



Time is Not a Label: Continuous Phase Rotation for Temporal Knowledge Graphs and Agentic Memory

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Agent memory stores facts, and some of them go out of date

Long-running agents keep what they learn in an external memory, often a knowledge graph: **(subject, relation, object)** plus the time it happened.

Fact in memory	Time
(Obama, born_in, Hawaii)	1961
(US, president, Obama)	2009
(US, president, Trump)	2025

Q1 “Who is the US president?”

Two facts disagree. We want the newer one: time matters.

Q2 “Where was Obama born?”

The answer is the oldest fact in memory, and it is still true.

A timestamp is only a **label**: it says when a fact happened, not **whether it is still true**.

Three common fixes, and what each one gives up

Fix	Used by	What goes wrong
Overwrite the old fact	A-Mem, HippoRAG	History is lost: “Who was president in 2010?” has no answer
Ask an LLM at every write	Mem0, Zep	One LLM call per fact: fine for a chat, too costly for millions of facts
Sort by recency at search time	common default	“born in Hawaii” is 60 years old, so it sinks below newer, unrelated facts

The static–dynamic dilemma

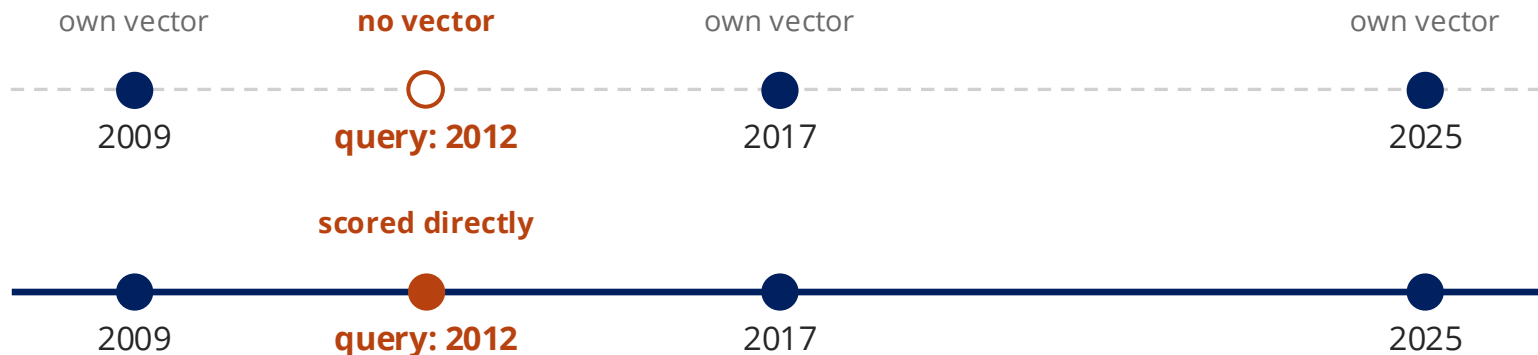
Lean on recency and permanent facts get buried. Ignore it and old and new facts conflict. The memory needs to know **which relations change**.

Temporal KG embeddings put time in the model, but still as a label

Family	How time enters	What is missing
Additive (T-TransE, HyTE)	a time vector is added to the score	a popular entity can still win at the wrong time
Discrete rotation (TeRo, ChronoR)	one learned vector per observed timestamp	no score between or beyond those timestamps

