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CoorLog: Efficient-Generalizable Log Anomaly Detection via Adaptive Coordinator in Software Evolution

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1. Background & Motivation

Log anomaly detection (AD) is crucial for ensuring system reliability.

- **Problem:** Frequent software updates change log structures and patterns.

Motivation

- **SM :** Cost 👍 Genrealization 👎
- **LLM:** Cost 👎 Genrealization 👍

Case 1 Log Entry Evolution

Spark 2 Started reading broadcast variable <*>

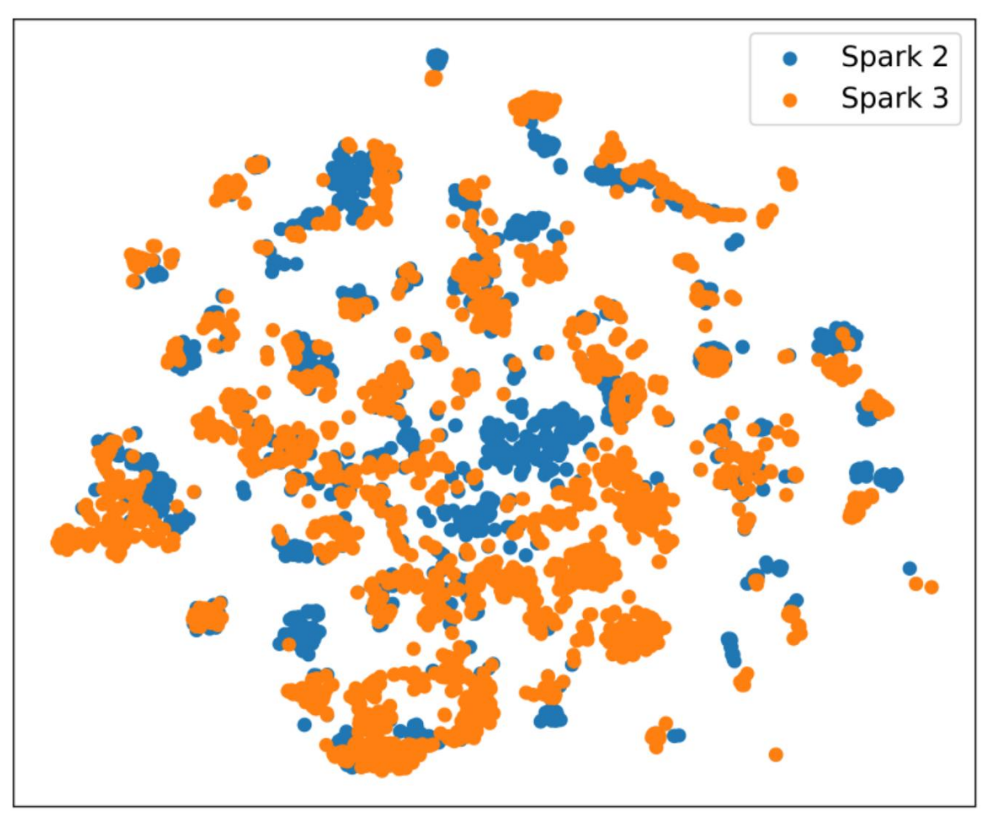
Spark 3 Started reading broadcast variable <*> with <*> pieces(estimated total size <*> MiB)

