Neuro-Symbolic Compliance:
Integrating LLMs and SMT Solver for Automated Financial Legal Analysis

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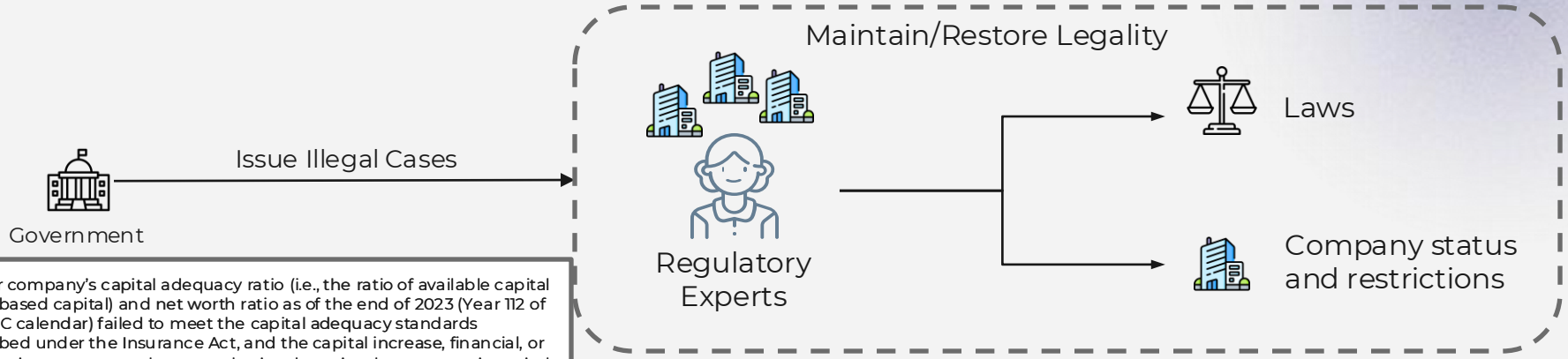
Financial Compliance Analysis



As your company's capital adequacy ratio (i.e., the ratio of available capital to risk-based capital) and net worth ratio as of the end of 2023 (Year 112 of the ROC calendar) failed to meet the capital adequacy standards prescribed under the Insurance Act, and the capital increase, financial, or business improvement plan you submitted to raise the company's capital adequacy level could not bring the 2024 (Year 113) capital adequacy ratio up to the statutory requirement, your company has violated the relevant provisions of the Insurance Act.

In accordance with Article 143-6, Paragraph 2, Subparagraphs 1 and 6 of the Insurance Act, it is hereby decided that your company shall be restricted from entering into any new credit extensions or other transactions with related parties (excluding existing transactions or renewals of already contracted related-party transactions), until your company's capital adequacy ratio meets the statutory standard and approval is granted by this Commission to resume such activities.

Furthermore, your company is ordered to submit within one month a specific and comprehensive capital increase, financial, or business improvement plan that will enable the company to achieve compliance with the statutory capital adequacy requirements during 2024.

A highly expert and labor-intensive process

- to interpret complex legal provisions
- to provide compliance recommendations tailored to a company's needs

Financial Compliance Analysis with the Aid of LLMs

The appearance of LLMs has made understanding text much faster, and the use of RAG modules can further enhance an LLM's comprehension across different domains.

Regulatory Expert

Base on the illegal case and its related laws, please suggest how to restore legality.

LLM

Article § 143-6 violation: must be done together with raising the capital adequacy ratio

You can lift the credit restriction with related parties and ensure the improvement plan is executed to achieve a penalty-free compliant status.

Regulatory Expert

If we can't adjust the status of improvement plan, is there any solution that allows us to make only minimal changes?

