AI That Sees the Future:
Multimodal LLMs for Open-World Forecasting

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HMCS Cluster, SCIS SMU
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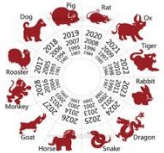
History of temporal forecasting

Oracle

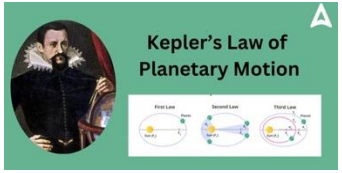
I Ching
(BC xx)



Zodiac

Constellations
(BC xx)

Newton's laws of motion
(1687)



Kepler's law of
planetary motion
(1619)

Udny Yule
Autoregression for
Sunspot Prediction
(1927)

Computer Science
Data Science
Artificial Intelligence

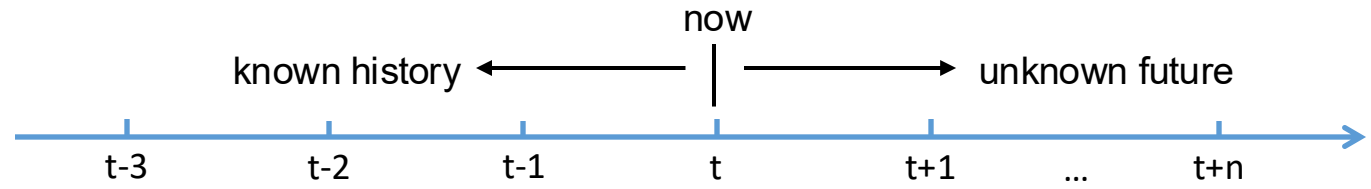
Divination

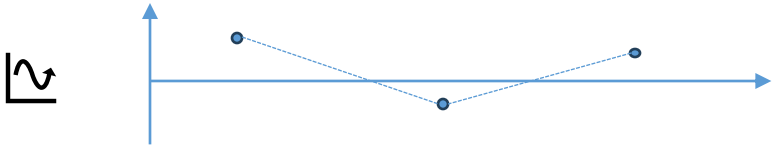
Astrology

Physics

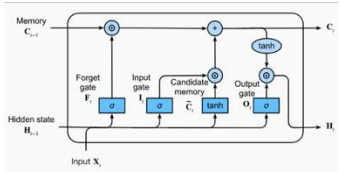
Statistics

Data-driven approaches

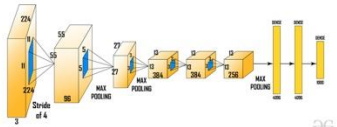