Case 2 Log Sequences Evolution

Spark 2 E1 → E3

Spark 3 E1 → E2 → E3

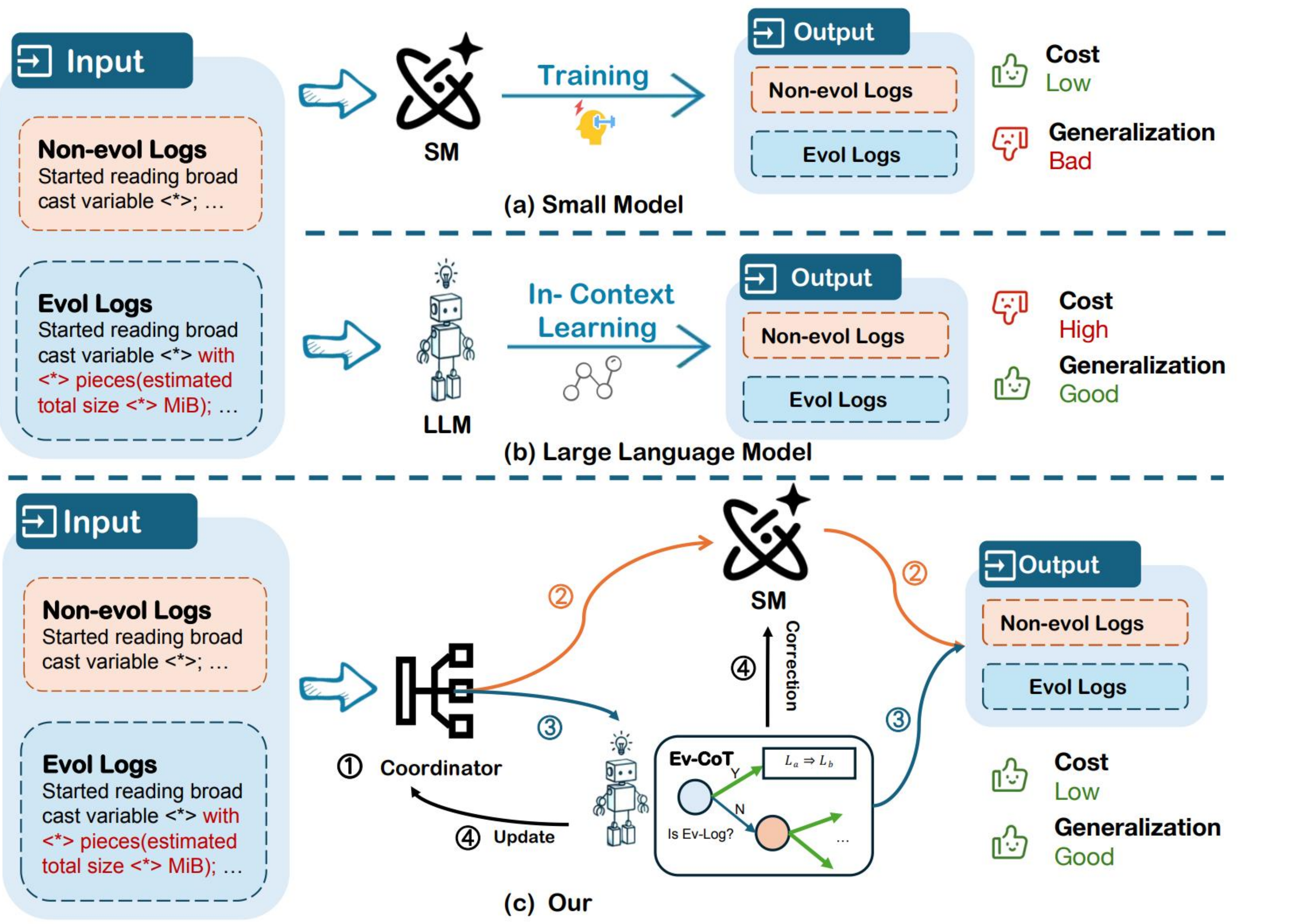
E1: Connecting to driver: <*>
E2: Successfully registered with driver
E3: Resources for <*>:



(a) Spark

Proposed Solution

- Collaboration between LLM and SM to balance efficiency and generalization via the Adaptive Coordinator.



2. Method

Stage 1: Log Identification via the Coordinator

Use an **AutoEncoder** to distinguish between known and new log pattern.

