Unifying Inference-Time Planning Language Generation

Anonymous ACL submission

Abstract

A line of work in planning uses LLM not to generate a plan, but to generate a formal representation in some planning language, which can be input into a symbolic solver to deterministically find a plan. While showing improved trust and promising performance, dozens of recent publications have proposed scattered methods on a variety of benchmarks under different experimental settings. We attempt to unify the inference-time LLM-as-formalizer methodology for classical planning by proposing a unifying framework based on intermediate representations. We thus systematically evaluate more than a dozen pipelines that subsume most existing work, while proposing novel ones that involve syntactically similar but high resource intermediate languages (such as a Python wrapper of PDDL). We provide recipes for planning language generation pipelines, draw a series of conclusions showing the efficacy of their various components, and evidence their robustness against problem complexity. [1]

1 Introduction

Large language models (LLMs) have been extensively applied to classical planning, an important step for complex problem solving in artificial intelligence. Given a textual description of the domain and problem of an environment, LLMs often directly generate a sequence of actions in an end-to-end manner (Wei et al., 2025). Despite much better domain adaptation ability than symbolic methods, the *LLM-as-planner* methodology is not verifiable and interpretable by nature, in addition to underperforming complex problems (Valmeekam et al., 2023a). Alternatively, a recent line of work re-imagines the role of LLMs not to generate the plan, but to generate a formal program in languages such as the Planning Domain Definition Language (PDDL). Such a program is input into a formal solver to deterministically search for a plan (Tantakoun et al., 2025). The *LLM-as-formalizer* methodology (Figure 1) has been widely advocated in literature due to its reportedly better performance and formal guarantees compared to *LLM-as-planner* (Liu et al., 2023). However, the success of *LLM-as-formalizer* in previous work has primarily been tied to closed-source LLMs that are likely huge in terms of parameters and esoteric in terms of engineering. In contrast, preliminary experiments on open-source, smaller LLMs have been shown to exhibit much lower performance (Huang and Zhang, 2025), severely hindering the accessibility and democratization of LLM-assisted planning. Moreover, most if not all past work has employed unsystematic designs of pipelines of piecemeal techniques, hence the direction of improvement remains unclear.

In this work, we attempt to unify the *LLM-as-formalizer* methodology for classical planning. We first propose a theoretical framework based on the number and interplay of intermediate representations (IR). This framework subsumes most if not all prior work on planning language generation while opening new paths for experimentation. Concretely, we propose the use of a high-resource but syntactically similar IR, namely a Python wrapper of PDDL, to achieve competitive performance. We systematically instantiate and evaluate pipelines that subsume most prior work and validate the challenge for open-source, mid-sized LLMs no more than 32B parameters. On 4 standard benchmarks (IPC, 1998), we show that IR and revision by solver feedback are the keys ingredients of a successful *LLM-as-formalizer* pipeline, which consistently outperforms *LLM-as-formalizer* especially when the problem complexity increases. Even so, other intuitive methods such as constrained decoding by grammar or a natural language IR resembling chain-

[1] Our code and data are attached with the submission.

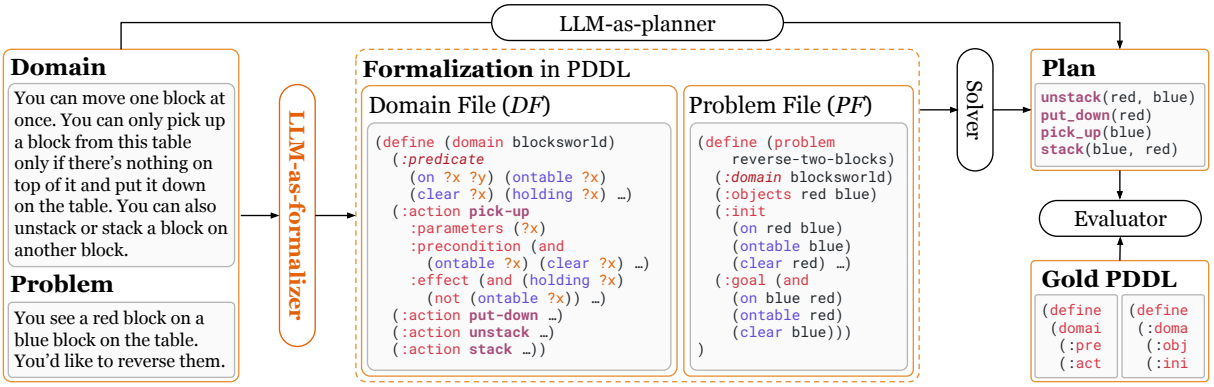

Figure 1: An illustration of using LLM as a planner or a formalizer in classical planning. While *LLM-as-planner* generates a plan directly, *LLM-as-formalizer* formalizes a PDDL domain file and problem which evoke a solver to find a plan. The plan is evaluated against ground-truth PDDL that simulates the environment.

of-thought do not improve performance over end-to-end PDDL generation. We pose this work as a building block to greatly accelerate progress in *LLM-as-formalizer* and planning.

2 Task Formulation

We will first formally define the classical planning task in line with established literature of STRIPS (Fikes and Nilsson, 1971) and recent conventions in the natural language processing community (Huang and Zhang, 2025), before introducing our theoretic framework for *LLM-as-formalizer*.

Formally, the input I of a classical planning task consists of a triplet $(D_d, D_p, \mathcal{DF}'_{\mathcal{G}})$, where:

1. D_d is a textual description of the domain, specifying the types (the type system for entities e), predicates (in relation to the types), and actions A including pre-conditions and effects (parameterized by conjunctive logical formulas over the the predicates).
2. D_p is a textual description of the problem, specifying the objects, initial states and goal states in terms of predicates;
3. $\mathcal{DF}'_{\mathcal{G}}$ is the header of the ground-truth PDDL domain file $\mathcal{DF}_{\mathcal{G}}$ that only provides the names and parameters of the actions. This is required so that the eventual plan is grounded to an existing ontology and can be evaluated fairly.

The final objective is a plan $L = [a_1(\bar{e}_1), \ldots, a_m(\bar{e}_m)]$, where each $a_i \in A$ is an action provided by $\mathcal{DF}'_{\mathcal{G}}$, and each $\bar{e}_i$ is a tuple of grounded entities corresponding to the parameters of a_i. The plan L, when executed in the environment expressed by a ground-truth $\mathcal{DF}_{\mathcal{G}}$ and $\mathcal{PF}_{\mathcal{G}}$, must (i) be executable, fulfilling the pre-conditions of each action, and (ii) constitutes a successful transition from the initial states and goal states.

The domain file $\mathcal{DF}$ is defined by three main components: types (T), predicates (R), and action semantics (a_m, a_p, a_e):

1. Types: $T = t_1, \ldots, t_n$ is the set of entity types present in the environment.
2. Predicates: $R = r_1, \ldots, r_n$ is the set of relational predicates, each in the form of $r(\bar{t})$, where $\bar{t}$ is a tuple of types that participate in relation r.
3. Action semantics: given an action $a \in A$, a_m, a_p and a_e are its parameters, pre-conditions and effects. The parameters a_m are a set of types $\bar{t}$ that participate in this action. The pre-conditions a_p are a set of predicates $\bar{r}$ that must hold true for this action to be executed. The effects a_e are a set of new predicates $\bar{r}'$ of which the new state takes the value after the execution of this action.

The problem file $\mathcal{PF}$ is defined by three main components: objects (E), the initial state (s_0), and the goal state ($\psi_{\texttt{goal}}$):

1. Objects: $E = e_1, \ldots, e_n$ is the set of named entities present in the environment. Each object is an instance of an entity type defined in $\mathcal{DF}'_{\mathcal{G}}$.
2. Initial State: $s_0 \in \mathcal{S}$ is a set of relational facts of the form $r(\bar{e})$, where $r \in R$ is a relational predicate defined in $\mathcal{D}$; $\bar{e}$ is a tuple of entities from E that participate in relation r.
3. Goal State: $\psi_{\texttt{goal}} : \mathcal{S} \to \mathbb{B}$ is a boolean formula over relational facts, where S is the state space and $\mathbb{B} = \{\text{True}, \text{False}\}$. When $\psi_{\texttt{goal}}(s^*) = \text{True}$, state s^* achieves the problem goal.

Here, the state space $\mathcal{S}$ comprises all possible configurations of relational facts over the object set E with the predicates R. Each state $s \in \mathcal{S}$ is

a set of instantiated facts $r(\bar{e})$, describing which relations hold among the objects. Successfully executing a plan L from the initial state s_0 yields a sequence of intermediate states $s_1, s_2, \ldots, s^*$ such that the goal formula $\psi_{\texttt{goal}}(s^*)$ evaluates to True.

While an end-to-end *LLM-as-planner* pipeline maps the input triplet I directly to a plan L, in this work we focus on *LLM-as-formalizer* pipelines which instead generate the domain file $\mathcal{DF}_\mathcal{P}$ and $\mathcal{PF}_\mathcal{P}$ before inputting them into a PDDL solver to search for a plan.

3 Framework and Related Work

We propose a theoretical framework for LLM-based classical planning revolving around levels of intermediate representations (IR), where the numbering of levels corresponds to the number of IRs involved.

- Level 0: $I \rightarrow L$
- Level 1: $I \rightarrow$ PDDL $\rightsquigarrow L$
- Level 2: $I \rightarrow$ IR $\rightarrow$ PDDL $\rightsquigarrow L$
- Level 3: $I \rightarrow$ IR $\rightarrow$ IR $\rightarrow$ PDDL $\rightsquigarrow L$
- Level 4: ...

Level 0 is essentially *LLM-as-planner*, mapping the input I to the plan L. While it is possible to involve IR in this level as a chain-of-thought, we do not discuss it as our focus is on *LLM-as-formalizer* represented by the other levels, where PDDL is always the final IR before the plan. We can thus increase the level of complexity of a pipeline with more IRs. To instantiate a pipeline with the formulation above, we will first discuss the choice of IRs before the choice of modules.

Choice of IR IRs used in past work include:

1. A **natural language**, where the LLM converts the input description into a free-form representation that facilitate later PDDL generation. This representation can range from loose sentences (Zhang et al., 2024; Hu et al., 2025) to a semi-formal data structure (Wong et al., 2024; Hao et al., 2025), but in any case cannot be executed by an external solver. Such a conversion can involve information extraction, chain-of-thought, or summarization.
2. Another **PDDL**, where the module that takes one PDDL as input and outputs another is a revision module discussed in details below.