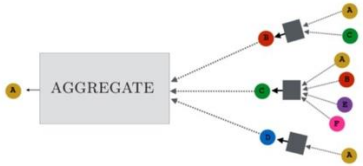
Numerical value: predict a number



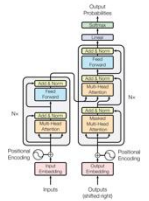
RNN



CNN

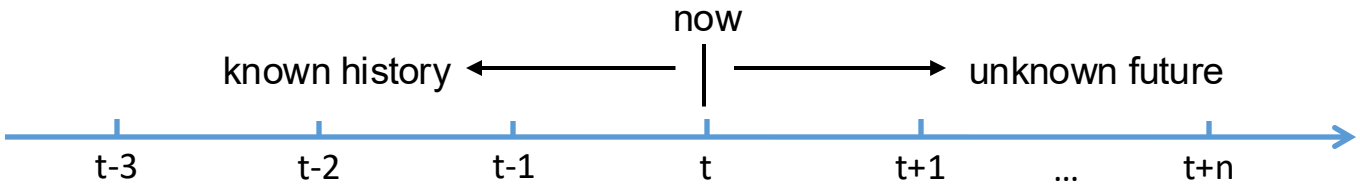


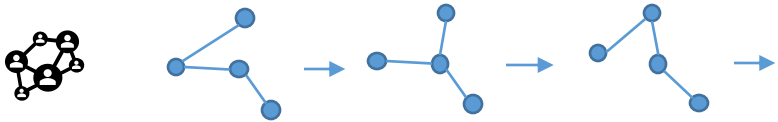
GNN



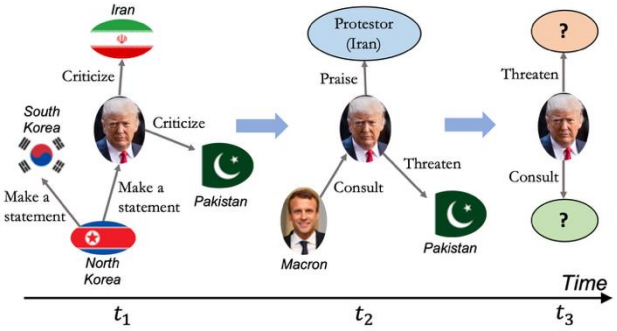
Transformer

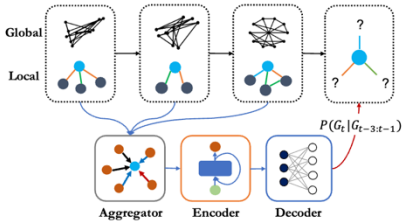
Data-driven approaches



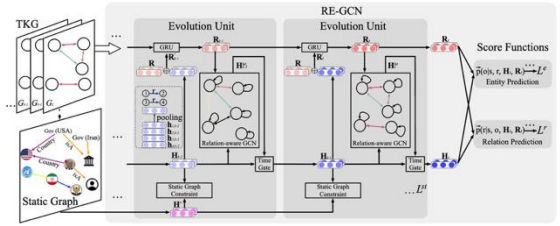


Triplet or graph: retrieve an entity or relation





RE-NET[1]



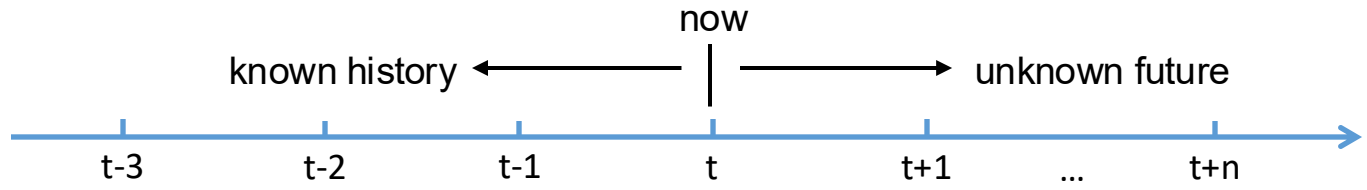
REGCN[2]

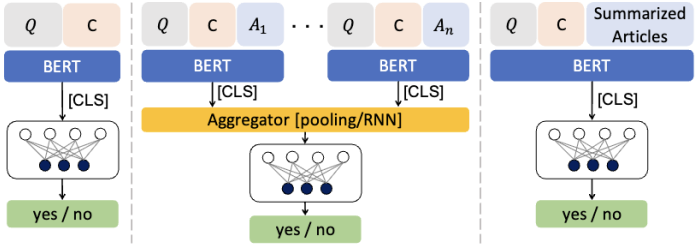
A spatial module (e.g., GCN) + A temporal module (e.g., RNN)

[1] Jin et al. Recurrent Event Network: Autoregressive Structure Inference over Temporal Knowledge Graphs. ACL 2020.

[2] Li et al. Temporal Knowledge Graph Reasoning Based on Evolutional Representation Learning. SIGIR 2021.