Stage 2: Non-Evolved Log Detection via SM

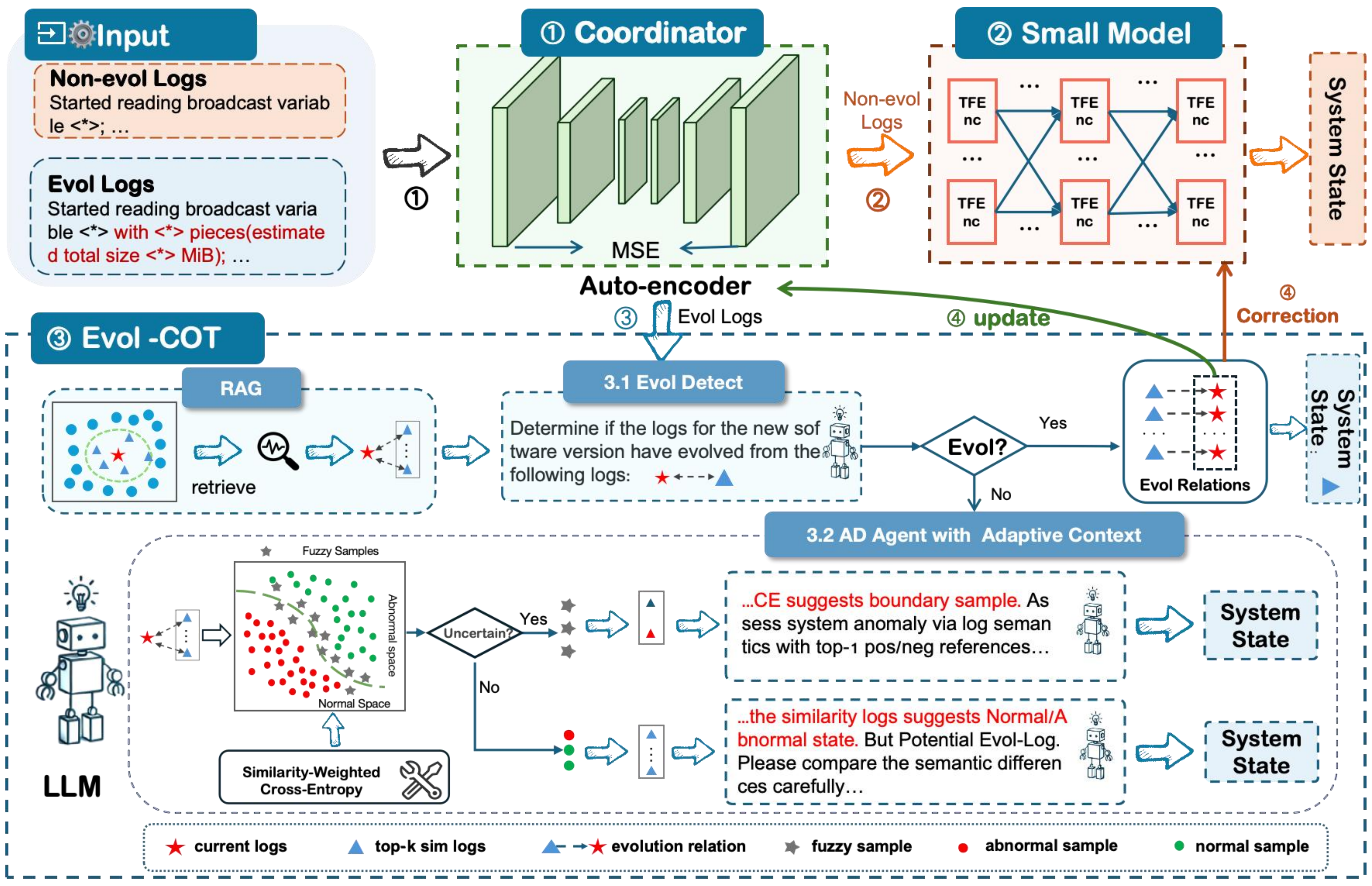
Use a **BERT-based** Network to handle in-distribution logs.

Stage 3: Evolved Log Detection via LLM

Design the **Evol-CoT** framework for fine-grained inference on evolved logs.

Stage 4: Adaptive Evolution Mechanism

Use **AEM** to avoid redundant inference for the same samples in LLM.



Determine if the logs for the new software version have evolved from the following logs: ★←→▲

…CE suggests boundary sample. Assess system anomaly via log semantics with top-1 pos/neg references…

…the similarity logs suggests Normal/Abnormal state. But Potential Evol-Log. Please compare the semantic differences carefully…

3. Experiment and Result

Key Conclusion

- The coordinator can identify concept drift logs.
- Evol-CoT provides interpretability.
- CoorLog achieves a high F1-score with low cost, making it suitable for real-world deployment.