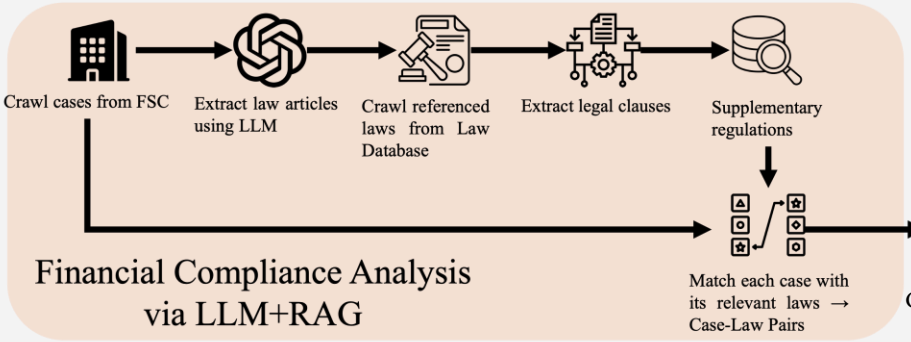
LLM

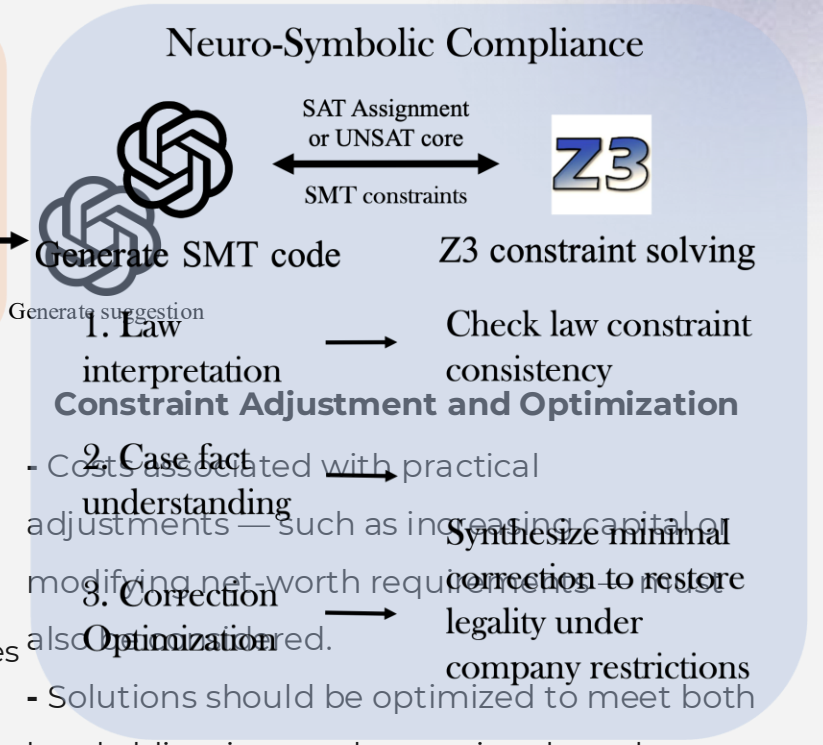
Article § 143-6 violation : only required at Capital Level 4, but this case is at Level 3

If the improvement plan status cannot be adjusted, you should accelerate approval for asset disposal and initiate limited capital reinforcement to strengthen its financial position.

LLMs read fast — but can they reason right?

Our Method : Neuro-Symbolic Compliance





LLM Performs Case Understanding and Legal Interpretation

The LLM analyzes case facts and interprets relevant legal provisions, converting them into formal logical constraints for SMT solving.

SMT Performs Symbolic Constraint Solving and Optimization

Using the Z3 solver, the system checks logical consistency, extracts unsatisfiable cores, and optimizes adjustable variables to produce minimal-change compliant solutions.

Logic Consistency

- Large Language Models (LLMs) may generate responses that are illusory, incomplete, or logically inconsistent with statutory provisions.
- Therefore, it is essential to ensure that all outcomes are formally verified to conform to legal constraints.