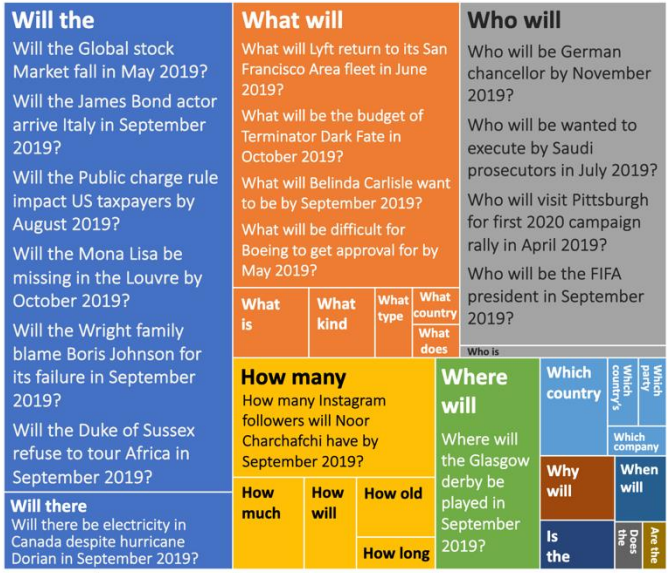
Data-driven approaches





BERT + Classification Head

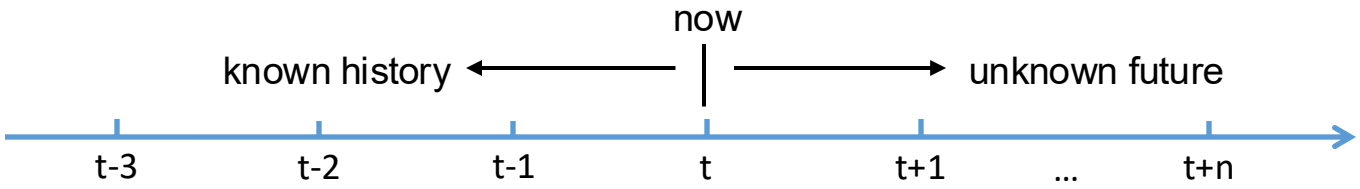
Natural language QA: MCQ

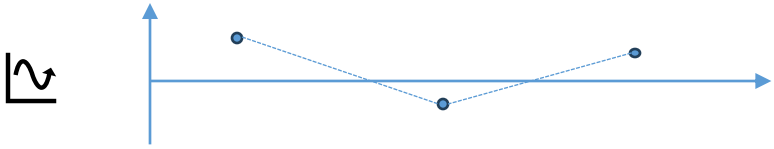


Statistics of the first two words of the questions [ForecastQA]

Jin et al. FORECASTQA: A Question Answering Challenge for Event Forecasting with Temporal Text Data. ACL 2021.

Data-driven approaches