We will show in later discussions that neither of these two IRs are sufficiently effective for open-source, mid-size LLMs generating PDDL, as one is too distant from the generation target while PDDL itself is too low-resource. We draw inspiration from related work in program synthesis that suggests high-resource languages (Cassano et al., 2024; Zhang et al., 2025) may be effect IRs for generating low-resource languages like PDDL. We also note from previous work that the rigid and particular syntax of PDDL calls for a syntax alignment with an IR. Based on these criteria, we additionally propose two fully formal IRs:

3. **Python simulator**, where the LLM is instructed to generate a Python code that simulates the domain and the problem. We place minimal requirement on the structure of the code to leverage the coding ability of high-resource programming languages. We require the generated Python code to be directly executable to return a plan, though in this work treat it as an IR that we transpile to PDDL to take advantage of the optimized planners.
4. **PyPDDL**, where the LLM is instructed to generate Python code in a specific wrapper for PDDL referred to as PyPDDL[2]. The documentation for PyPDDL is provided in the prompt along with a domain-agnostic example. While the library does not provide a solver, implementing one is feasible as the language is fully formal. Even so, in this work we again transpile the PyPDDL code to PDDL either deterministically with tools from the library or with an LLM.

Examples of IRs are shown in Appendix F.

Choice of Modules $I \rightarrow L$: In general planning tasks, there exists much prior work of *LLM-as-planner* that generates plans in an end-to-end manner (Valmeekam et al., 2023a,b, 2025). This line of work commonly involves LLM *agents*. Common techniques include reasoning before planning (Yao et al., 2023), task decomposition (Prasad et al., 2024), reflection after planning (Majumder et al., 2024), continuous learning (Wang et al., 2024), and so on. As a complete survey exists (Wei et al., 2025), we do not dive into more discussions.

$I \rightarrow$ PDDL: In PDDL-based classical planning, most existing work of *LLM-as-formalizer* generates various parts of the PDDL without involving additional IR. The generation target includes the goal states (Xie et al., 2023), problem file (Liu et al., 2023; Zuo et al., 2025), action semantics (Zhang et al., 2024; Zhu et al., 2025; Hu et al., 2025), domain file (Guan et al., 2023; Wong et al., 2024), and complete PDDL (Huang

[2] https://github.com/remykarem/Py2PDDL

and Zhang, 2025; Gong et al., 2025) like us. Following cited work, we do not consider methods that require supervised training due to the extreme low-resource nature of PDDL. Common inference techniques include basic **few-shot prompting** (e.g., Xie et al. (2023)), where the LLM is prompted via in-context learning with some exemplars to translate the natural language D_d and/or D_p into PDDL $\mathcal{DF}$ and/or $\mathcal{PF}$. We do this by default with a prompt that introduces the basic structure of PDDL with a domain-agnostic example. Other techniques include sequential generation (e.g., Gong et al. (2025)), where the LLM generates $\mathcal{DF}$ and/or $\mathcal{PF}$ sequentially instead of at once with distinctive prompts, or retrieval of documentation (e.g., Wang and Zhang (2025)), where the LLM retrieves the documentation of the PDDL language along with examples before generation. We consider those contemporaneous techniques out of scope.

PDDL $\rightsquigarrow L$: All cited work above use a symbolic PDDL solver such as Fast Downward planner (Helmert, 2006), as do we. Another strand of work has used LLMs in lieu of such solvers to take PDDL as input and outputs a plan (Stein et al., 2025), or to generate programs that emulate such solvers (Silver et al., 2024; Chen et al., 2025).

PDDL $\rightarrow^*$ PDDL: This represents a revision module, where the LLM first generates an initial PDDL, before revising it multiple times ($\rightarrow^*$). In conjunction with the PDDL solver, the validity of the predicted PDDL along with syntax error messages are typically provided to the LLM for regeneration, denoted as $\rightarrow^{\text{FB}}$ (Zhu et al., 2025; Hu et al., 2025). It is also possible to revise PDDL solely based on LLMs' own feedback without invoking the solver.

IR $\rightarrow^*$ IR: A generated IR can also be revised similarly. However, not all IRs can work with a formal solver, so we rely on the LLM to optionally revise them without indication if their correctness.

IR $\rightarrow$ PDDL: Overall, higher-order chaining of general purpose IRs (e.g., natural language, JSON) has proven effective for non-PDDL planning language generation (Wong et al., 2024; Hao et al., 2025). In our work, we specifically propose IRs with high syntax alignment with PDDL. To transpile an IR to PDDL, we rely on either (i) a deterministic rule-based transpiler or (ii) an LLM. We default to the latter following cited work and discuss the former in a later ablation study.

Non-PDDL Planning Languages Even in planning, LLM-as-formalizer is a general methodology that can be instantiated with many planning languages other than PDDL, including satisfiability modulo theories (SMT) (Guo et al., 2024; Hao et al., 2025), linear temporal logic (LTL) (Yang et al., 2023; Li et al., 2024), Answer Set Programming (Lin et al., 2024), action languages (AL) (Ishay and Lee, 2025), and so on. While our work is largely applicable to any planning language (except for IRs requiring affinity to a particular language), we only study PDDL which is widely used in literature and also the language that underlies many classical planning benchmarks.

4 Experimental Setup

Datasets. We consider 4 simulated planning environments highly common in cited literature. First, we have BlocksWorld, Logistics, and Sokoban from the International Planning Competition (IPC, 1998). These domains represent object manipulation and range from 4 actions to 12 actions. We use the moderately templated version of the datasets from Huang and Zhang (2025). Next, we have CoinCollector (Yuan et al., 2019), a partially observable navigation domain, which convert to be fully observable just as the other three. The dataset of each environment comes with 100 tuples of domain description, problem description, ground-truth domain and problem files. Examples are shown in Appendix E. While we focus on Moderately-Templated descriptions as in prior work (Huang and Zhang, 2025), we also experiment with Natural descriptions for key pipelines, two models, and two domains with results in Appendix A that aligns with our overal conclusions in this work.

Metrics. We use syntactic and semantic accuracy to assess the generated PDDL. *Syntactic accuracy* is the percentage where no syntax error are returned by the planning solver.*Plan accuracy* is the percentage where a plan is not only found by the solver but also correct based on validation. We use the `dual-bfws-ffparser` planner (Muise, 2016) to solve for the plan and VAL (Howey et al., 2004) to validate the plan against the ground-truth PDDL.

Pipelines. We instantiate an array of pipelines based on our previously introduced framework. Recall that we define the *level* of a pipeline as the number of IRs (including PDDL) it involves. We notate each pipeline as the intermediate IRs in-

Lv.	Input	1st IR	2nd IR	3rd IR	Output	Description	Example work
0	I				$\rightarrow L$	LLM-as-planner (ϕ)	End-to-end *LLM-as-planner* (Valmeekam et al., 2023a,b, 2025);
1	I	$\rightarrow$ PDDL			$\rightsquigarrow L$	*PDDL-base*: directly generating PDDL.	*LLM-as-formalizer* generates PDDL parts: goals (Xie et al., 2023), problem (Liu et al., 2023; Zuo et al., 2025), action semantics (Zhang et al., 2024; Zhu et al., 2025; Hu et al., 2025), domain (Guan et al., 2023; Wong et al., 2024), complete PDDL (Huang and Zhang, 2025; Gong et al., 2025).
2	I	$\rightarrow$ NL	$\rightarrow$ PDDL		$\rightsquigarrow L$	Generating an NL description of the actions and entity states before PDDL	NL IR used in Silver et al. (2024) and in Ishay and Lee (2025) for non-PDDL planning language generation.
	I	$\rightarrow$ PyPDDL	$\rightarrow \mid \rightsquigarrow$ PDDL		$\rightsquigarrow L$	†Transpiling a PyPDDL program to PDDL either with Py2PDDL ($\rightsquigarrow$) or by an LLM ($\rightarrow$).	N/A
	I	$\rightarrow$ PySim	$\rightarrow$ PDDL		$\rightsquigarrow L$	†Generating a Python-based simulator before translating to PDDL.	N/A
	I	$\rightarrow$ PDDL	$\rightarrow^{\text{FB?}}$ PDDL		$\rightsquigarrow L$	Refining the generated PDDL once (with or without the solver feedback).	Revision with solver feedback ($\rightarrow^{\text{FB}}$) (Zhu et al., 2025; Hu et al., 2025).
3	I	$\rightarrow$ PyPDDL	$\rightarrow$ PDDL	$\rightarrow$ PDDL	$\rightsquigarrow L$	†Generating a PyPDDL wrapper before generating PDDL that receives one revision.	N/A
	I	$\rightarrow$ PDDL	$\rightarrow$ PyPDDL	$\rightarrow$ PDDL	$\rightsquigarrow L$	†Generating PDDL first and then generating PyPDDL wrapper followed by PDDL generation.	N/A
	I	$\rightarrow$ PDDL	$\rightarrow^{\text{FB?}}$ PDDL	$\rightarrow^{\text{FB?}}$ PDDL	$\rightsquigarrow L$	Iteratively refining the PDDL program twice (with or without solver feedback).	Iterative refinement with solver feedback ($\rightarrow^{\text{FB}}$) (Zhu et al., 2025; Hu et al., 2025).

Table 1: Pipelines that we evaluate in this work, ranging from level 0 to level 3. For each pipeline, we specify the IRs before reaching the final plan (L). Pipelines marked with † are newly introduced in this work. Straight arrows ($\rightarrow$) denote procedures involving LLMs, with superscripts indicating special variants—FB for solver feedback. Wavy arrows ($\rightsquigarrow$) represent purely symbolic solving or compilation processes.

volves, excluding the input description I and the output plan L. For example, PDDL $\rightarrow$ PDDL denotes a pipeline $I \rightarrow$ PDDL $\rightarrow$ PDDL $\rightsquigarrow L$. The evaluated pipelines are illustrated in Table 1, ranging from level 0 to level 3. We do not consider level 4 onward pipelines.

Models. We evaluate 4 recent and best performing open-source LLMs, QwQ-32B, Qwen3-32B, gpt-oss-120b (total 117B with 5.1B active parameters), and GLM-4.5-Air-FP8 (total 106B with 12B active parameters) We use vLLM (Kwon et al., 2023) to speed up inference and set temperature of 0.4 for each of our experiments on one H100 GPU. We report mean of three runs and their standard deviation is shown as error bars. Examples of prompts are shown in Appendix G.

5 Results and Discussions

With our unifying framework, we present a comprehensive evaluation for inference-time LLM-assisted planning focusing on PDDL generation.