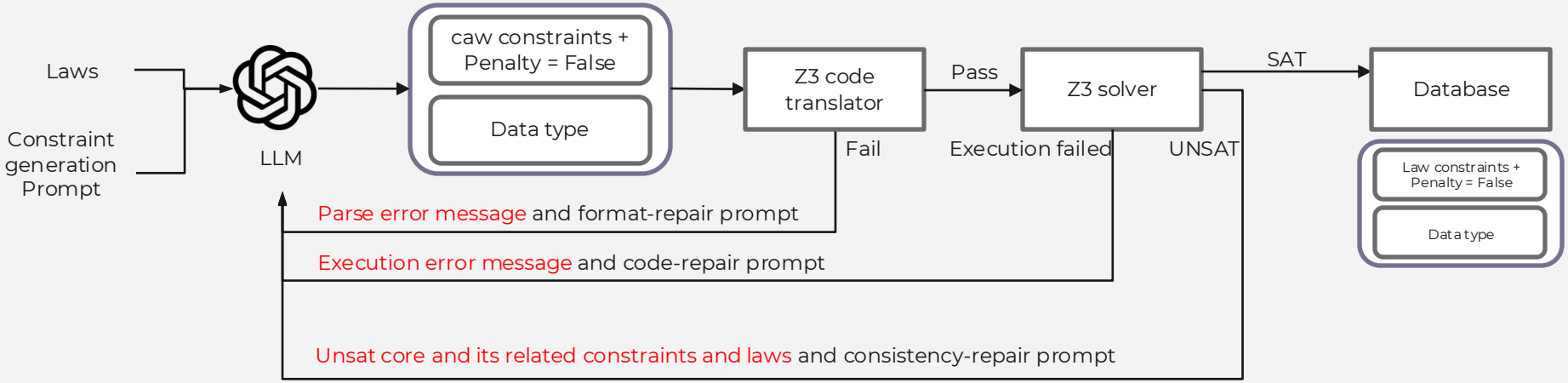
- Costs associated with practical adjustments — such as increasing capital or modifying net-worth requirements — must also be considered.
- Solutions should be optimized to meet both legal obligations and operational needs.

Law Interpretation and Legality Consistency Checking

The LLM formalizes legal provisions into logical constraints, while Z3 validates their correctness.

Parsing errors, execution failures, and unsat cores are used to refine the constraints.

Only solver-verified constraints are stored as legally consistent representations.