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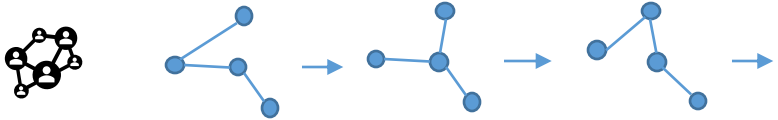


Triplet or graph: retrieve an entity or relation

Hamas-led militants storm across Israel's southern border with Gaza. Israel says the attack killed 1,200 people

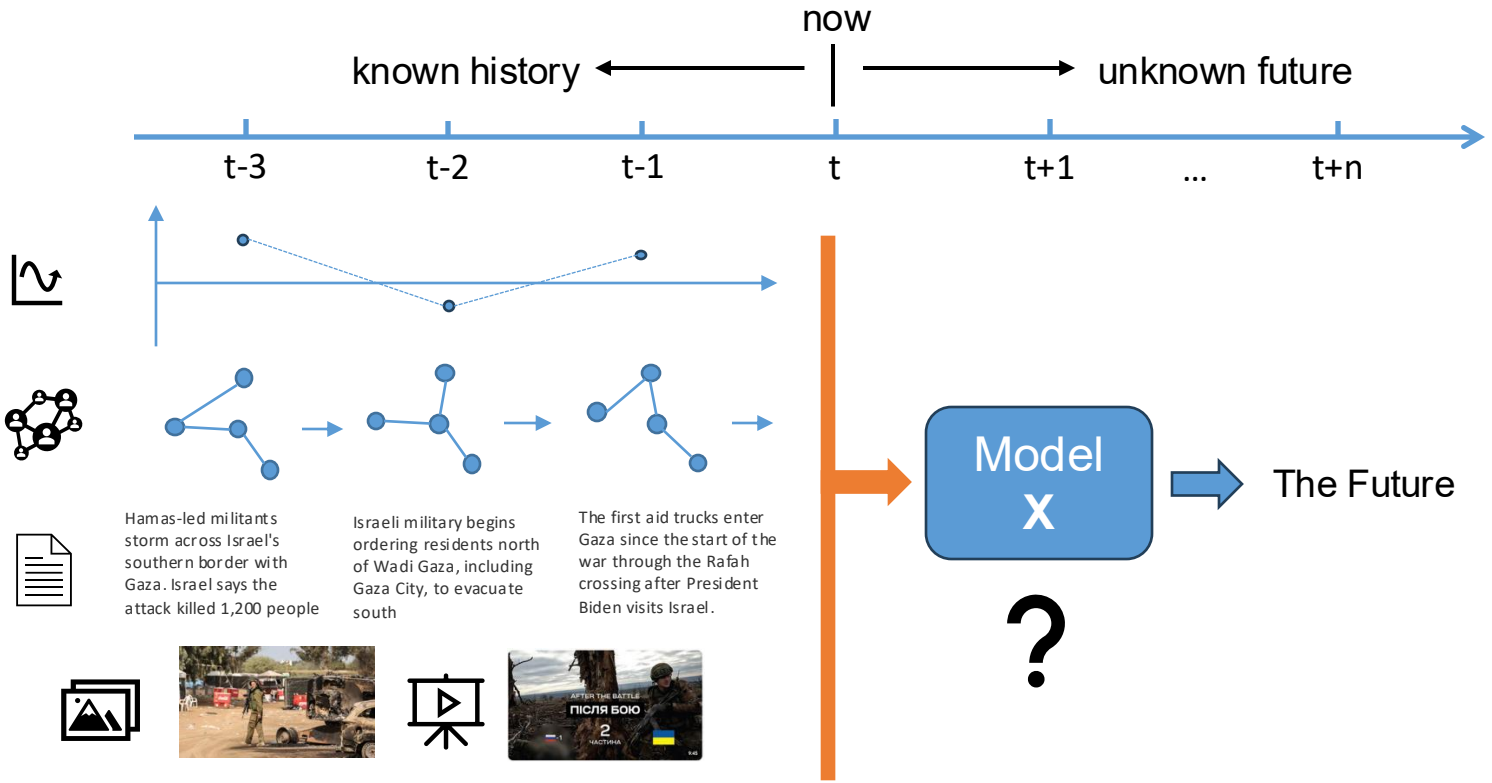
Israeli military begins ordering residents north of Wadi Gaza, including Gaza City, to evacuate south

