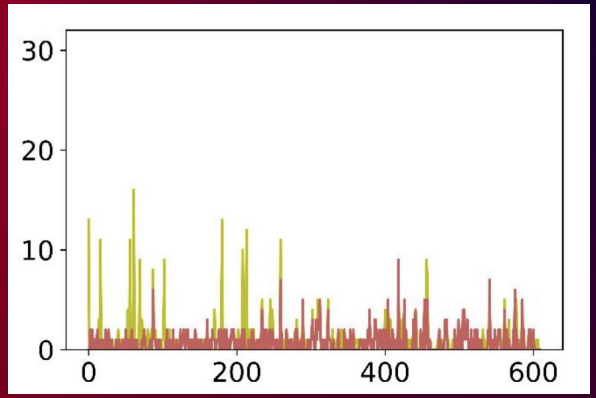
(1) Data in nodes, unlabeled edges. Difficult to manage and consolidate.

(2) Triplets (subject, verb, content)
   - (a) E.g. (John, owns, 9 cats)
   - (b) E.g. (The pencil, is in, the drawer)
   - (c) E.g. (The drawer, is, open)

Second one was easier to validate, and seemed more effective (never quantified). Used the second approach for all further results.

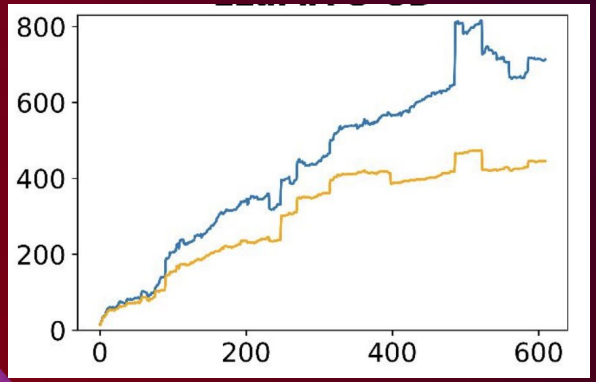
Conflict Resolution

Include GIF / Examples



Replaced information if confidence score of new information was greater than persistence score of past information.

Graph Building + Consolidation



No good consolidation architecture for schema (2).

However, ‘forgot’ information if utilization score decayed too much.

Results

Compile a graph of all literature tests vs MAGs.

37%

Improvements in accuracy over Base Model (Gemma 4B)

13%

Improvements in accuracy over Base Model (Gemma 4B) + Static RAG (adding all information, querying, 10)

Reflection

Major Technical Difficulty

Getting a SLM to reliably output the engram and recall steps using RL. Most of our initial implementations didn't work, and in the end we didn't have >70% F1.

Workflow

Easier: Developing the Graph System
Harder: Tuning hyperparameters for the graph system.

Next Steps (if more time)

Spending the time trying out larger (11B-16B) models
Trying more advanced Graph Algorithms.

Yuh

PITCH DECK

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TABLE OF CONTENTS

01.

ABOUT US

Elaborate on what you want to discuss.

HELLO THERE!

I'm Raina, and I'll be sharing with you my beautiful ideas. Follow me a @reallygreatsite to learn more.

ABOUT US

What we do?

Briefly elaborate on what you want to discuss.

Who we are?

Briefly elaborate on what you want to discuss.

ADD A TABLE

Add a main point What do you do during your free time? Write them here!	**Add a main point** What do you do during your free time? Write them here!	**Add a main point** What do you do during your free time? Write them here!
Add a main point What do you do during your free time? Write them here!	**Add a main point** What do you do during your free time? Write them here!	**Add a main point** What do you do during your free time? Write them here!

WRITE AN ORIGINAL STATEMENT OR INSPIRING QUOTE

— INCLUDE A CREDIT, CITATION, OR SUPPORTING MESSAGE

ADD A TEAM MEMBERS PAGE

Name

Title or Position

Name

Title or Position

Name

Title or Position

02.

OUR PROJECTS

Elaborate on what you want to discuss.