Time as a label

a lookup table of timestamps

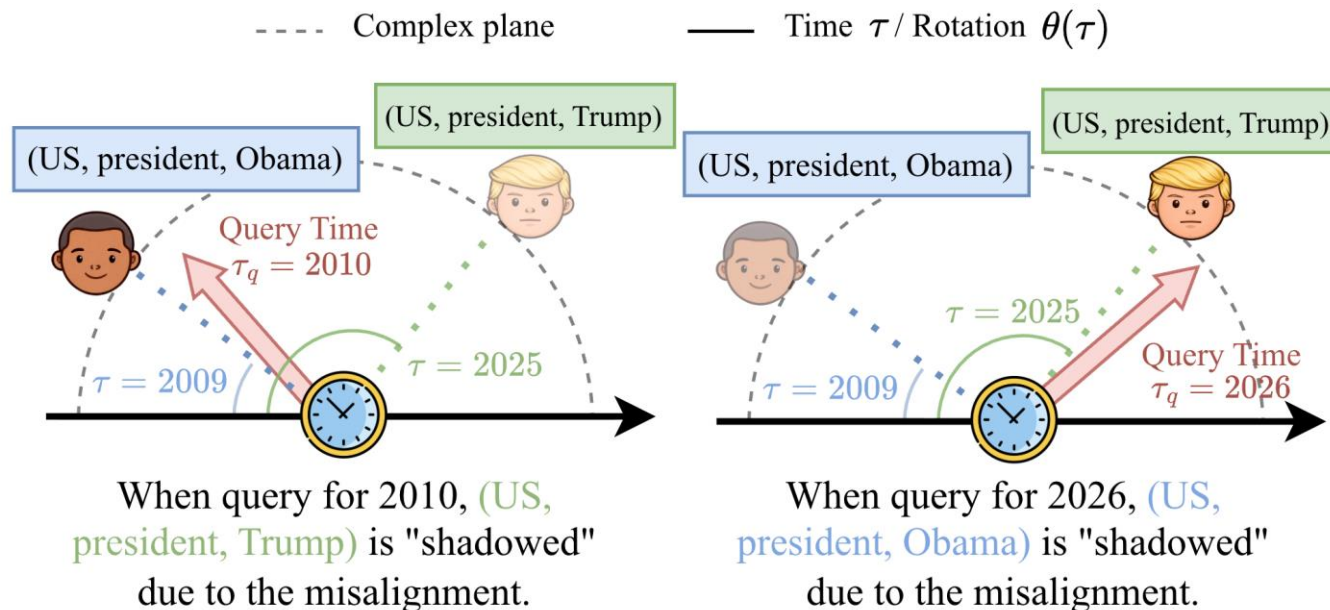


Time as a function (ours)

$\theta(\tau)$ is defined for every τ

In both families time is a discrete index, and nothing says **how fast a relation changes**.

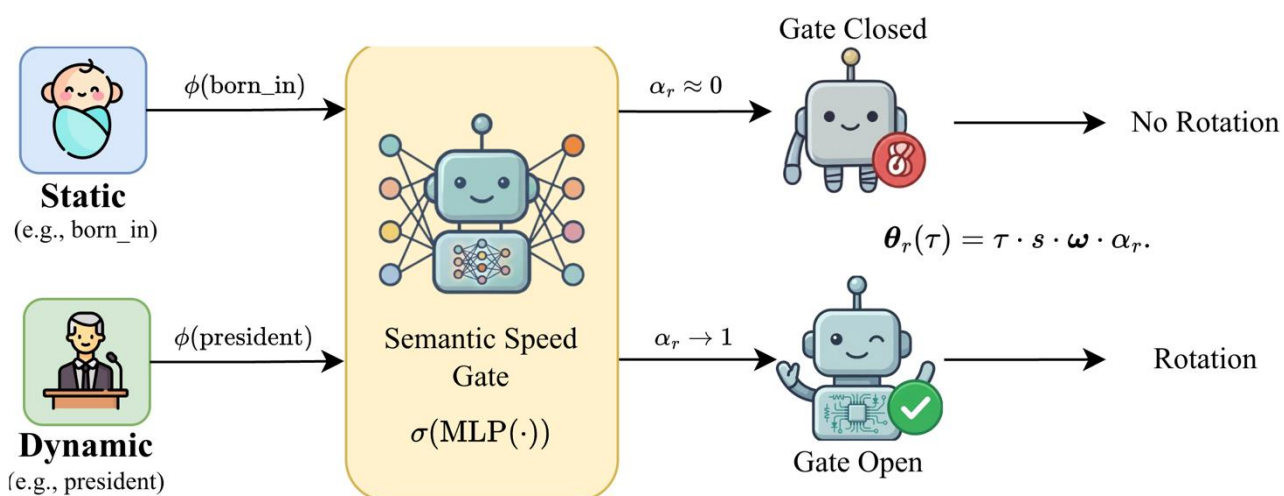
Our idea: time is not a label, it is a continuous rotation



- **Facts are vectors.** The time of a fact sets the direction it points in.
- **A query has a time too.** The fact that lines up with the query time scores highest.
- **Nothing is deleted.** An outdated fact is only out of phase ("shadowed"), so questions about the past still work.
- **Time is a function, not a lookup.** Any date can be scored, including dates never seen in training.

Not every relation should rotate: the Semantic Speed Gate

$$\theta_r(\tau) = s \cdot \alpha_r \cdot \tau \cdot \omega \quad \alpha_r = \sigma(\text{MLP}(\text{text embedding of } r)) \in (0, 1)$$



Relation	Speed α	
Consult	0.87	seen in training
Host a visit	0.86	
Cooperate militarily	0.09	
met with	0.71	never seen
CEO of	0.44	
citizen of	0.17	

The speed is read from the **meaning** of the relation, so “married to” and “wedded to” get a similar speed. **No static/dynamic labels.**

Training and use: two phases, then a reranker

1 Pretrain the gate (once)

- Data: ICEWS05-15 political events.
- Signal: for the same (subject, relation), did the object change between two timestamps?
- Changes often → fast. Stays the same → slow.