The first aid trucks enter Gaza since the start of the war through the Rafah crossing after President Biden visits Israel.

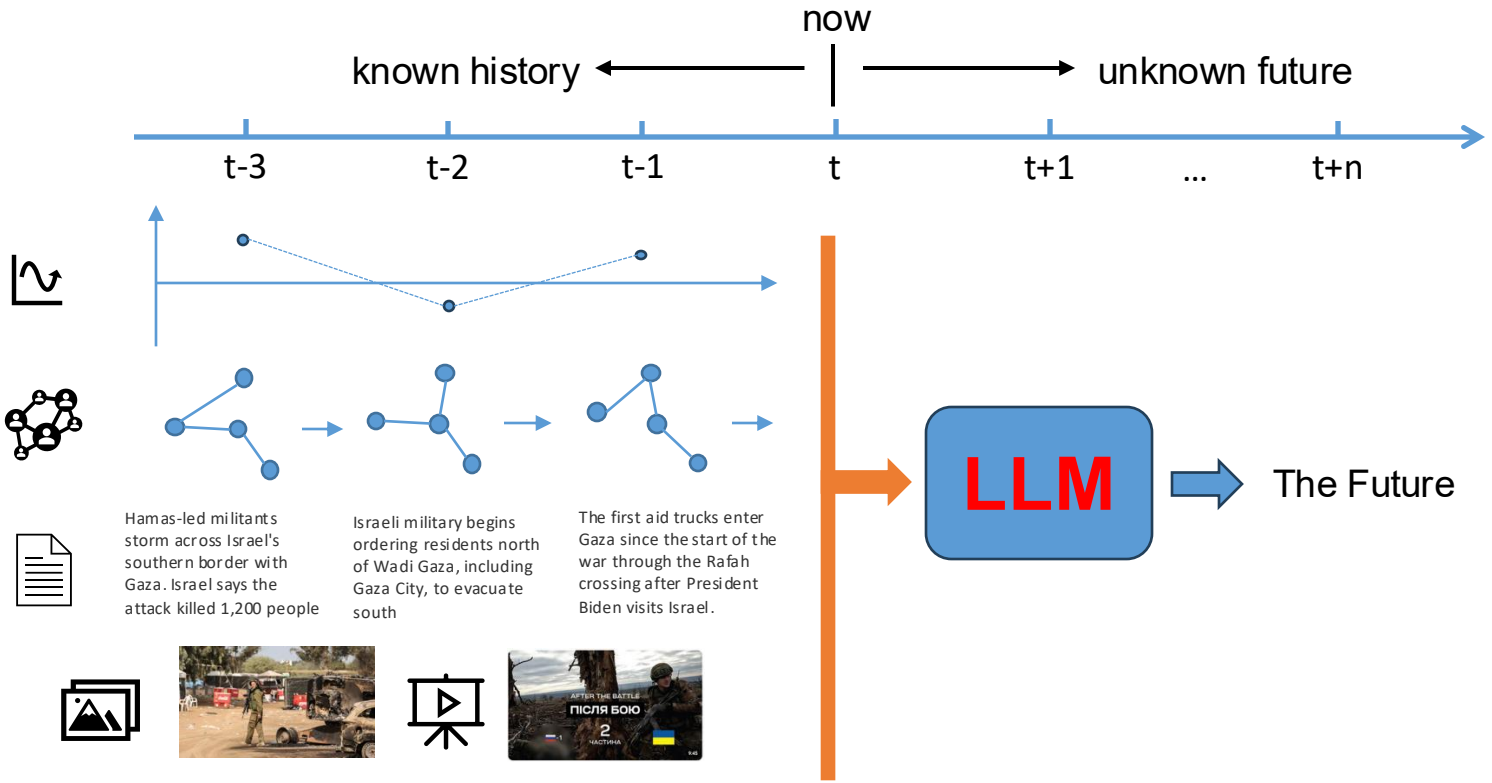
Natural language QA: MCQ

More modalities input: image, video, etc.
Open-world question: can be any format

Can we have one model for all?

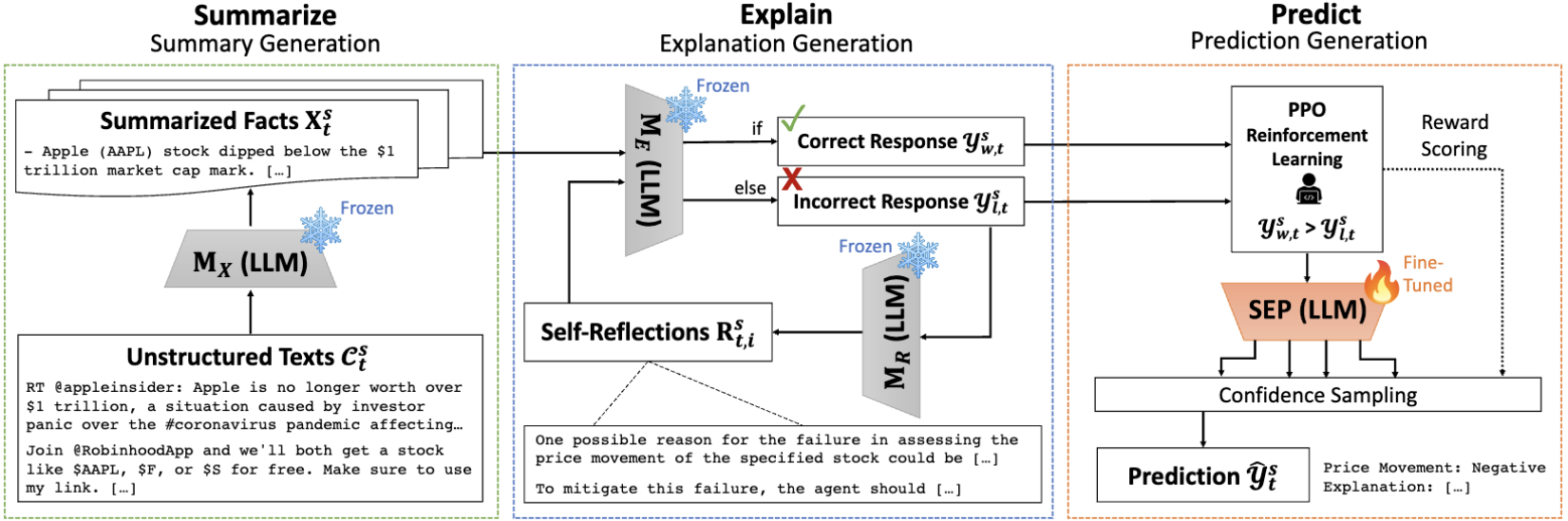


Can we have one model for all? - Yes



LLM for multimodal open-world forecasting

- **LLM for stock forecasting (1/3)**
  - Predict the movement (up or down) of a stock, given its historical prices and relevant news.
  - Provide verbal explanations along with the movement prediction.