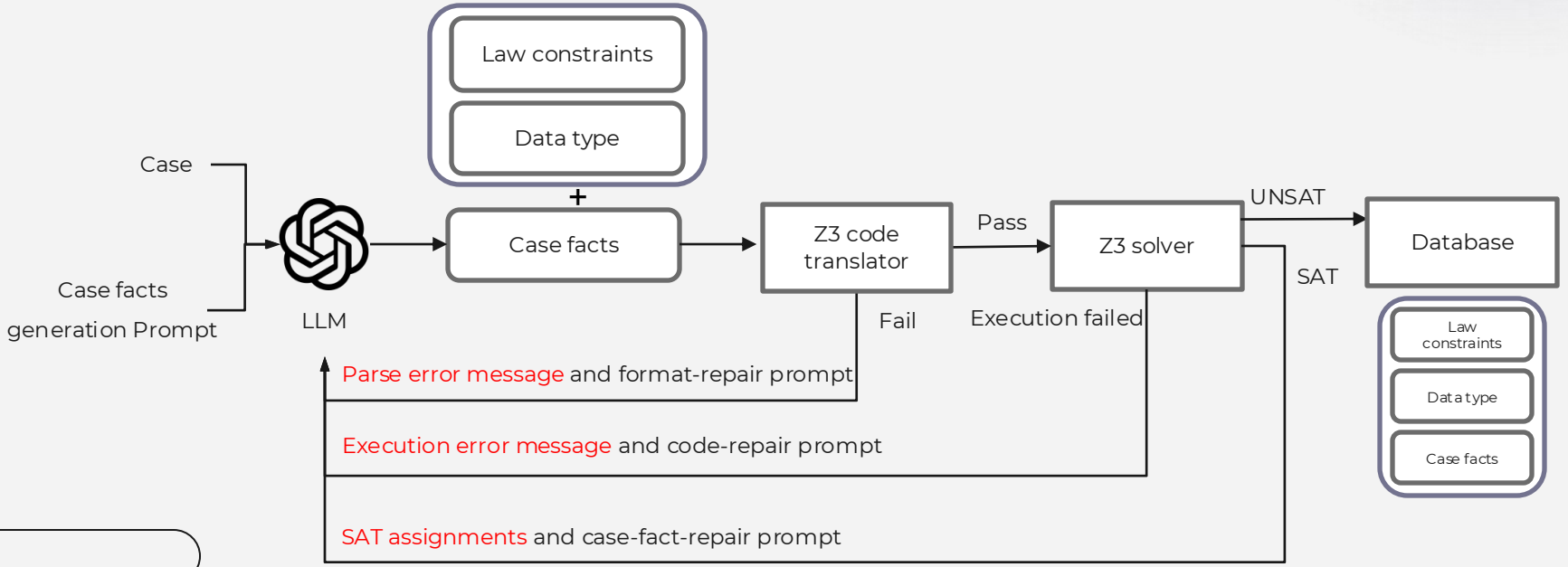


Case Fact Understanding and Illegality Consistency Checking

The LLM generates case fact assignments, which are translated and checked by the Z3 solver.

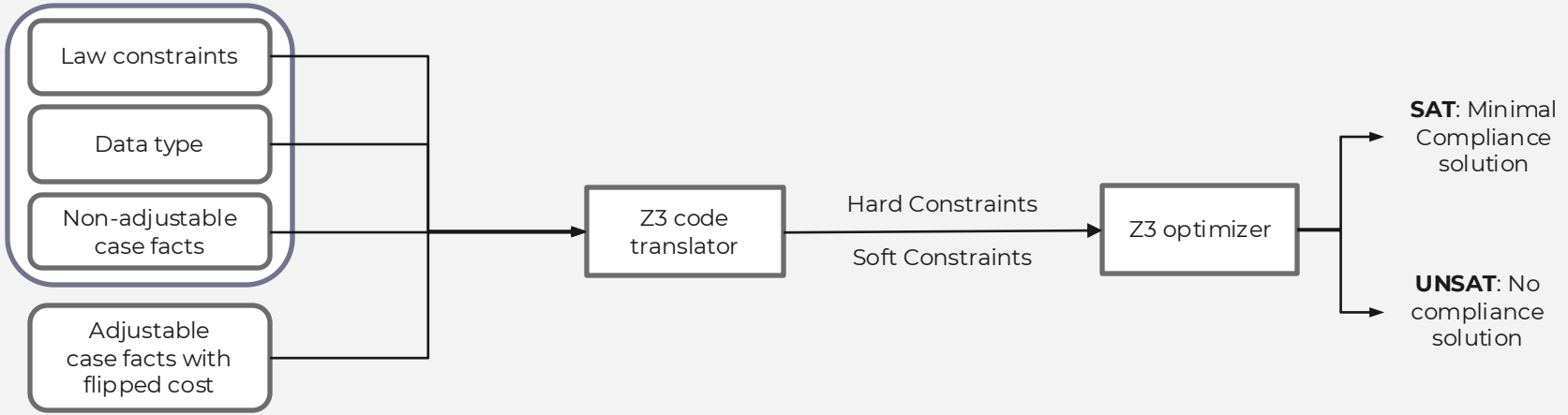
Any parsing, execution, or inconsistency errors trigger automated repair.

For violation cases, the solver returns **UNSAT**, and the case facts are stored.



Minimal Compliance Solving using Z3 Optimizer (MaxSMT)

Once law constraints and case facts are generated and validated,
the Z3 Optimizer is used to compute the minimal compliant adjustment.
Non-adjustable facts become hard constraints, while adjustable facts become weighted soft constraints for prioritized optimization.



RQ1: To what extent can LLMs effectively generate SMT constraints in the legal domain?

We evaluate our pipeline against 87 real-world regulatory cases from the Taiwan FSC[1].