YOUR PROJECT

Presentations are communication tools that can be used as demonstrations, lectures, speeches, reports, and more. It is mostly presented before an audience. It serves a variety of purposes, making presentations powerful tools for convincing and teaching.

Year: 2022

Role: Write your role

S	W	O	T
STRENGTHS	**WEAKNESSES**	**OPPORTUNITIES**	**THREATS**
What are you doing well? What sets you apart? What are your good qualities?	Where do you need to improve? Are resources adequate? What do others do better than you?	What are your goals? Are demands shifting? How can it be improved?	What are the blockers you're facing? What are factors outside of your control?

OUR SERVICES

Service One

Elaborate on what you want to discuss.

Service Two

Elaborate on what you want to discuss.

Service Three

Elaborate on what you want to discuss.

Service Four

Elaborate on what you want to discuss.

WRITE YOUR BIG TOPIC OR IDEA

Presentations are communication tools that can be used as demonstrations, lectures, speeches, reports, and more.

It serves a variety of purposes, making presentations powerful tools for convincing and teaching.

03.

STATS & NUMBERS

Elaborate on what you want to discuss.

2 OUT OF 5

Elaborate on the featured statistic.

37%

Elaborate on the featured statistic.

95%

Elaborate on the featured statistic.

12 MILLION

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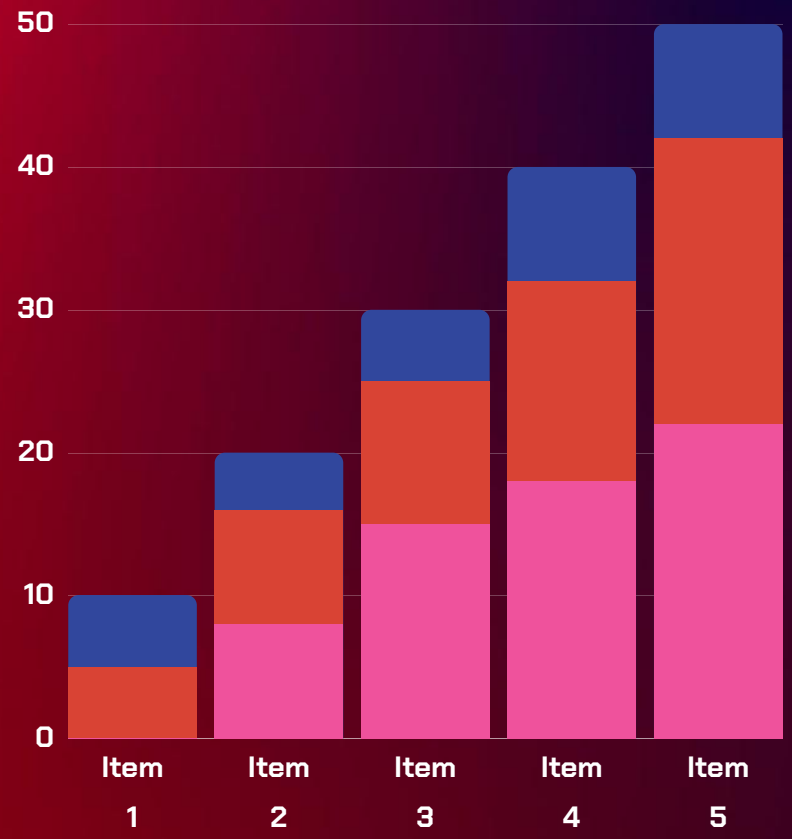

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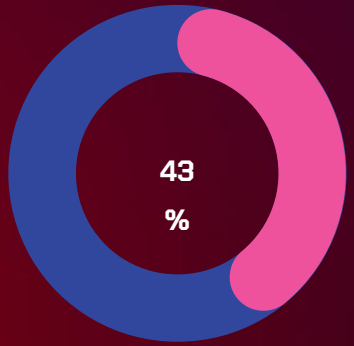