5.1 The Effect of Level

Figure 2 shows the performance of 4 LLMs with representative pipelines for each level on BlocksWorld and Logistics. Overall, the highest plan accuracy is achieved by a Level 3 pipeline (PDDL $\rightarrow$ PDDL $\rightarrow$ PDDL) involving 3 IRs, in 6 out of 8 LLM-domain combinations. Generally, our finding **recommends a higher level pipeline that involves IRs and revisions**, for the LLM-as-formalizer methodology, that is inline with findings from existing work.

However, as real-life planning applications cannot assume unlimited computational resource. Therefore, we now consider the most resource-constrained case of Level 0 and Level 1 pipelines where the most costly step, an LLM generation, happens once. The comparison between the vanilla LLM-as-planner (ϕ) and LLM-as-formalizer (PDDL-base) has no clear winner (3 against 5 in 8 LLM-domain combinations), corroborating similar claims in recent work that evaluated reasoning LLMs with inference-time scaling (Huang and Zhang, 2025; Amonkar et al., 2025).

With one more IR, **the best Level 2 LLM-as-**

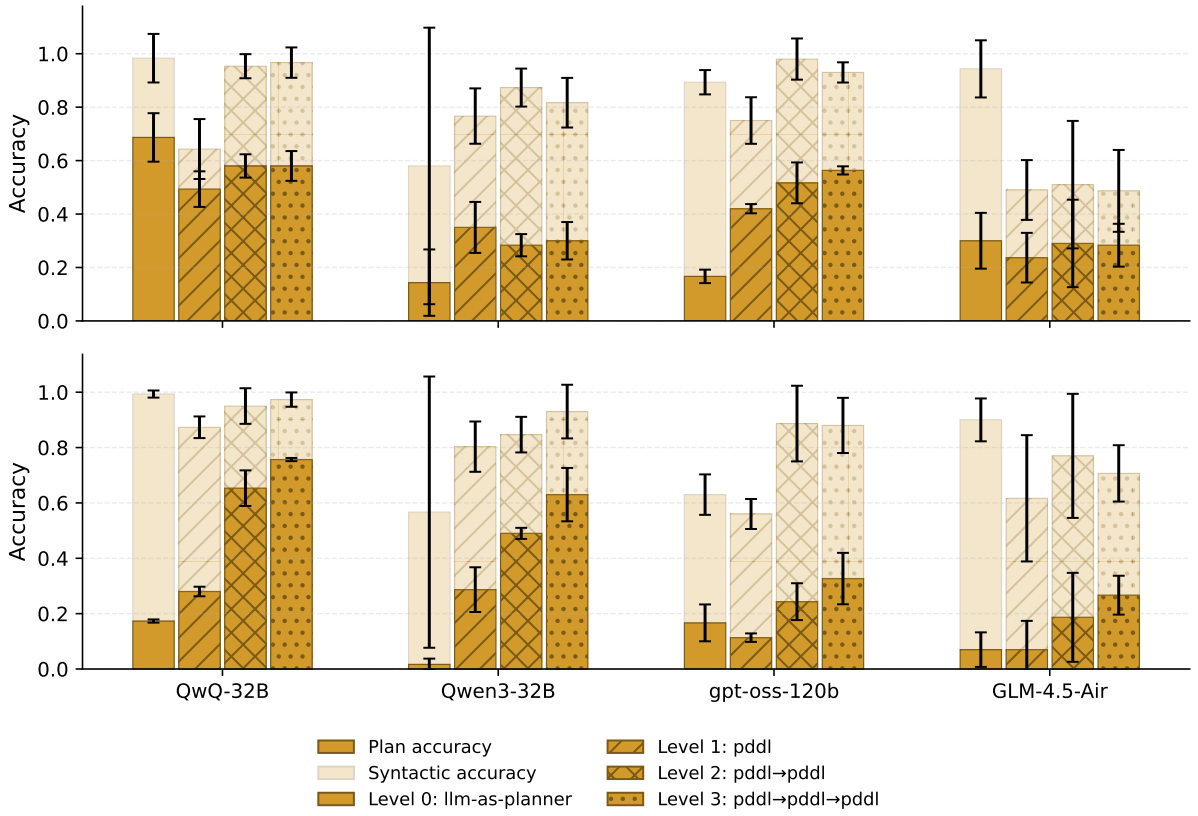

Figure 2: The performance of four LLMs with a representative pipeline from each of the levels.

formalizer pipeline always outperforms LLM-as-planner and also the Level 1 pipelines in all 8 out of 8 cases. This finding cautions against generating planning languages with merely one LLM call.

5.2 The Effect of IR

We now zoom onto Level 2 with one additional IR before the final PDDL to be generated. Our pipelines are instantiated with 4 types of IR: NL, Python Simulator, PyPDDL, and PDDL, with results in Figure 3. Compared to Level 1, NL as an IR consistently hurts performance. Python Simulator is similar yet sometimes improves performance. In contrast, **PyPDDL and PDDL as IRs consistently improves performance**. Notably, PyPDDL $\rightarrow$ PDDL and PDDL $\rightarrow^{\text{FB}}$ PDDL out-performs each other in half of the 8 LLM-domain combinations. Without the solver feedback but with the LLM feedback, the PDDL $\rightarrow$ PDDL pipeline loses its advantage of revision. Whenever invoking the solver may be costly, this finding presents the community an alternative to revision with solver feedback: transpilation from a syntax-aligned IR to the target language. Figure 4 shows qualitative examples of different IRs and their typical mistakes.

For any pipeline that involves PyPDDL $\rightarrow$ PDDL, recall that PyPDDL is a formal language where a solver *could* be defined in situ (though, this is a non-trivial effort) yet is not provided by the library we use, so we default to using the LLM to transpile PyPDDL to PDDL to leverage the PDDL solver. As an ablation study, we also attempt to perform transpilation deterministically using Py2PDDL library (denoted as PyPDDL $\rightsquigarrow$ PDDL). One may expect such a deterministic transpilation to outperform LLM generating PDDL, considering Python is much higher-resource than PDDL. Transpilation with Py2PDDL performs much worse than LLM-based transpilation. For instance, with accuracy 16% vs 68% for QwQ-32B model in BlocksWorld. The generated PyPDDL tends to not follow non-trivial way of representing different PDDL components. As shown in Figure 4, a set of `blocks` created by `create_objs` is mistakenly treated as a `List` instead of a `Dict`.

Based on the comparison of level 3 pipelines in Figure 3, PyPDDL is effective before revision but not during. This informs the architecture of pipelines with IR that maximize performance by

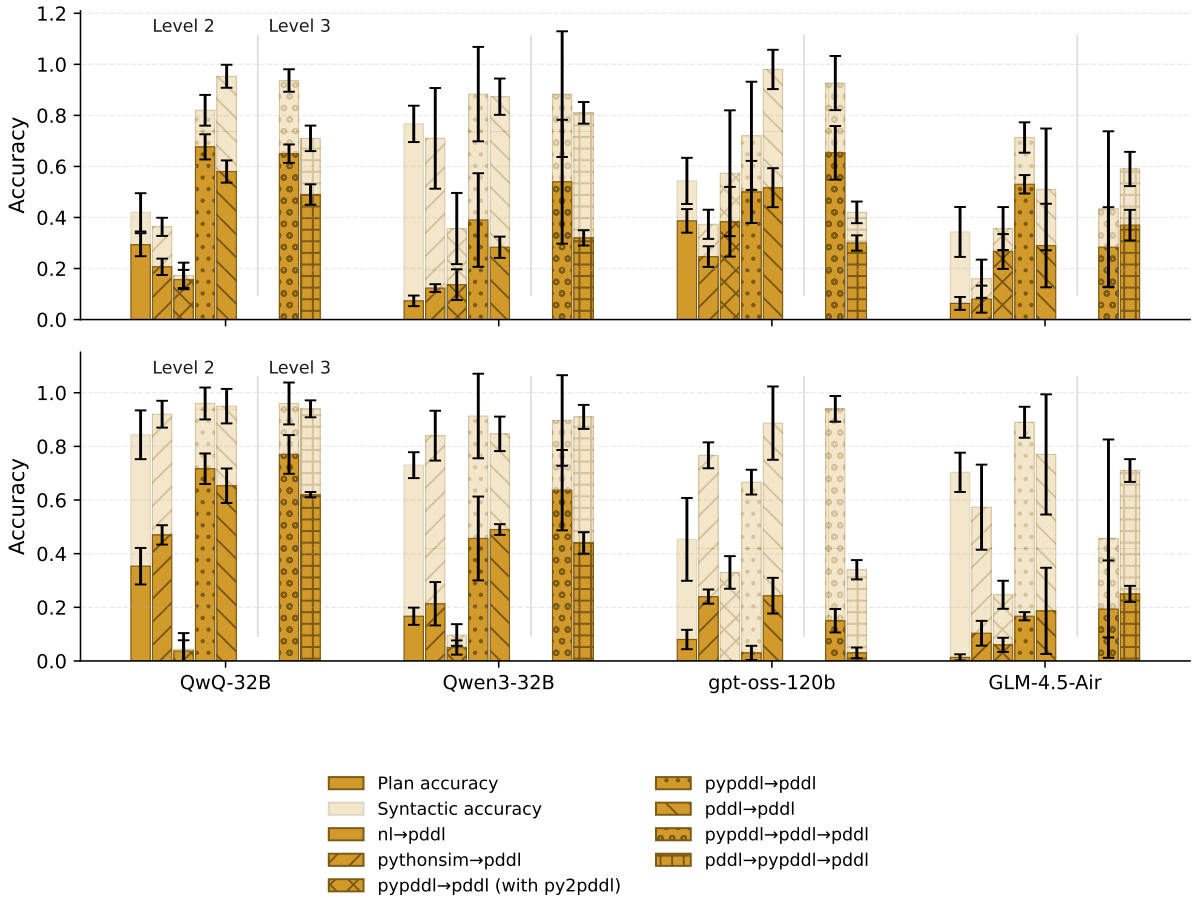

Figure 3: The performance of four LLMs with five pipelines in level 2 comparing IRs and two pipelines from level 3 comparing the ordering of IRs. (PyPDDL→PDDL→PDDL vs PDDL→PyPDDL→PDDL)

effectively using all LLM calls.

All the results with performance of 4 LLMs and 12 pipelines on BlocksWorld, Logistics, Sokoban, and CoinCollector are shown in Appendix C. We focus on the first two domains here due to space limitation and relatively consistent findings.