Koa et al. Learning to generate explainable stock predictions using self-reflective large language models. WWW 2024.

LLM for multimodal open-world forecasting

- **LLM for stock forecasting (1/3)**
  - Dataset: ACL18 StockNet dataset, updated for the year 2020–2022
  - Evaluation metrics: prediction accuracy and Matthews Correlation Coefficient (MCC)
  - Overall performance

Models		Top 1 Stock, GPT-3.5				Remaining Stocks, Vicuna			
		All Texts		Informative Texts		All Texts		Informative Texts	
		Accuracy	**MCC**	**Accuracy**	**MCC**	**Accuracy**	**MCC**	**Accuracy**	**MCC**
Deep-Learning Models	VAE+Att	49.96	0.0046	-	-	49.83	0.0070	-	-
	GRU+Att	50.15	0.0125	-	-	**50.77**	0.0189	-	-
	Transformer	50.06	0.0089	-	-	50.17	0.0135	-	-
Large Language Models	GPT-3.5	20.80	0.0094	29.35	0.0298	17.57	0.0027	22.99	0.0052
	Vicuna	40.85	0.0114	45.29	0.0368	39.66	0.0115	43.30	0.0301
	FinGPT	47.61	0.0158	51.56	0.0384	45.76	0.0161	46.12	0.0379
	SEP (Ours)	**51.38**	**0.0302**	**54.35**	**0.0993**	47.59	**0.0203**	**50.57**	**0.0508**

- Our method outperforms both deep-learning methods and LLM methods
- LLMs without finetuning perform worse in forecasting accuracy due to mixed or neutral prediction

Koa et al. Learning to generate explainable stock predictions using self-reflective large language models. WWW 2024.

LLM for multimodal open-world forecasting

- **LLM for stock forecasting (1/3)**
  - Explanation quality

Metric	GPT-3.5	Vicuna	SEP (Ours)
Relevance to Stock Movement	5.407	5.396	**5.449**
Financial Metrics	2.957	3.146	**3.334**
Global & Industry Factors	3.180	3.576	**3.700**
Company Developments	3.905	4.066	**4.224**
Temporal Awareness	3.951	4.066	**4.170**
Balance of Positive & Negative	4.030	4.084	**4.224**
Contextual Understanding	4.012	4.098	**4.193**
Clarity & Coherence	6.271	6.325	**6.439**
Consistency with Information	5.575	5.652	**6.006**
Sensitivity to Updates	4.112	4.172	**4.362**

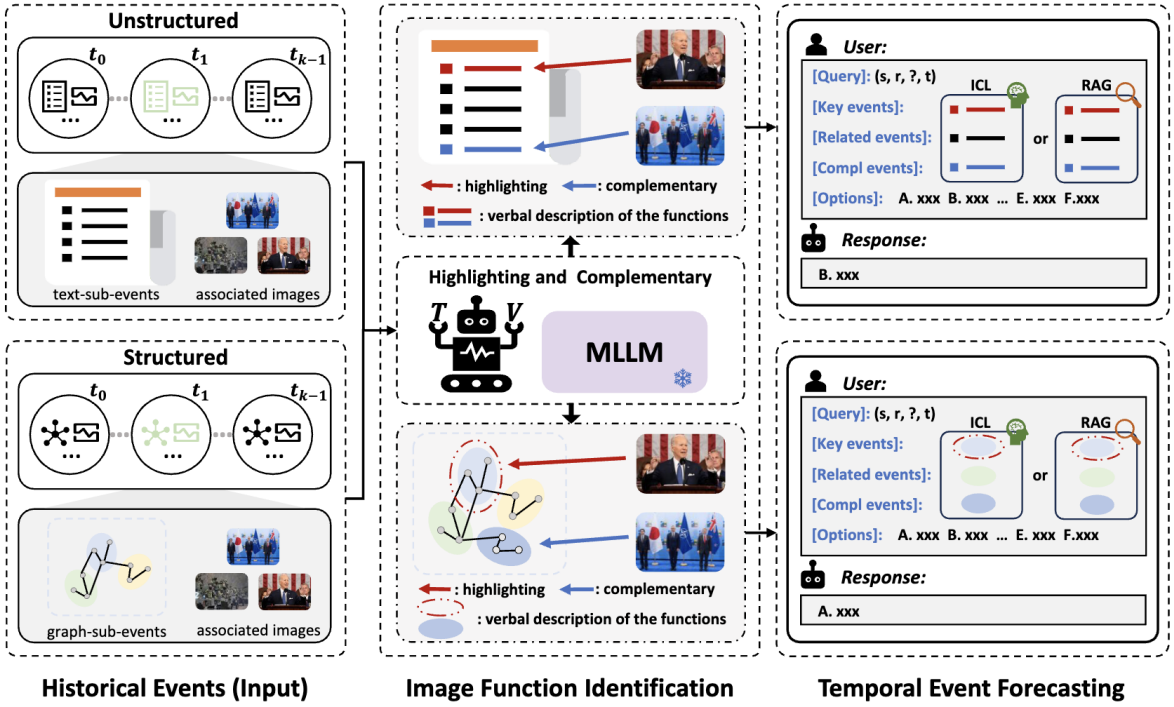
		Accuracy	MCC
Deep-Learning Models	VAE+Att	49.96	0.0046
	GRU+Att	50.15	0.0125
	Transformer	50.06	0.0089
Large Language Models	GPT-3.5	20.80	0.0094
	Vicuna	40.85	0.0114
	FinGPT	47.61	0.0158
	SEP (Ours)	**51.38**	**0.0302**