LogEvol-Hadoop

	Intra-version						Inter-version					
	Hadoop 2 → Hadoop 2			Hadoop 3 → Hadoop 3			Hadoop 2 → Hadoop 3			Hadoop 3 → Hadoop 2		
Method	Pr	Re	F1	Pr	Re	F1	Pr	Re	F1	Pr	Re	F1
LogSed	0.910	**0.995**	0.951	0.925	0.986	0.955	0.371	0.988	0.540	0.390	0.993	0.560
DeepLog	0.913	0.985	0.947	0.926	**1.000**	0.961	0.386	**0.999**	0.556	0.410	0.971	0.576
LogAnomaly	0.926	0.994	0.958	0.939	0.988	0.963	0.389	0.998	0.560	0.407	**0.995**	0.578
BERT	0.928	0.731	0.817	0.959	0.837	0.894	0.865	0.706	0.778	0.952	0.763	0.847
LogRobust	0.935	0.981	0.957	0.948	0.983	0.965	0.782	0.824	0.803	0.813	0.846	0.829
LogBERT	0.941	0.977	0.959	0.953	0.987	0.970	0.875	0.852	0.863	0.898	0.871	0.884
LogOnline	0.948	0.984	0.966	0.963	0.989	0.976	0.893	0.895	0.894	0.913	0.908	0.911
LLMeLog	0.952	0.967	0.959	0.963	0.975	0.969	0.912	0.923	0.917	0.928	0.934	0.931
EvLog	0.945	0.982	0.963	0.952	0.988	0.970	0.770	0.941	0.847	0.857	0.913	0.884
Our	**0.993**	0.968	**0.980**	**0.997**	0.982	**0.990**	**0.946**	0.983	**0.964**	**0.994**	0.957	**0.975**

LogEvol-Spark

	Intra-version						Inter-version					
	Spark 2 → Spark 2			Spark 3 → Spark 3			Spark 2 → Spark 3			Spark 3 → Spark 2		
Method	Pr	Re	F1	Pr	Re	F1	Pr	Re	F1	Pr	Re	F1
LogSed	0.842	0.914	0.877	0.907	0.923	0.915	0.013	0.917	0.026	0.010	0.914	0.020
DeepLog	0.862	**0.952**	0.905	0.858	**0.976**	0.914	0.017	**0.947**	0.032	0.014	0.909	0.026
LogAnomaly	0.931	0.939	0.935	0.898	0.947	0.922	0.020	0.923	0.038	0.017	**0.948**	0.034
BERT	0.943	0.750	0.835	**1.000**	0.684	0.812	0.550	0.696	0.615	**1.000**	0.568	0.715
LogRobust	0.949	0.837	0.889	0.974	0.857	0.912	0.732	0.753	0.742	0.934	0.783	0.851
LogBERT	0.948	0.875	0.909	0.973	0.886	0.927	0.805	0.813	0.809	0.949	0.822	0.881
LogOnline	0.954	0.904	0.928	0.986	0.899	0.940	0.843	0.864	0.853	0.957	0.875	0.914
LLMeLog	0.959	0.920	0.938	0.950	0.857	0.900	0.840	0.799	0.828	0.762	0.934	0.851
EvLog	0.970	**0.974**	**0.972**	0.944	0.888	0.915	0.922	0.700	0.795	0.920	0.812	0.863
Our	**0.976**	0.932	0.954	0.979	0.918	**0.947**	**0.904**	0.855	**0.879**	0.968	0.904	**0.935**

Table I Comparison of different strategies

Logs	Method	Spark 2 → 3			Hadoop 2 → 3		
		Pr	Re	F1	Pr	Re	F1
Non-evol	Our$_{SM}$	0.950	0.901	0.925	0.985	0.979	0.982
	+AEM	0.935	0.925	0.930	0.955	0.943	0.949
Evol	Our$_{SM}$	0.468	0.417	0.441	0.375	0.402	0.387
	+AEM	0.640	0.610	0.625	0.537	0.489	0.512
	Vanilla	0.785	0.209	0.330	0.705	0.518	0.595
	Evol-CoT	0.829	0.913	0.870	0.944	0.885	0.914
ALL	Our$_{SM}$	0.698	0.848	0.766	0.893	0.861	0.876
	+AEM	0.721	0.867	0.794	0.895	0.872	0.883
	Our	0.904	0.855	0.879	0.946	0.983	0.964

Table II Ablation study on different log categories

	#Relations	Accuracy	AEM Time (ms)
Spark 2 → 3	288	0.993	0.18
Hadoop 2 → 3	541	0.986	0.02

Table III Statistics of evolution relations

Metric	Method	Spark 2 → 3	Hadoop 2 → 3
Calls	w/o coord	4,246	34,302
	Our	289	2,174
Token (k)	w/o coord	9,048.85	21,347.73
	Our	1,557.30	2,480.65
Time (ms)	LogRobust	0.96	0.43
	LogAnomaly	1.69	0.83
	Our$_{SM}$	0.23	0.04
	w/o coord	810.10	724.61
	Our	78.40	54.30