5.3 Robustness against Complexity

Recent work has cast doubt on the ability of LLM, both as a planner and as a formalizer, to scale with the problem complexity (Shojaee et al., 2025; Lin et al., 2025; Amonkar et al., 2025). For example, the BlocksWorld dataset evaluated in this work ranges from 2 to 15 blocks, while other cited previous work often relied on datasets with even smaller entity space. In real-life applications such as robotics or logistics, current benchmarks do not help understand LLMs' robustness in planning for complex problems, either as planners or as formalizers. Therefore, we specifically construct BlocksWorld problems with increasing number of entities (blocks), ranging from 10 to 50, with an increment of 10 and 10 problems per bucket. We evaluate the robustness of some of the most commonly used and best-performing pipelines LLM-as-planner (Level 0) and three LLM-as-formalizer pipelines including PDDL (Level 1), PyPDDL → PDDL, and PDDL → PDDL (Level 2).

Figure 5, clearly shows that while **all methods degrade with complexity, LLM-as-formalizer is much more robust than LLM-as-planner**. We observe that, as the number of blocks approaches 20, the performance of LLM-as-planner halves compared to 10; approaching 50, its performance drops to zero. In contrast, all LLM-as-formalizer pipelines are more robust to increased entity-space complexity despite reduction in performance. Notably, directly generating PDDL (Level 1) loses no more than 20% plan accuracy as the number of entities increases from 10 to 50. In comparison, the Level 2 pipelines perform better with less entities, but degrade more severely with more entities.

Situated among recent studies, our findings corroborate the claim that even reasoning LLMs with

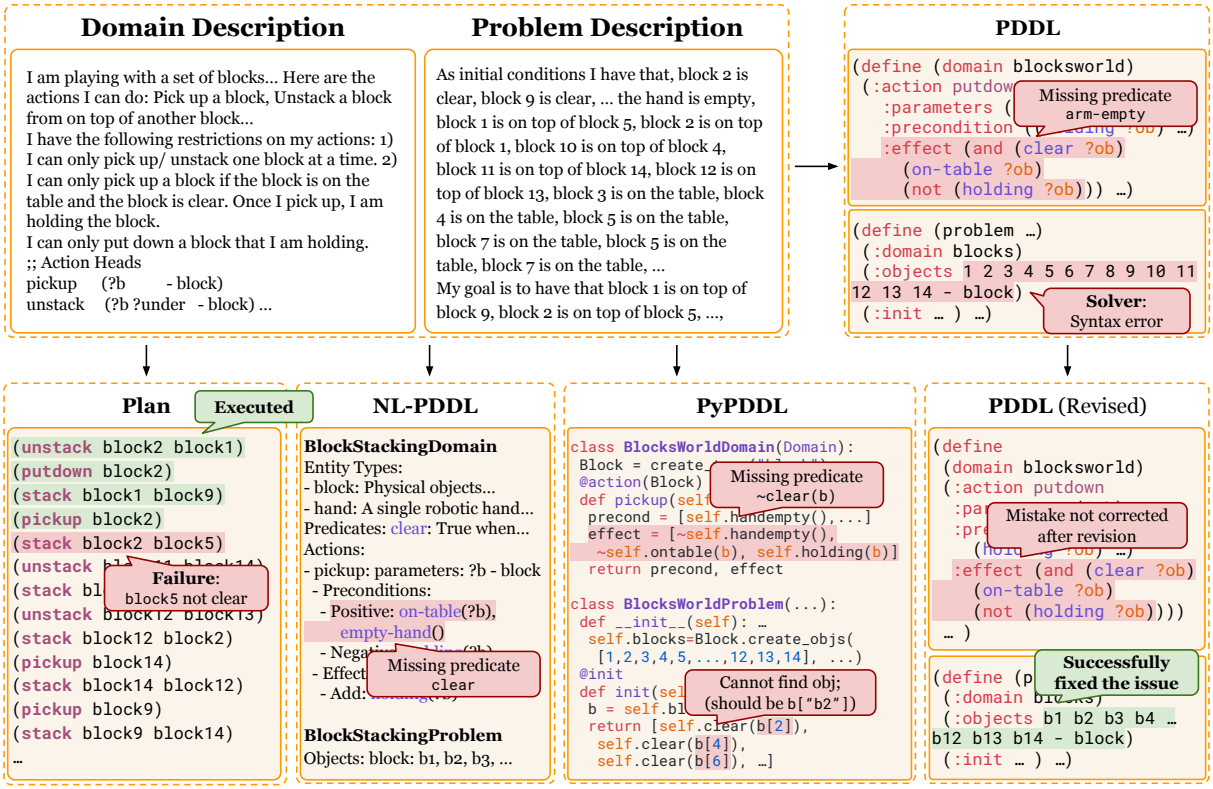

Figure 4: Qualitative examples of a same problem in BlocksWorld, juxtaposing different IRs generated including NL, PyPDDL, PDDL, before generating the final PDDL (Level 2). Also included is a revised PDDL based on solver feedback and a directly generated plan (Level 0).

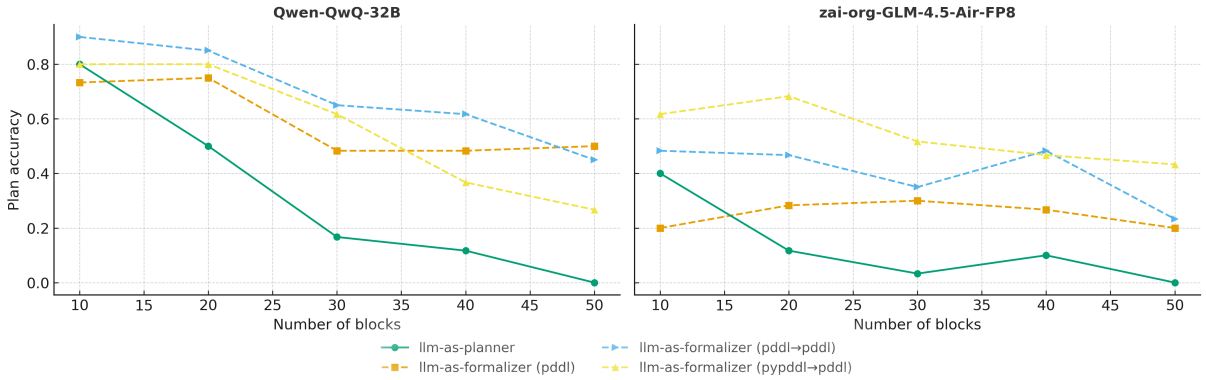

Figure 5: The performance of two LLMs and four methods including usage as planners and as formalizers on BlocksWorld problems with an increasing entity space.

inference-time scaling are not robust to problem complexity. Moreover, we are the first to evidence and advocate for the robustness of LLM-as-formalizer in planning. For more multi-IR pipelines of higher levels, we also caution against the tradeoff between performance and robustness against complexity.

6 Conclusion

We propose a unifying framework of inference-time planning language generation. Based on the interplay of IR, our framework not only subsumes most prior work involving multi-stage LLM pipelines but also inspires novel pipelines, such as those involving a high-resource, syntax-aligned IR to the target language. In addition to providing immediately applicable recipes for high-performing planning methods, our work opens up promising directions of research in designing efficient LLM pipelines applicable to alternative planning languages (e.g., LTL) and even non-planning domain-specific languages (e.g., SMT).

7 Limitations

We only consider pipelines with three levels i.e. three IRs for planning language generation. Some of the existing work already have more than three IRs in their pipelines (Hao et al., 2025; Ishay and Lee, 2025). Thus, instantiation of our framework presented here is still limited in all possible insights applicable to contemporary work. We defer this to future work.

References

Rikhil Amonkar, May Lai, Ronan Le Bras, and Li Zhang. 2025. Are llms better formalizers than solvers on complex problems? *Preprint*, arXiv:2505.13252.

Federico Cassano, John Gouwar, Francesca Lucchetti, Claire Schlesinger, Anders Freeman, Carolyn Jane Anderson, Molly Q Feldman, Michael Greenberg, Abhinav Jangda, and Arjun Guha. 2024. Knowledge transfer from high-resource to low-resource programming languages for code llms. *Preprint*, arXiv:2308.09895.

Yongchao Chen, Yilun Hao, Yang Zhang, and Chuchu Fan. 2025. Code-as-symbolic-planner: Foundation model-based robot planning via symbolic code generation. *Preprint*, arXiv:2503.01700.

Richard E. Fikes and Nils J. Nilsson. 1971. Strips: a new approach to the application of theorem proving to problem solving. In *Proceedings of the 2nd International Joint Conference on Artificial Intelligence*, IJCAI'71, page 608–620, San Francisco, CA, USA. Morgan Kaufmann Publishers Inc.

Liancheng Gong, Wang Zhu, Jesse Thomason, and Li Zhang. 2025. Zero-shot iterative formalization and planning in partially observable environments. *Preprint*, arXiv:2505.13126.

Lin Guan, Karthik Valmeekam, Sarath Sreedharan, and Subbarao Kambhampati. 2023. Leveraging pretrained large language models to construct and utilize world models for model-based task planning. In *Thirty-seventh Conference on Neural Information Processing Systems*.

Weihang Guo, Zachary Kingston, and Lydia E. Kavraki. 2024. Castl: Constraints as specifications through llm translation for long-horizon task and motion planning. *Preprint*, arXiv:2410.22225.

Yilun Hao, Yang Zhang, and Chuchu Fan. 2025. Planning anything with rigor: General-purpose zero-shot planning with llm-based formalized programming. *Preprint*, arXiv:2410.12112.

Malte Helmert. 2006. The fast downward planning system. *J. Artif. Int. Res.*, 26(1):191–246.

R. Howey, D. Long, and M. Fox. 2004. Val: automatic plan validation, continuous effects and mixed initiative planning using pddl. In *16th IEEE International Conference on Tools with Artificial Intelligence*, pages 294–301.

Mengkang Hu, Tianxing Chen, Yude Zou, Yuheng Lei, Qiguang Chen, Ming Li, Yao Mu, Hongyuan Zhang, Wenqi Shao, and Ping Luo. 2025. Text2World: Benchmarking large language models for symbolic world model generation. In *Findings of the Association for Computational Linguistics: ACL 2025*, pages 26043–26066, Vienna, Austria. Association for Computational Linguistics.

Cassie Huang and Li Zhang. 2025. On the limit of language models as planning formalizers. In *Proceedings of the 63rd Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 4880–4904, Vienna, Austria. Association for Computational Linguistics.

IPC. 1998. International planning competition. `https://www.icaps-conference.org/competitions`.

Adam Ishay and Joohyung Lee. 2025. Llm+al: Bridging large language models and action languages for complex reasoning about actions. *Preprint*, arXiv:2501.00830.