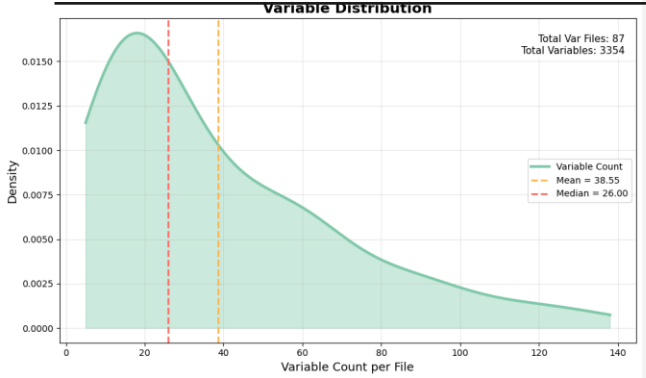
Neuro-Symbolic Compliance		Pass	Repair (Needed/Success)	Pass rate(%)
Law Interpretation	Format-repair	87	0/0	100.00
	Code-repair	83	4/4	100.00
	Consistency-repair	87	0/0	100.00
Case Fact Understanding	Format-repair	87	0/0	100.00
	Code-repair	87	0/0	100.00
	Case-fact-repair	87	0/0	100.00
Cost-aware Compliance	Z3-MaxSAT Optimization	87	0/0	100.00

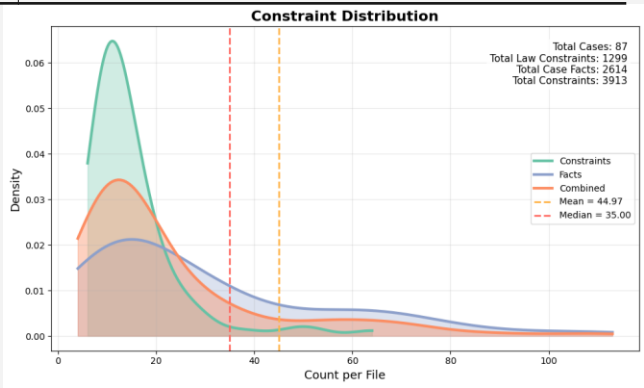
1.https://www.fsc.gov.tw/en/

RQ1: To what extent can LLMs effectively generate SMT constraints in the legal domain?

To further analyze task complexity, we examined the structural diversity of constraints and variables, confirming that the constraint generation task is inherently non-trivial.

	#Var	Real	Int	Bool	#Con	Law	Case	Law Ratio(%)
Avg	**38.55**	1.23	0.92	36.40	**44.97**	14.93	30.04	38.61
Mln	5	0	0	5	12	6	4	13.33
Max	138	15	11	138	139	64	113	86.36
Std.	30.85	2.60	1.92	29.63	29.99	9.64	24.83	15.90



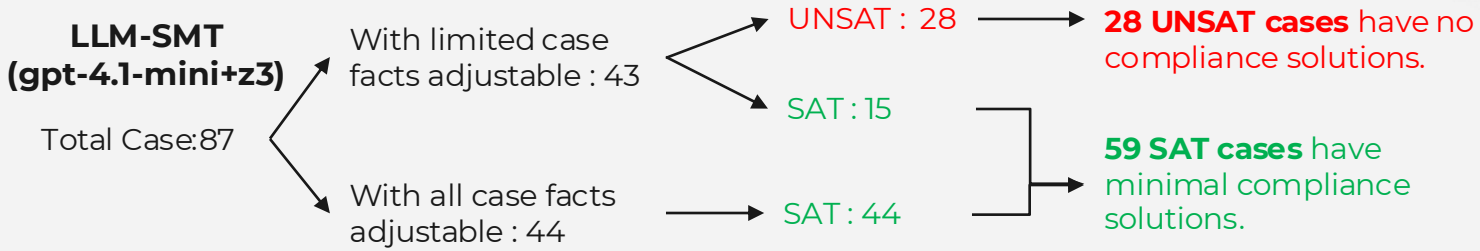


RQ2: Does LLM-SMT Integration Outperform Standalone LLMs in Finding Legally Compliant Solutions?

For each case, we provide LLM-SMT / Pure LLM

(1) the case description, (2) relevant legal articles, (3) adjustable case facts with flipped cost

The model is required to check whether a feasible (SAT) solution (with minimal cost) exists.