- We derive a set of evaluation metrics for explanation quality and use GPT-4 to score.
- All LLMs give good-quality explanations even if the prediction is wrong.
- Our method got the highest scores among all the metrics, even though it is not trained directly following these metrics.

Koa et al. Learning to generate explainable stock predictions using self-reflective large language models. WWW 2024.

LLM for multimodal open-world forecasting

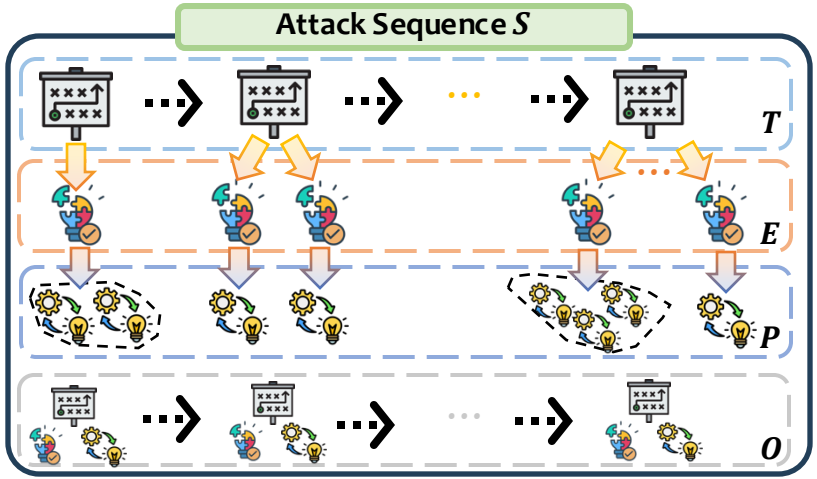
- **LLM for geo-political event forecasting (2/3)**
  - Leverage both image and text

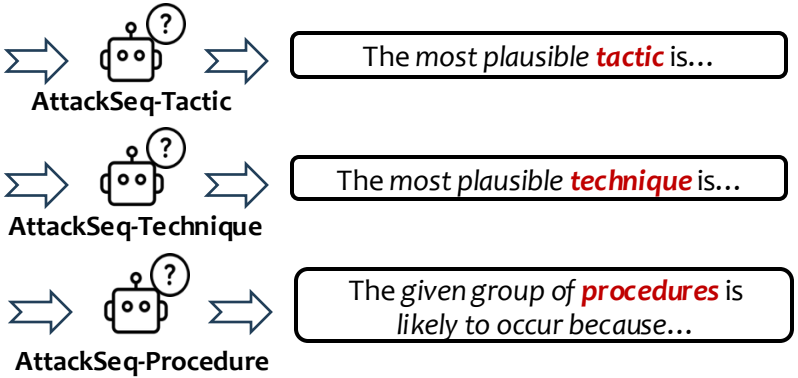


Li et al. MM-forecast: A multimodal approach to temporal event forecasting with large language models. ACM MM 2024.