2 Fit the target memory

- The gate is frozen.
- Learn entity and relation embeddings and the global time scale on the target graph.
- The memory stays append-only.

3 Rerank at query time

- Same candidates as HippoRAG.
- Time only boosts facts that are already on topic.
- No LLM call to resolve conflicts.

Final score $S_{\text{final}} = S_{\text{sem}} \cdot (1 + \alpha_g \cdot S_{\text{kge}})$ semantic score from HippoRAG $\times$ temporal score from the rotation

Sanity check: continuous time does not hurt KG completion

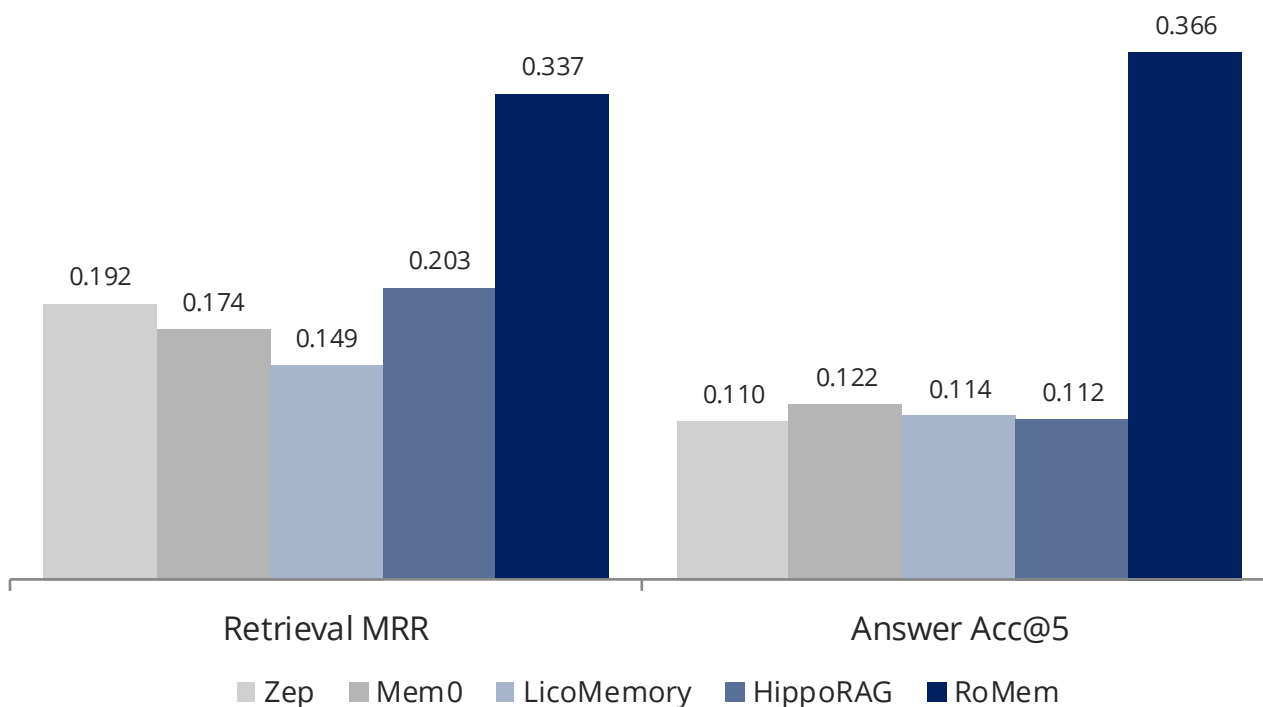
ICEWS05-15, temporal link prediction (filtered)

Method	MRR	Hit@1	Hit@3	Hit@10
ChronoR (our backbone)	68.4	61.1	73.0	82.1
TimeGate	69.2	61.3	74.5	83.7
TCompoundE	69.2	61.2	74.3	83.7
3DG-TE	69.4	61.4	74.7	84.1
RoMem-ChronoR	72.6	66.8	75.9	83.7

- **+4.2 MRR** over the ChronoR backbone it is built on
- Best MRR, Hit@1 and Hit@3 among the listed methods
- Hit@10 is **0.4 below** 3DG-TE
- The same change lifts DistMult from 45.6 to 62.1 MRR