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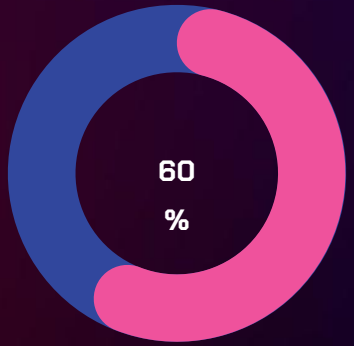

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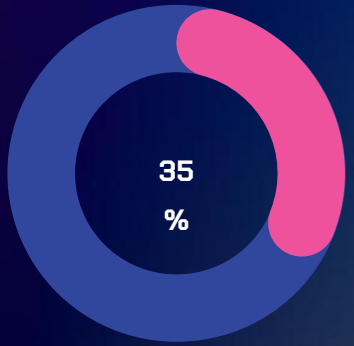

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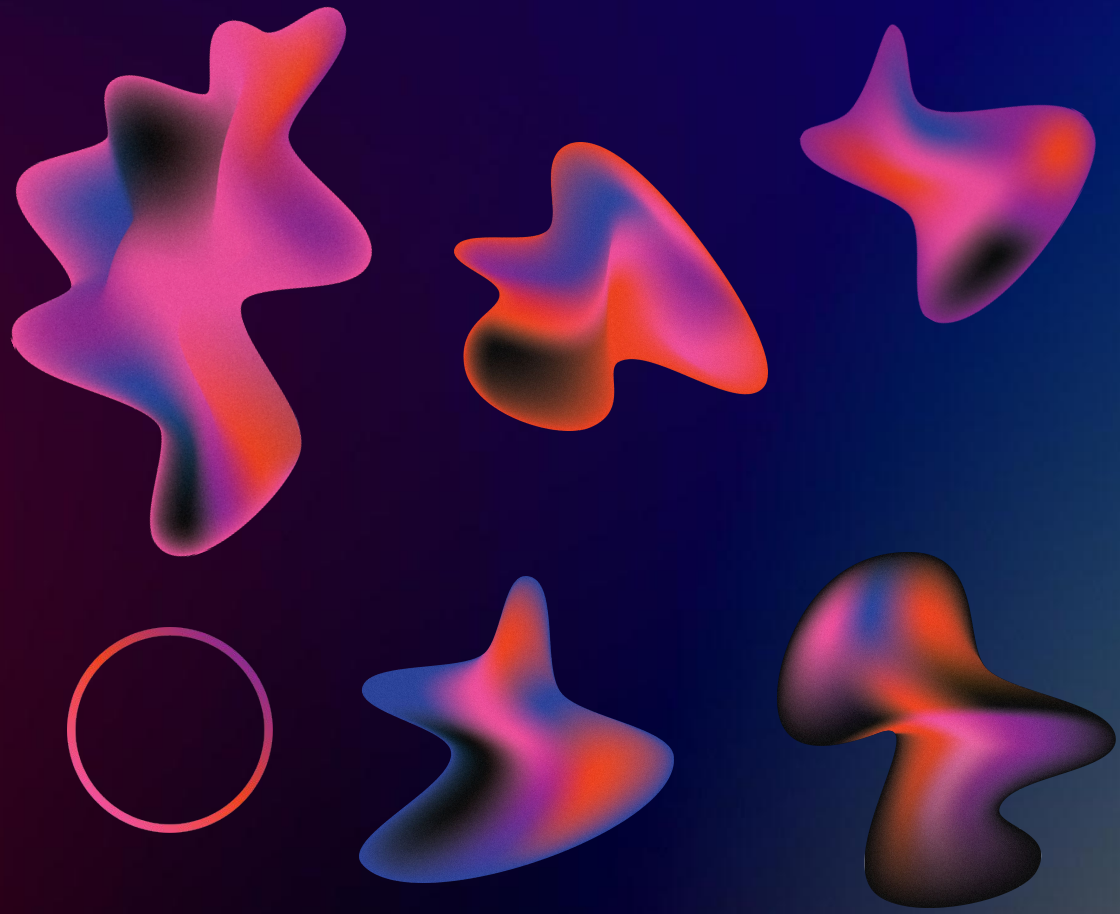

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