LLM for multimodal open-world forecasting

- **LLM for cyber security event forecasting (3/3)**
  - Cyber attacks often involves multiple consecutive steps, forming an attack sequence (attack flow).
  - Understanding the sequential patterns and making accurate prediction are essential for cyber attack analysis.

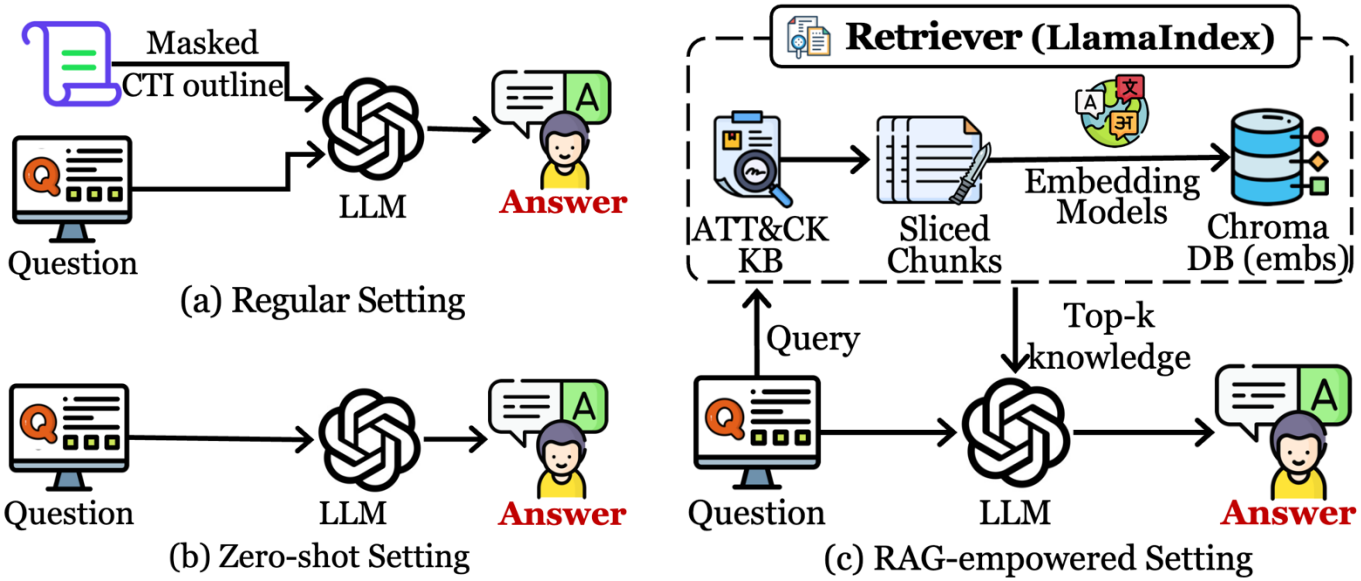




Yong et al. AttackSeqBench: Benchmarking Large Language Models' Understanding of Sequential Patterns in Cyber Attacks. arXiv 2025.

LLM for multimodal open-world forecasting

- **LLM for cyber security event forecasting (3/3)**
  - We leverage LLM and RAG for attack sequence prediction .



Yong et al. AttackSeqBench: Benchmarking Large Language Models' Understanding of Sequential Patterns in Cyber Attacks. arXiv 2025.

Take-aways

- History of temporal forecasting
  - From ancient times to modern data-driven approaches
- Conventional data-driven approaches
  - Time series, temporal knowledge graph, temporal QA
  - Deep-learning methods with supervised training
- LLM for multimodal open-world forecasting
  - Multiple domains: stock, geo-political event, cyber attack sequence
  - Multimodal inputs: time series, graph, text, image

Future works

There're a bunch of works released recently, most are benchmark works:

- Tsinghua: OpenEP: Open-Ended Future Event Prediction 2025
- ByteDance: FutureX: An Advanced Live Benchmark for LLM Agents in Future Prediction 2025
- CAS: OpenForecast: A Large-Scale Open-Ended Event Forecasting Dataset 2025

What shall we do beyond benchmarking, simple fine-tuning and RAG?

- Study the in-depth mechanism of reasoning LLMs in temporal forecasting
  - Time series reasoning in finance forecasting
  - Multi-threaded hypothetical thinking in geo-political event forecasting
  - Mitigate the over-thinking problem in attach sequence prediction

Disclaim: **All models are wrong, but some are useful. -- George E. P. Box**

Thanks & QA

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