Agent memory: the largest gains are on temporal questions

MultiTQ, GPT-5-mini + text-embedding-3-small



- MultiTQ: every question is about time, and the memory holds conflicting facts
- HippoRAG and RoMem share one pipeline. **Only the reranking differs.**
- Retrieval MRR **0.203** → **0.337**
- Answer accuracy **0.112** → **0.366** ($3.3\times$)
- Open-source setup (LLaMA-3.1-70B + BGE-M3):
Acc@5 0.122 → 0.312

No loss on static memory, and the gate transfers to finance

Benchmark	What it tests	Metric	Best other	HippoRAG	RoMem
LoCoMo	temporal questions	Recall@10	0.691	0.645	0.726
LoCoMo	all question types	Recall@10	0.834	0.815	0.857
DMR-MSC	largely non-temporal memory	MRR	0.847	0.848	0.856
FinTMMBench	unseen domain (finance)	MRR	0.716	0.690	0.728

- **Static relations do not rotate**, so non-temporal retrieval is left intact
- The gate was pretrained on political events and used on finance **without retraining**
- **Caveat:** on LoCoMo, answer F1 is unchanged (0.457) although retrieval improves

GPT-5-mini + text-embedding-3-small. “Best other”: best of Zep, Mem0, A-Mem, LicoMemory.

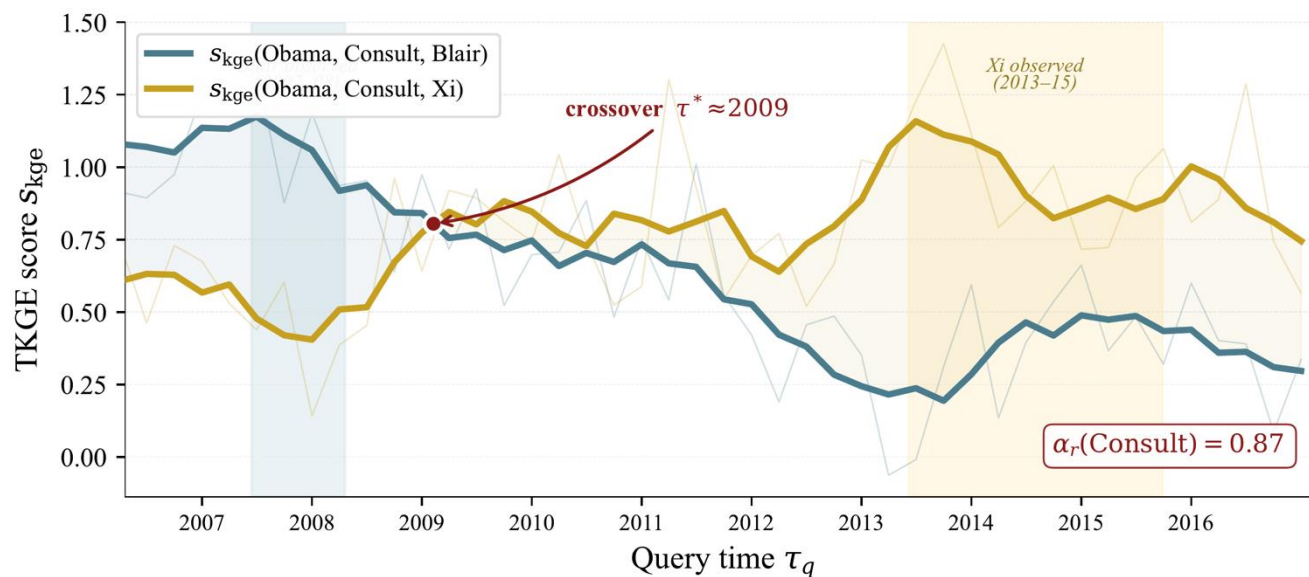
What matters: a speed per relation, and continuous time

Ablation on MultiTQ

Variant	MRR	Acc@5
Full RoMem	0.337	0.366
without time-contrastive loss	0.325	0.340
without speed gate (one speed)	0.104	0.100
time as a label (lookup)	0.045	0.040

Both ideas are needed. Without the gate MRR falls by 69%; with a timestamp lookup, by 87%.

Shadowing in real scores: (Obama, Consult, ?)



As the query time moves, Xi overtakes Blair around 2009. Nothing is deleted.

Takeaways

- **Time is not a label.** As a continuous rotation inside the embedding, it lets the memory keep every fact and still rank the right one for the time you ask about.
- **Relations change at different speeds, and this can be learned.** One number per relation, read from its text, with no labels.
- **It is a drop-in reranker.** Large gains on temporal questions, no loss on static memory, zero-shot transfer to finance.



Thank you

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Paper



Code



Project page

arxiv.org/abs/2604.11544
github.com/Tencent/RoMem
tencent.github.io/RoMem

Questions are welcome