Woosuk Kwon, Zhuohan Li, Siyuan Zhuang, Ying Sheng, Lianmin Zheng, Cody Hao Yu, Joseph E. Gonzalez, Hao Zhang, and Ion Stoica. 2023. Efficient memory management for large language model serving with pagedattention. In *Proceedings of the ACM SIGOPS 29th Symposium on Operating Systems Principles*.

Manling Li, Shiyu Zhao, Qineng Wang, Kangrui Wang, Yu Zhou, Sanjana Srivastava, Cem Gokmen, Tony Lee, Li Erran Li, Ruohan Zhang, et al. 2024. Embodied agent interface: Benchmarking llms for embodied decision making. *arXiv preprint arXiv:2410.07166*.

Bill Yuchen Lin, Ronan Le Bras, Kyle Richardson, Ashish Sabharwal, Radha Poovendran, Peter Clark, and Yejin Choi. 2025. Zebralogic: On the scaling limits of LLMs for logical reasoning. In *Forty-second International Conference on Machine Learning*.

Xinrui Lin, Yangfan Wu, Huanyu Yang, Yu Zhang, Yanyong Zhang, and Jianmin Ji. 2024. Clmasp: Coupling large language models with answer set programming for robotic task planning. *Preprint*, arXiv:2406.03367.

Bo Liu, Yuqian Jiang, Xiaohan Zhang, Qiang Liu, Shiqi Zhang, Joydeep Biswas, and Peter Stone. 2023. Llm+ p: Empowering large language models with optimal planning proficiency. *arXiv preprint arXiv:2304.11477*.

Bodhisattwa Prasad Majumder, Bhavana Dalvi Mishra, Peter Jansen, Oyvind Tafjord, Niket Tandon, Li Zhang, Chris Callison-Burch, and Peter Clark. 2024. CLIN: A continually learning language agent

for rapid task adaptation and generalization. In *First Conference on Language Modeling*.

Christian Muise. 2016. Planning.Domains. In *The 26th International Conference on Automated Planning and Scheduling - Demonstrations*.

Archiki Prasad, Alexander Koller, Mareike Hartmann, Peter Clark, Ashish Sabharwal, Mohit Bansal, and Tushar Khot. 2024. ADaPT: As-needed decomposition and planning with language models. In *Findings of the Association for Computational Linguistics: NAACL 2024*, pages 4226–4252, Mexico City, Mexico. Association for Computational Linguistics.

Torsten Scholak, Nathan Schucher, and Dzmitry Bahdanau. 2021. PICARD: Parsing incrementally for constrained auto-regressive decoding from language models. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pages 9895–9901, Online and Punta Cana, Dominican Republic. Association for Computational Linguistics.

Parshin Shojaee, Iman Mirzadeh, Keivan Alizadeh, Maxwell Horton, Samy Bengio, and Mehrdad Farajtabar. 2025. The illusion of thinking: Understanding the strengths and limitations of reasoning models via the lens of problem complexity. *Preprint*, arXiv:2506.06941.

Tom Silver, Soham Dan, Kavitha Srinivas, Joshua B. Tenenbaum, Leslie Kaelbling, and Michael Katz. 2024. Generalized planning in pddl domains with pretrained large language models. In *Proceedings of the Thirty-Eighth AAAI Conference on Artificial Intelligence and Thirty-Sixth Conference on Innovative Applications of Artificial Intelligence and Fourteenth Symposium on Educational Advances in Artificial Intelligence*, AAAI'24/IAAI'24/EAAI'24. AAAI Press.

Katharina Stein, Daniel Fišer, Jörg Hoffmann, and Alexander Koller. 2025. Automating the generation of prompts for llm-based action choice in pddl planning. In *Proceedings of the Workshop on Bridging the Gap Between AI Planning and Reinforcement Learning (PRL) at ICAPS*.

Marcus Tantakoun, Christian Muise, and Xiaodan Zhu. 2025. LLMs as planning formalizers: A survey for leveraging large language models to construct automated planning models. In *Findings of the Association for Computational Linguistics: ACL 2025*, pages 25167–25188, Vienna, Austria. Association for Computational Linguistics.

Karthik Valmeekam, Matthew Marquez, Alberto Olmo, Sarath Sreedharan, and Subbarao Kambhampati. 2023a. Planbench: An extensible benchmark for evaluating large language models on planning and reasoning about change. *Advances in Neural Information Processing Systems*, 36:38975–38987.

Karthik Valmeekam, Matthew Marquez, Sarath Sreedharan, and Subbarao Kambhampati. 2023b. On the planning abilities of large language models: a critical investigation. In *Proceedings of the 37th International Conference on Neural Information Processing Systems*, NIPS '23, Red Hook, NY, USA. Curran Associates Inc.

Karthik Valmeekam, Kaya Stechly, Atharva Gundawar, and Subbarao Kambhampati. 2025. A systematic evaluation of the planning and scheduling abilities of the reasoning model o1. *Transactions on Machine Learning Research*.

Bailin Wang, Zi Wang, Xuezhi Wang, Yuan Cao, Rif A. Saurous, and Yoon Kim. 2023. Grammar prompting for domain-specific language generation with large language models. In *Proceedings of the 37th International Conference on Neural Information Processing Systems*, NIPS '23, Red Hook, NY, USA. Curran Associates Inc.

Guanzhi Wang, Yuqi Xie, Yunfan Jiang, Ajay Mandlekar, Chaowei Xiao, Yuke Zhu, Linxi Fan, and Anima Anandkumar. 2024. Voyager: An open-ended embodied agent with large language models. *Transactions on Machine Learning Research*.

Renxiang Wang and Li Zhang. 2025. Documentation retrieval improves planning language generation. *Preprint*, arXiv:2509.19931.

Hui Wei, Zihao Zhang, Shenghua He, Tian Xia, Shijia Pan, and Fei Liu. 2025. PlanGenLLMs: A modern survey of LLM planning capabilities. In *Proceedings of the 63rd Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 19497–19521, Vienna, Austria. Association for Computational Linguistics.

Lionel Wong, Jiayuan Mao, Pratyusha Sharma, Zachary S. Siegel, Jiahai Feng, Noa Korneev, Joshua B. Tenenbaum, and Jacob Andreas. 2024. Learning adaptive planning representations with natural language guidance. In *International Conference on Learning Representations (ICLR)*.

Yaqi Xie, Chen Yu, Tongyao Zhu, Jinbin Bai, Ze Gong, and Harold Soh. 2023. Translating natural language to planning goals with large-language models. *Preprint*, arXiv:2302.05128.

Ziyi Yang, Shreyas S. Raman, Ankit Shah, and Stefanie Tellex. 2023. Plug in the safety chip: Enforcing constraints for llm-driven robot agents. *Preprint*, arXiv:2309.09919.

Shunyu Yao, Jeffrey Zhao, Dian Yu, Nan Du, Izhak Shafran, Karthik Narasimhan, and Yuan Cao. 2023. React: Synergizing reasoning and acting in language models. *Preprint*, arXiv:2210.03629.

Xingdi Yuan, Marc-Alexandre Côté, Alessandro Sordoni, Romain Laroche, Remi Tachet des Combes, Matthew Hausknecht, and Adam Trischler. 2019. Counting to explore and generalize in text-based games. *Preprint*, arXiv:1806.11525.

Jipeng Zhang, Jianshu Zhang, Yuanzhe Li, Renjie Pi, Rui Pan, Runtao Liu, Zheng Ziqiang, and Tong Zhang. 2025. Bridge-coder: Transferring model capabilities from high-resource to low-resource programming language. In *Findings of the Association for Computational Linguistics: ACL 2025*, pages 10865–10882, Vienna, Austria. Association for Computational Linguistics.

Tianyi Zhang, Li Zhang, Zhaoyi Hou, Ziyu Wang, Yuling Gu, Peter Clark, Chris Callison-Burch, and Niket Tandon. 2024. PROC2PDDL: Open-domain planning representations from texts. In *Proceedings of the 2nd Workshop on Natural Language Reasoning and Structured Explanations (@ACL 2024)*, pages 13–24, Bangkok, Thailand. Association for Computational Linguistics.

Wang Bill Zhu, Ishika Singh, Robin Jia, and Jesse Thomason. 2025. Language models can infer action semantics for symbolic planners from environment feedback. In *Proceedings of the 2025 Conference of the Nations of the Americas Chapter of the Association for Computational Linguistics: Human Language Technologies (Volume 1: Long Papers)*, pages 8751–8773, Albuquerque, New Mexico. Association for Computational Linguistics.

Max Zuo, Francisco Piedrahita Velez, Xiaochen Li, Michael Littman, and Stephen Bach. 2025. Planetarium: A rigorous benchmark for translating text to structured planning languages. In *Proceedings of the 2025 Conference of the Nations of the Americas Chapter of the Association for Computational Linguistics: Human Language Technologies (Volume 1: Long Papers)*, pages 11223–11240, Albuquerque, New Mexico. Association for Computational Linguistics.

A Results for Natural Version of Data

We also present results with Natural version of data instead of Moderately-Templated input data. The results highlight the same conclusions showing the competence of PyPDDL as an IR compared to PDDL or PDDL revision. The results are in Figure 6.

B Results with Constrained Decoding

We additionally apply **decoding by grammar** technique (denoted $\rightarrow^{\text{GD}}$) to PDDL generation based on grammar (Wang et al., 2023) and constrained decoding (Scholak et al., 2021) favorable in the program synthesis community. We translate the formal BNF definition of PDDL 3.1[3] into a LALR(1)-compatible EBNF grammar used to limit LLMs' decoding to trivially syntactically correct PDDL, but may degrade semantics.

[3]Kovacs, 2011: http://pddl4j.imag.fr/repository/wiki/BNF-PDDL-3.1.pdf

Applicable for all levels, we evaluate PDDL-grammar with constrained decoding as a drop-in replacement for standard decoding in PDDL-base pipeline. Although performance on BlockWorld domain is comparable (38% for PDDL-grammar vs 36% for PDDL-base), the performance on Logistics domain is zero. Constrained decoding showed an hit or miss behaviour; either performing comparable to standard decoding or catastrophically making similar mistakes in all the problems. We defer comprehensive evaluation of constrained decoding to future work while suggesting for robust decoding techniques.

C All Results

The results for all the pipelines with two additional domains Sokoban and CoinCollector are shown in Figure 7 & Figure 8.

D Discussion: Justification of Modeling Style

A reviewer questioned the significance of benchmarks whose natural language explicitly mentions action names and arguments, since end users (e.g., in robotics) may not know solver-facing schemas. We emphasize that this is not a pipeline-specific simplification, but the modeling convention used by existing datasets and prior work that we aim to unify. Accordingly, our task includes an *action header* (action names and parameter signatures) to fix the ontology and enable fair, controlled evaluation across methods, rather than to propose a more "natural" user interface.