Pure LLM (gpt-4.1-mini)

	59 SAT cases	28 UNSAT cases
Have correction	59 (**8 / 51**)	**19**
No suggestions	0	**9**

Accuracy rate drops to 21.8%.
(**8**+**9** / 87)

RQ3 Does LLM-SMT Integration Better Identify Minimal Compliant Solutions Than LLMs Alone?

For 8 SAT cases that LLM returns valid suggestions, its suggestion on average increases 33% cost compared to solutions from LLM-SMT (5.25→ 7).

LLM-SMT provides the optimal correction with 30.41% (42.08%) flipped rate for limited (all) adjustable cases.

Cost(#Flips)	LLM (8)	LLM-SMT (8)
Mean	7.00	5.25
Median	4.5	3
Min	2	1
Max	20	15
Std. Dev.	6.78	5.55
Avg. Flip rate	53.23%	42.30%

Cost (#Flips)	Limited case facts LLM-SMT (15)	All case facts LLM-SMT (44)
Mean	4.60	11.14
Median	3	8
Min	1	1
Max	15	56
Std. dev.	3.83	11.45
Avg. flip rate	30.41%	42.08%

Conclusion & Extension

We propose a Neuro-Symbolic Compliance framework that integrates LLMs and SMT optimization for automated legal reasoning, providing efficient, cost-aware compliance analysis.

Extension:

- Agentic pipeline and platform deployment
- Public available dataset with extensive case study

Demo

Artifacts

Full Paper

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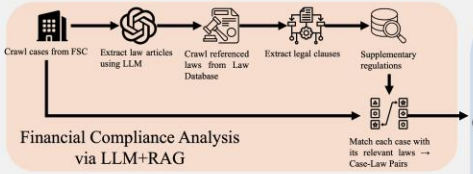

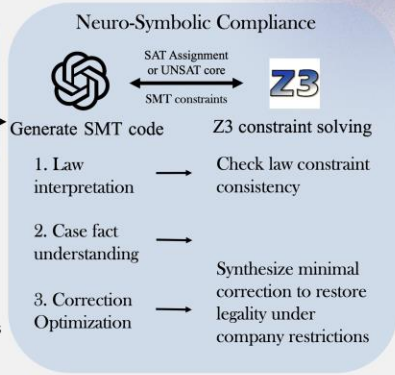

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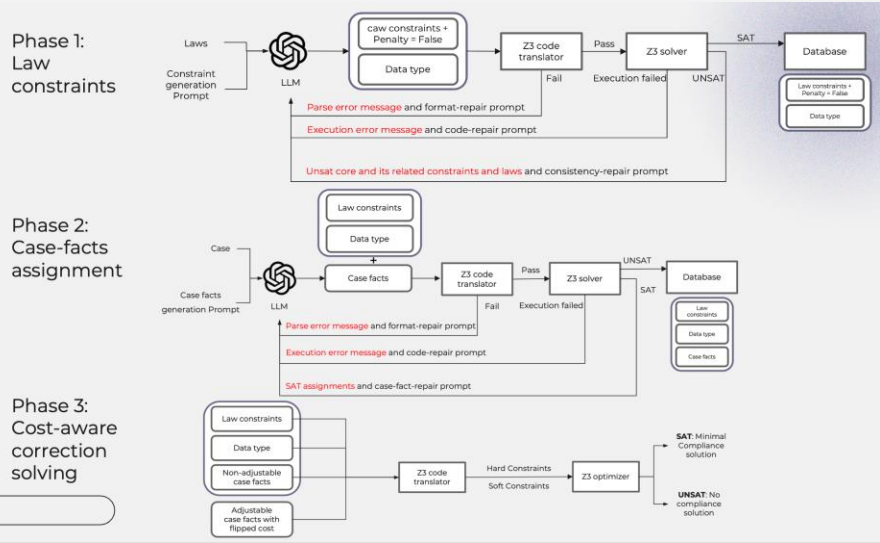

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