Table IV Comparison of efficiency and cost

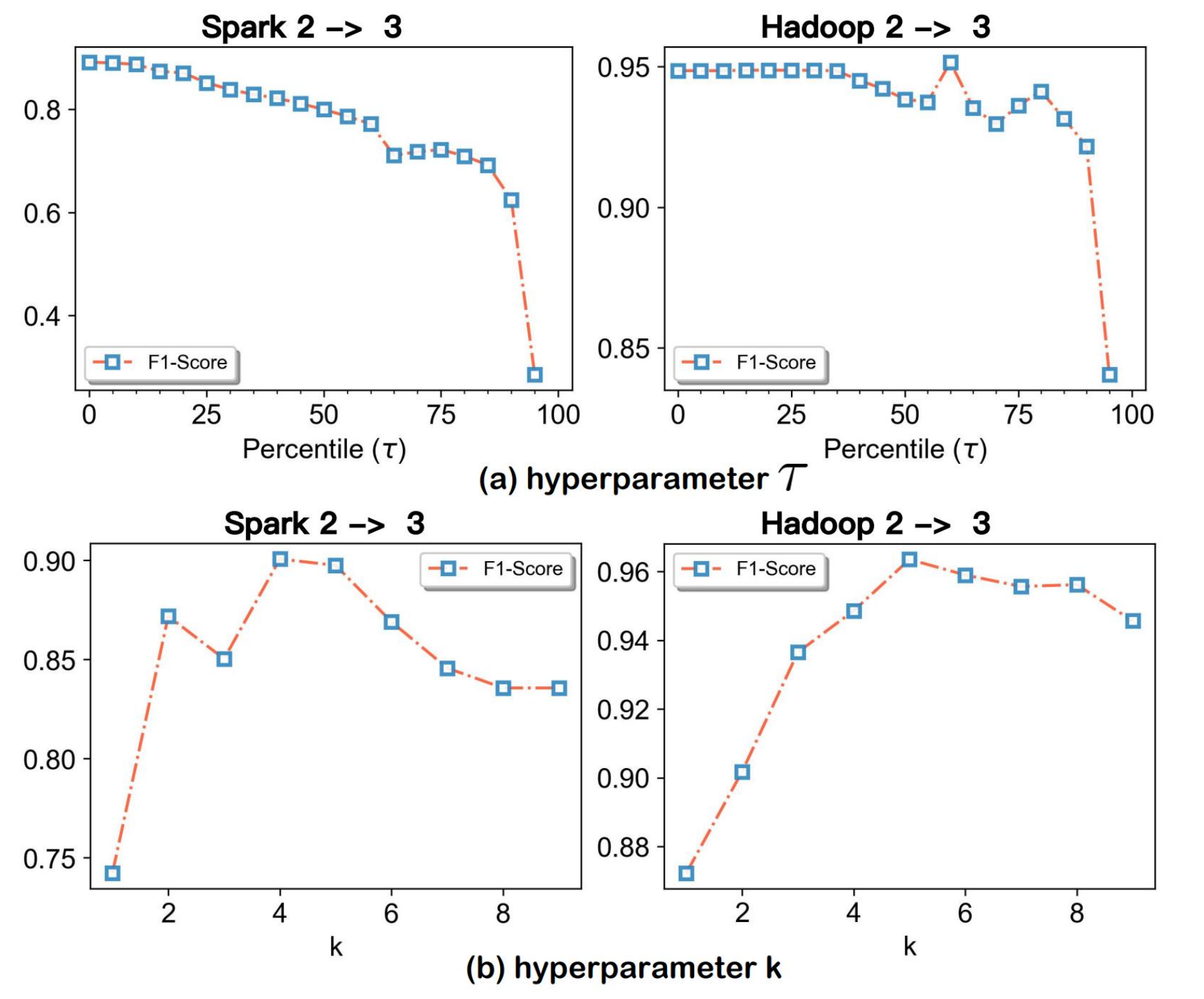
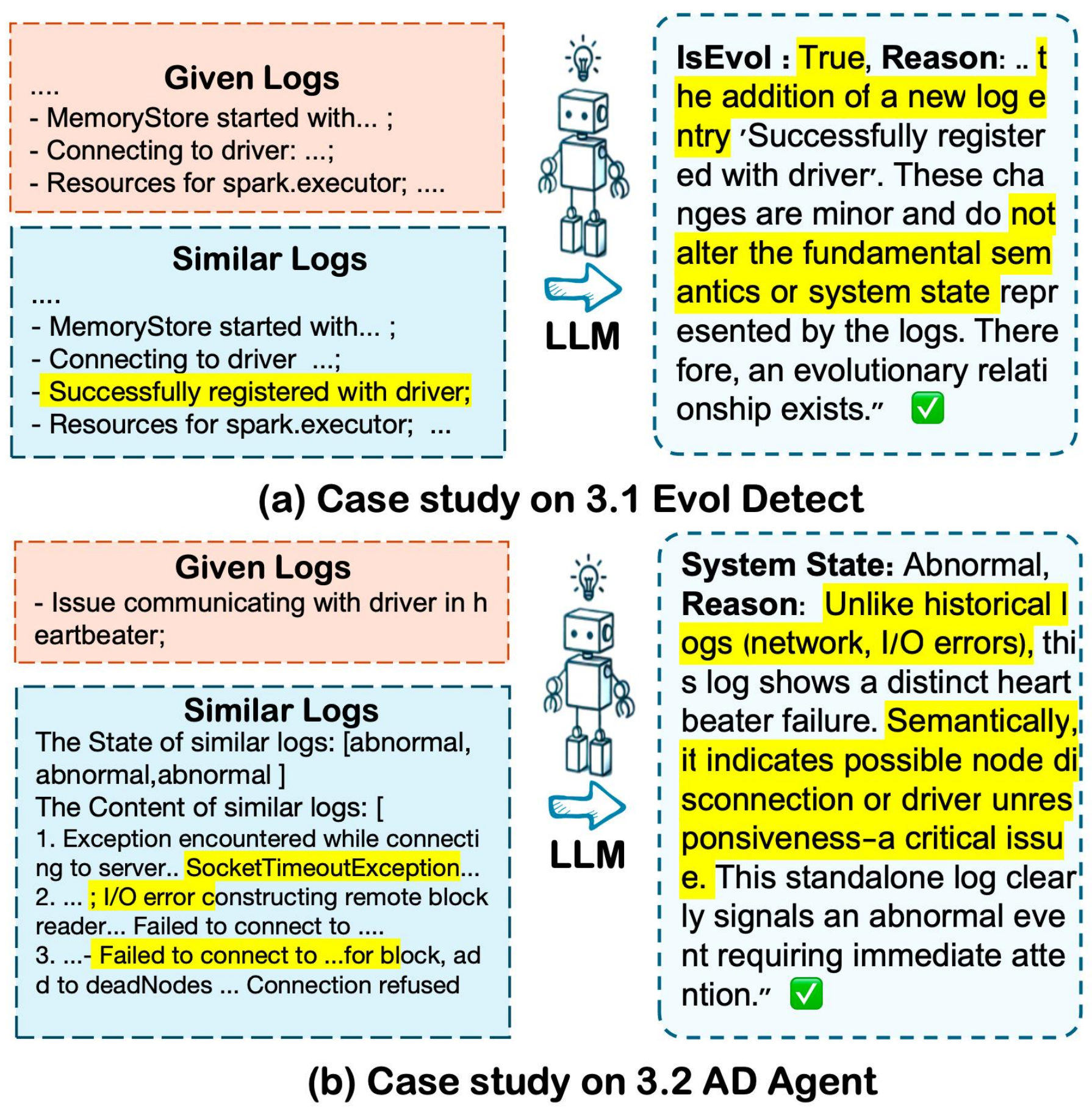