We agree there is an ontological gap between natural, dynamics-oriented descriptions and solver-oriented PDDL. Our contribution targets the *Spec-to-Code* bottleneck: translating an informal functional specification into solver-ready code, not inferring dynamics/ontologies from raw observations (*World-to-Code*). This scope is motivated by feasibility: practical classical planners typically require explicit, grounded transition schemas, while leaving dynamics implicit (e.g., via deep quantification) often yields formulations that are hard to compile and intractable for heuristic search. Crucially, even with an action header, formalization is non-trivial—strong open-source LLMs frequently fail to produce syntactically valid and semantically correct PDDL—so isolating this stage provides a clean and meaningful evaluation signal.

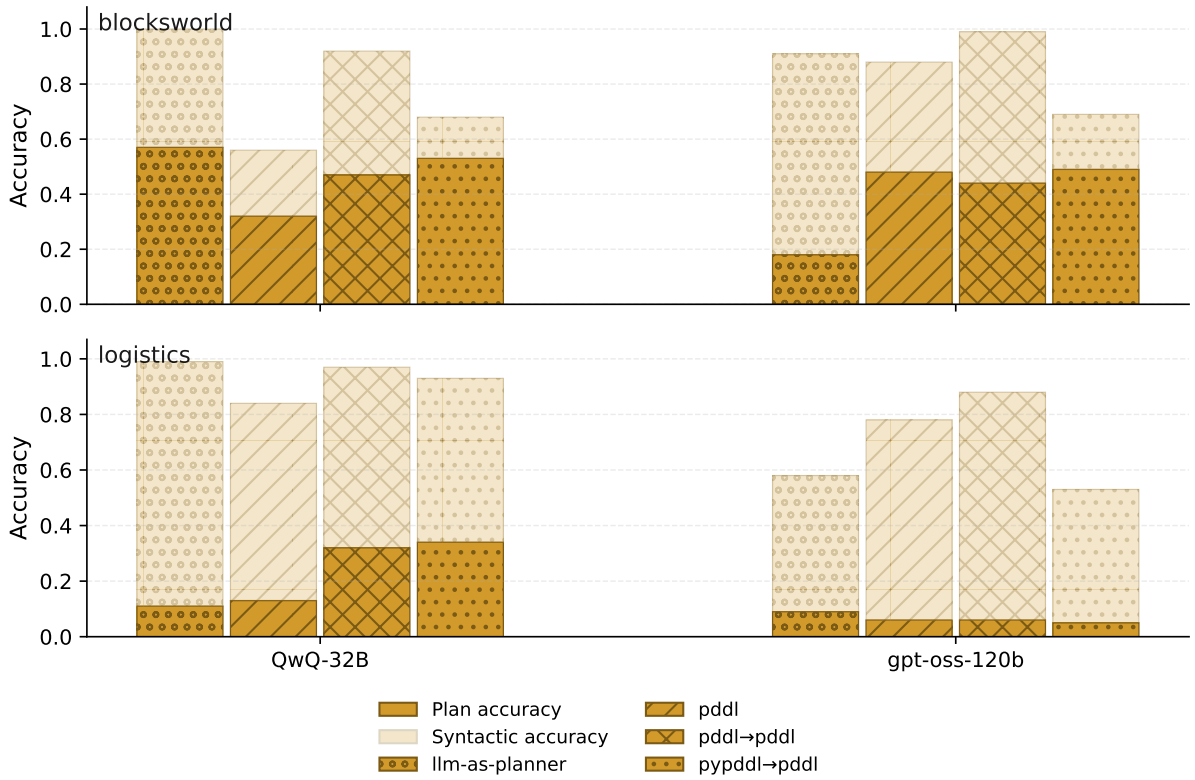

Figure 6: The performance of two LLMs and four pipelines for BlocksWorld and Logistics

E Examples of Input and Output

E.1 BlocksWorld

Blocksworld. Find the domain description (dd; Listing 9), problem description (pd; Listing 10), domain file (df; Listing 11), problem file (pf; Listing 12), and plan (plan; Listing 13).

E.2 Logistics

Logistics. Find the domain description (dd; Listing 14), problem description (pd; Listing 15), domain file (df; Listings 16 and 17), problem file (pf; Listing 18), and plan (plan; Listing 19).

E.3 CoinCollector

CoinCollector. Find the domain description (dd; Listing 20), problem description (pd; Listing 21), domain file (df; Listing 22), problem file (pf; Listing 23), and plan (plan; Listing 24).

E.4 Sokoban

Sokoban. Find the domain description (dd; Listing 25), problem description (pd; Listing 26), domain file (df; Listings 27 and 28), problem file (pf; Listing 29), and plan (plan; Listing 30).

F Examples of IRs

F.1 NL→PDDL (nl_pddl)

Listing 31 and Listing 32 present NL-PDDL IR Example.

F.2 PythonSim→PDDL (pythonsim_pddl)

Listings 33–35 and Listing 36 present the PythonSim IR example.

F.3 PyPDDL→PDDL (pypddl_pddl)

Listings 37–38 and Listing 39 present PyPDDL IR example.

F.4 PDDL→PDDL (pddl_pddl)

Listing 40 and Listing 41 present PDDL IR example.

G Examples of Prompts

G.1 Plan Generation (plan_gen)

Uses `plan_instruction` together with the natural-language domain and problem descriptions for direct plan synthesis.

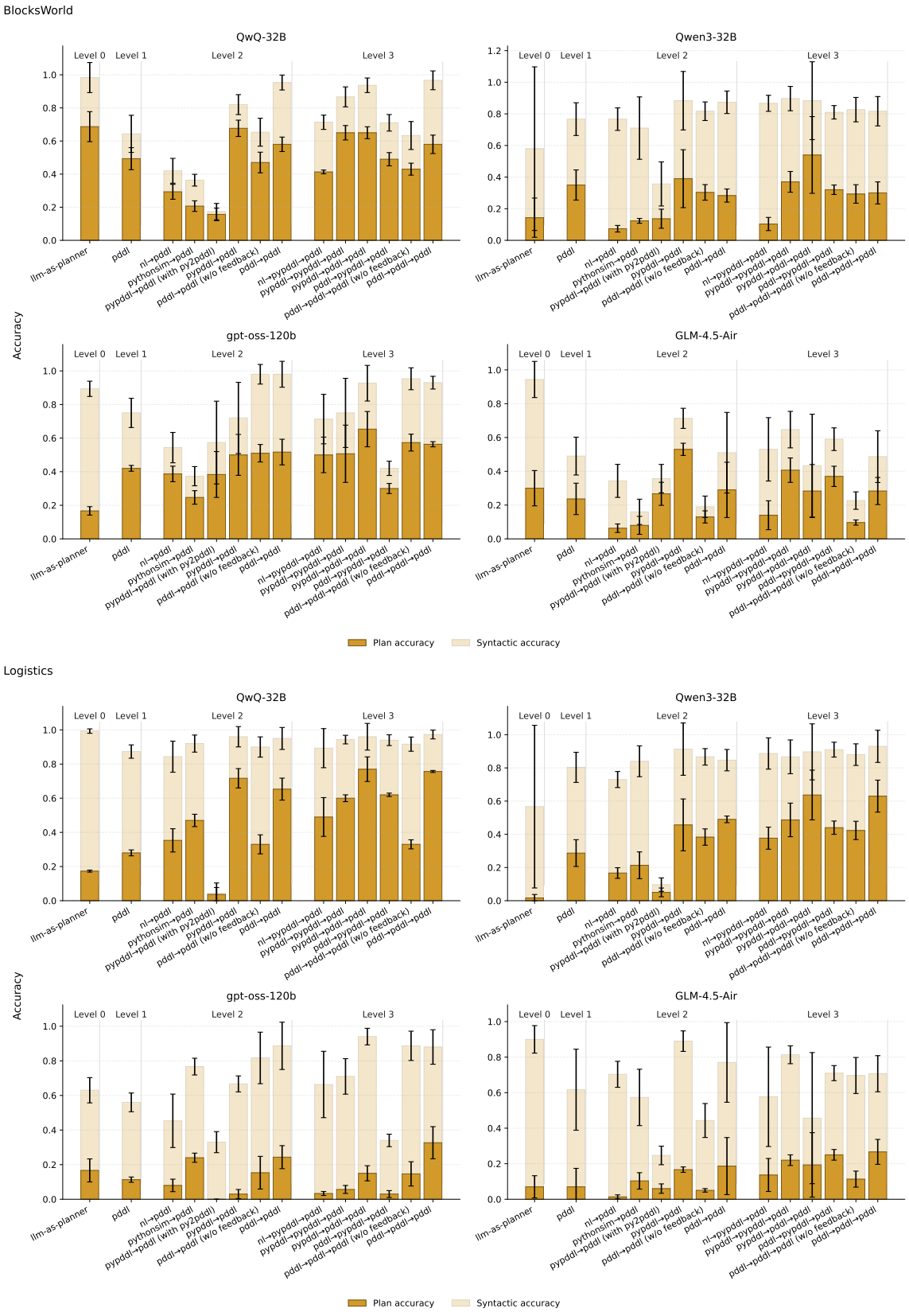

Figure 7: Syntactic accuracy and plan accuracy of various methods grouped by levels and LLMs on BlocksWorld and Logistics. Error bars shows the standard deviation over 3 runs.

G.2 Single-Stage PDDL (pddl)

Uses `only_pddl_instruction` before asking for domain and problem files grounded in the original

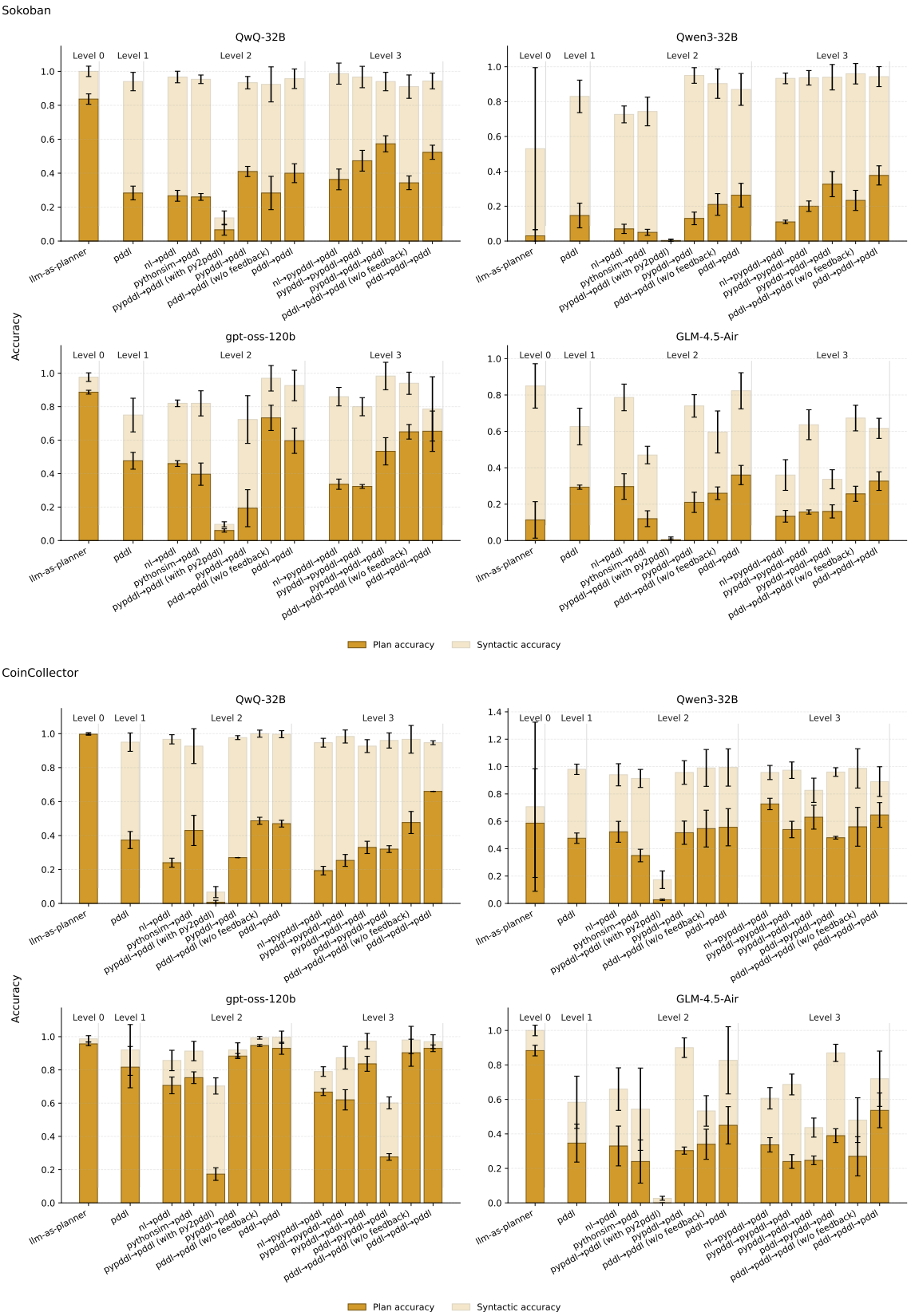

Figure 8: Syntactic accuracy and plan accuracy of various methods grouped by levels and LLMs on Sokoban and CoinCollector. Error bars shows the standard deviation over 3 runs.

descriptions.

```
I am playing with a set of blocks where I need to arrange the blocks into stacks.
Here are the actions I can do

   Pick up a block
   Unstack a block from on top of another block
   Put down a block
   Stack a block on top of another block

   I have the following restrictions on my actions:
   I can only pick up or unstack one block at a time.
   I can only pick up or unstack a block if my hand is empty.
   I can only pick up a block if the block is on the table and the block is clear.
A block is clear if the block has no other blocks on top of it and if the block is
not picked up.
   I can only unstack a block from on top of another block if the block I am
unstacking was really on top of the other block.
   I can only unstack a block from on top of another block if the block I am
unstacking is clear.
   Once I pick up or unstack a block, I am holding the block.
   I can only put down a block that I am holding.
   I can only stack a block on top of another block if I am holding the block being
stacked.
   I can only stack a block on top of another block if the block onto which I am
stacking the block is clear.
   Once I put down or stack a block, my hand becomes empty.
   Once you stack a block on top of a second block, the second block is no longer
clear.

;; Action Heads
pickup      (?b          - block)
unstack     (?b ?under   - block)
putdown     (?b          - block)
stack       (?b ?under   - block)
```

Figure 9: Blocksworld Domain Description

```
As initial conditions I have that, block1 is clear, block2 is clear, block3 is
clear, block5 is clear, the hand is empty, block5 is on top of block4, block1 is on
the table, block2 is on the table, block3 is on the table, and block4 is on the
table.
My goal is to have that block4 is on top of block5, block1 is on the table, block2
is on the table, block3 is on the table, and block5 is on the table.
```

Figure 10: Blocksworld Problem Description

G.3 NL→PDDL (nl_pddl)

Stage one converts natural language to a structured prose specification using `nl_instruction`; stage two calls `only_pddl_instruction` to emit PDDL from the summary plus original descriptions.

G.4 PythonSim→PDDL (pythonsim_pddl)

Stage one gathers a Python simulator via `python_sim_instruction`; stage two invokes `only_pddl_instruction` with the simulator alongside the original descriptions.

G.5 PyPDDL→PDDL (pypddl_pddl)

Stage one elicits PyPDDL code with `pypddl_instruction`; stage two relies on `only_pddl_instruction` plus the generated program.

G.6 PDDL→PDDL with Feedback (pddl_pddl)

Stage one uses `pddl_instruction` for direct PDDL; stage two revises the files using solver feedback from the first attempt.

G.7 PDDL→PDDL→PDDL (pddl_pddl_pddl)

Applies `pddl_instruction` across three solver-informed revisions.

```
(define (domain blocksworld)
  (:requirements :strips)
(:predicates (clear ?x)
             (on-table ?x)
             (arm-empty)
             (holding ?x)
             (on ?x ?y))

(:action pickup
  :parameters (?ob)
  :precondition (and (clear ?ob) (on-table ?ob) (arm-empty))
  :effect (and (holding ?ob) (not (clear ?ob)) (not (on-table ?ob))
               (not (arm-empty))))

(:action putdown
  :parameters  (?ob)
  :precondition (holding ?ob)
  :effect (and (clear ?ob) (arm-empty) (on-table ?ob)
               (not (holding ?ob))))

(:action stack
  :parameters  (?ob ?underob)
  :precondition (and (clear ?underob) (holding ?ob))
  :effect (and (arm-empty) (clear ?ob) (on ?ob ?underob)
               (not (clear ?underob)) (not (holding ?ob))))

(:action unstack
  :parameters  (?ob ?underob)
  :precondition (and (on ?ob ?underob) (clear ?ob) (arm-empty))
  :effect (and (holding ?ob) (clear ?underob)
               (not (on ?ob ?underob)) (not (clear ?ob)) (not (arm-empty)))))
```

Figure 11: Blocksworld Domain PDDL

```
(define (problem blocksworld-p02)
  (:domain blocksworld)
  (:objects block1 block2 block3 block4 block5 )
  (:init
    (on-table block1)
    (clear block1)
    (on-table block3)
    (clear block3)
    (on-table block2)
    (clear block2)
    (on-table block4)
    (on block5 block4)
    (clear block5)
    (arm-empty)
  )
  (:goal (and
    (on-table block3)
    (on-table block5)
    (on block4 block5)
    (on-table block2)
    (on-table block1)
  ))
)
```

Figure 12: Blocksworld Problem PDDL

```
1. (unstack block5 block4)
2. (putdown block5)
3. (pickup block4)
4. (stack block4 block5)
```

Figure 13: Blocksworld Plan

```
I need to move packages between locations. Here are the actions I can do

    Load an package onto a truck at a location (load-truck package truck location)
    Load an package onto an airplane at a location (load-airplane package airplane
location)
    Unload an package from a truck at a location (unload-truck package truck
location)
    Unload an package from an airplane at a location (unload-airplane package
airplane location)
    Drive a truck from location1 to location2 in a city (drive-truck truck
location1 location2 city)
    Fly an airplane from airport1 to airport2 (fly-airplane airplane airport1
airport2)

I have the following restrictions on my actions:
    I can only load a package onto a truck or airplane if both the package and
airplane are at the location.
    Once I load the package in the truck or airplane, it is no longer at the
location.
    I can only unload a package from a truck or airplane if the truck or airplane
is at the location and the package is in the truck or airplane.
    Once I unload the truck or airplane, the object is at the location and no
longer in the truck or airplane.
    I can only drive a truck between locations if the truck is at the first
location and both the first and second locations are in the same city. Once I drive
a truck, the truck is in the second city and no longer in the first city.
    I can only fly an airplane between two airports and the airplane is at the
first airport.
    Once I fly an airplane, the airplane is at the second airport and no longer at
the first airport.

;; Action Heads
load-truck        (?obj - package   ?truck - truck     ?loc - location)
load-airplane     (?obj - package   ?airplane - airplane  ?loc - airport)
unload-truck      (?obj - package   ?truck - truck     ?loc - location)
unload-airplane   (?obj - package   ?airplane - airplane  ?loc - airport)
drive-truck       (?truck - truck   ?loc-from - location  ?loc-to - location  ?city
- city)
fly-airplane      (?airplane - airplane  ?loc-from - airport  ?loc-to - airport)
```

Figure 14: Logistics Domain Description

```
As initial conditions, I have that, obj11 is a package, obj12 is a package, obj13
is a package, obj21 is a package, obj22 is a package, obj23 is a package, tru1 is a
truck, tru2 is a truck, cit1 is a city, cit2 is a city, pos1 is a location, apt1 is
a location, pos2 is a location, apt2 is a location, apt1 is an airport, apt2 is an
airport, apn1 is an airplane, apn1 is at apt2, tru1 is at pos1, obj11 is at pos1,
obj12 is at pos1, obj13 is at pos1, tru2 is at pos2, obj21 is at pos2, obj22 is at
pos2, obj23 is at pos2, pos1 is in cit1, apt1 is in cit1, pos2 is in cit2, and apt2
is in cit2.
My goal is to have that obj12 is at pos1, obj23 is at pos1, obj11 is at apt1, obj22
is at apt1, obj13 is at pos2, and obj21 is at pos2.
```