Fig. 6: Ablation study on hyperparameter (a) τ and (b) k.



Given Logs
....
- MemoryStore started with... ;
- Connecting to driver: ...;
- Resources for spark.executor; ....

Similar Logs
....
- MemoryStore started with... ;
- Connecting to driver ...;
- Successfully registered with driver;
- Resources for spark.executor; ...

IsEvol : True, Reason: .. the addition of a new log entry 'Successfully registered with driver'. These changes are minor and do not alter the fundamental semantics or system state represented by the logs. Therefore, an evolutionary relationship exists." ✅

(a) Case study on 3.1 Evol Detect

Given Logs
- Issue communicating with driver in heartbeater;

Similar Logs
The State of similar logs: [abnormal, abnormal,abnormal]
The Content of similar logs: [
1. Exception encountered while connecting to server.. SocketTimeoutException...
2. ... ; I/O error constructing remote block reader... Failed to connect to ....
3. ...- Failed to connect to ...for block, add to deadNodes ... Connection refused

System State: Abnormal, Reason: Unlike historical logs (network, I/O errors), this log shows a distinct heartbeater failure. Semantically, it indicates possible node disconnection or driver unresponsiveness–a critical issue. This standalone log clearly signals an abnormal event requiring immediate attention." ✅

(b) Case study on 3.2 AD Agent