Figure 15: Logistics Problem Description

```
;; logistics domain
;;

(define (domain logistics)
  (:requirements :strips)
  (:predicates  (package ?obj)
        (truck ?truck)
    (airplane ?airplane)
                (airport ?airport)
                  (location ?loc)
    (in-city ?obj ?city)
                (city ?city)
    (at ?obj ?loc)
    (in ?obj ?obj))


(:action load-truck
  :parameters
   (?obj
    ?truck
    ?loc)
  :precondition
   (and (package ?obj) (truck ?truck) (location ?loc)
   (at ?truck ?loc) (at ?obj ?loc))
  :effect
   (and (not (at ?obj ?loc)) (in ?obj ?truck)))

(:action load-airplane
  :parameters
   (?obj
    ?airplane
    ?loc)
  :precondition
   (and (package ?obj) (airplane ?airplane) (location ?loc)
   (at ?obj ?loc) (at ?airplane ?loc))
  :effect
   (and (not (at ?obj ?loc)) (in ?obj ?airplane)))

(:action unload-truck
  :parameters
   (?obj
    ?truck
    ?loc)
  :precondition
   (and (package ?obj) (truck ?truck) (location ?loc)
        (at ?truck ?loc) (in ?obj ?truck))
  :effect
   (and (not (in ?obj ?truck)) (at ?obj ?loc)))

(:action unload-airplane
  :parameters
   (?obj
    ?airplane
    ?loc)
  :precondition
   (and (package ?obj) (airplane ?airplane) (location ?loc)
        (in ?obj ?airplane) (at ?airplane ?loc))
  :effect
   (and (not (in ?obj ?airplane)) (at ?obj ?loc)))
```

Figure 16: Logistics Domain PDDL (Part 1)

```
; Logistics domain (continued)

(:action drive-truck
  :parameters
   (?truck
    ?loc-from
    ?loc-to
    ?city)
  :precondition
   (and (truck ?truck) (location ?loc-from) (location ?loc-to) (city ?city)
   (at ?truck ?loc-from)
   (in-city ?loc-from ?city)
   (in-city ?loc-to ?city))
  :effect
   (and (not (at ?truck ?loc-from)) (at ?truck ?loc-to)))

(:action fly-airplane
  :parameters
   (?airplane
    ?loc-from
    ?loc-to)
  :precondition
   (and (airplane ?airplane) (airport ?loc-from) (airport ?loc-to)
  (at ?airplane ?loc-from))
  :effect
   (and (not (at ?airplane ?loc-from)) (at ?airplane ?loc-to)))
)
```

Figure 17: Logistics Domain PDDL (Part 2)

```
(define (problem logistics-6-9)
(:domain logistics)
(:objects apn1 apt2 pos2 apt1 pos1 cit2 cit1 tru2 tru1 obj23 obj22 obj21 obj13
obj12 obj11 )
(:init (package obj11) (package obj12) (package obj13) (package obj21)
 (package obj22) (package obj23) (truck tru1) (truck tru2) (city cit1) (city cit2)
 (location pos1) (location apt1) (location pos2) (location apt2) (airport apt1)
 (airport apt2) (airplane apn1) (at apn1 apt2) (at tru1 pos1) (at obj11 pos1)
 (at obj12 pos1) (at obj13 pos1) (at tru2 pos2) (at obj21 pos2) (at obj22 pos2)
 (at obj23 pos2) (in-city pos1 cit1) (in-city apt1 cit1) (in-city pos2 cit2)
 (in-city apt2 cit2))
(:goal (and (at obj12 pos1) (at obj23 pos1) (at obj11 apt1) (at obj22 apt1)
            (at obj13 pos2) (at obj21 pos2)))
)
```

Figure 18: Logistics Problem PDDL

```
1. (load-truck obj11 tru1 pos1)
2. (load-truck obj13 tru1 pos1)
3. (drive-truck tru1 pos1 apt1 cit1)
4. (unload-truck obj11 tru1 apt1)
5. (unload-truck obj13 tru1 apt1)
6. (load-truck obj22 tru2 pos2)
7. (load-truck obj23 tru2 pos2)
8. (drive-truck tru2 pos2 apt2 cit2)
9. (unload-truck obj22 tru2 apt2)
10. (unload-truck obj23 tru2 apt2)
11. (load-airplane obj22 apn1 apt2)
12. (load-airplane obj23 apn1 apt2)
13. (fly-airplane apn1 apt2 apt1)
14. (unload-airplane obj22 apn1 apt1)
15. (unload-airplane obj23 apn1 apt1)
16. (load-airplane obj13 apn1 apt1)
17. (fly-airplane apn1 apt1 apt2)
18. (unload-airplane obj13 apn1 apt2)
19. (load-truck obj13 tru2 apt2)
20. (drive-truck tru2 apt2 pos2 cit2)
21. (unload-truck obj13 tru2 pos2)
22. (load-truck obj23 tru1 apt1)
23. (drive-truck tru1 apt1 pos1 cit1)
24. (unload-truck obj23 tru1 pos1)
```

Figure 19: Logistics Plan

```
I'm exploring a grid of rooms to collect items. Doors may block passage between
rooms until I open them. Here are the actions I can do:

    Move from one room to an adjacent room in a given direction
    Open a closed door between two rooms (which then allows travel both ways)
    Take (pick up) an item that's in the same room as me

I have the following restrictions on my actions:

    I can move only if there is an open connection from my current room to the
target room in the intended direction.
    If a door between two rooms is closed, I must open it before I can move through
it.
    To open a door, I must be in one of the two rooms the door connects, and I must
know both the direction I'm opening in and its reverse (e.g., east/west,
north/south).
    Opening the door removes the "closed" state and creates connections in both
directions.
    I can only take an item if I am in the same room as the item and the item
hasn't already been taken.
    Once I take an item, it is considered collected (no longer present in the room).

;; Action Heads

move  (?room1 - room ?room2 - room ?direction - direction)
open  (?room1 - room ?room2 - room ?direction - direction ?reverse - direction)
take  (?item  - item ?room  - room)
```

Figure 20: CoinCollector Domain Description

```
As initial conditions, I have that, kitchen is a room, corridor is a room, pantry
is a room, north is a direction, south is a direction, east is a direction, west is
a direction, coin is an item, I am at kitchen, there is an open connection from
kitchen to corridor going north, there is an open connection from corridor to
kitchen going south, there is a closed door from kitchen to pantry going east,
there is a closed door from pantry to kitchen going west, coin is in corridor,
direction north is reverse of south, direction south is reverse of north, direction
east is reverse of west, and direction west is reverse of east.
My goal is to have that coin is taken.
```

Figure 21: CoinCollector Problem Description

```
(define (domain coin-collector)
  (:requirements :strips :typing)
  (:types
    room
    direction
    item
  )
  (:predicates
    (at ?room - room)
    (connected ?room1 - room ?room2 - room ?direction - direction)
    (closed-door ?room1 - room ?room2 - room ?direction - direction)
    (location ?item - item ?room - room)
    (taken ?item - item)
    (is-reverse ?direction - direction ?reverse - direction)
  )

  (:action move
    :parameters (?room1 - room ?room2 - room ?direction - direction)
    :precondition (and (at ?room1) (connected ?room1 ?room2 ?direction))
    :effect (and (not (at ?room1)) (at ?room2))
  )

  (:action open
    :parameters (?room1 - room ?room2 - room ?direction - direction ?reverse -
direction)
    :precondition (and (at ?room1) (closed-door ?room1 ?room2 ?direction)
(is-reverse ?direction ?reverse))
    :effect (and (not (closed-door ?room1 ?room2 ?direction)) (not (closed-door
?room2 ?room1 ?reverse)) (connected ?room1 ?room2 ?direction) (connected ?room2
?room1 ?reverse))
  )

  (:action take
    :parameters (?item - item ?room - room)
    :precondition (and (at ?room) (location ?item ?room) (not (taken ?item)))
    :effect (and (taken ?item) (not (location ?item ?room)))
  )
)
```

Figure 22: CoinCollector Domain PDDL

```
(define (problem coin_collector_numLocations3_numDistractorItems0_seed54)
  (:domain coin-collector)
  (:objects
    kitchen corridor pantry - room
    north south east west - direction
    coin - item
  )
  (:init
    (at kitchen)
    (connected kitchen corridor north)
    (closed-door kitchen pantry east)
    (connected corridor kitchen south)
    (closed-door pantry kitchen west)
    (location coin corridor)
    (is-reverse north south)
    (is-reverse south north)
    (is-reverse east west)
    (is-reverse west east)
  )
  (:goal
    (taken coin)
  )
)
```

Figure 23: CoinCollector Problem PDDL

```
1. (move kitchen corridor north)
2. (take coin corridor)
```

Figure 24: CoinCollector Plan

```
I am playing a Sokoban puzzle where a player pushes stone crates onto goal squares.
Here are the actions I can do

   Move the player into an adjacent clear square
   Push a stone into an adjacent goal square
   Push a stone into an adjacent non-goal square

   I have the following restrictions on my actions:
   I can only move if I choose one of the four cardinal directions, I am the
player, I am at the from-square, the destination square is clear, and the two
squares are aligned with that direction.
   When I move, I leave my previous square clear and occupy the destination square.
   I can only push a stone toward a goal square if I am the player, the object is a
stone, I stand directly behind the stone in the chosen direction, the target square
is clear, that target square is marked as a goal, and both adjacency relations
match the direction of push.
   After pushing a stone toward a goal square, I advance into the stone's former
square, the stone moves into the goal square, the goal square is no longer clear,
my previous square becomes clear, and the stone is marked as being on a goal square.
   I can only push a stone toward a non-goal square if I am the player, the object
is a stone, I stand behind the stone in the direction of push, the destination
square is clear, that destination square is marked as a normal square, and the
adjacency relations match the direction of push.
   After pushing a stone toward a non-goal square, I move into the stone's former
square, the stone shifts forward, the destination square is no longer clear, and my
previous square becomes clear while the stone is marked as not being on a goal
square.

;; Action Heads
move             (?p - thing ?from - location ?to - location ?dir - direction)
push-to-goal     (?p - thing ?s - thing ?ppos - location ?from - location ?to -
location ?dir - direction)
push-to-nongoal  (?p - thing ?s - thing ?ppos - location ?from - location ?to -
location ?dir - direction)
```

Figure 25: Sokoban Domain Description

```
As initial conditions I have that, player-01 is at pos-1-1, stone-01 is at pos-1-2,
pos-1-3 is clear, pos-1-3 is a goal square, pos-1-1 is a normal square, pos-1-2 is
a normal square, player-01 is the player, stone-01 is a stone, dir-right is an
available move direction, dir-left is an available move direction, dir-up is an
available move direction, dir-down is an available move direction, moving from
pos-1-1 to pos-1-2 uses dir-right, moving from pos-1-2 to pos-1-1 uses dir-left,
moving from pos-1-2 to pos-1-3 uses dir-right, and moving from pos-1-3 to pos-1-2
uses dir-left.
My goal is to have that stone-01 is at a goal square.
```

Figure 26: Sokoban Problem Description

```
(define (domain sokoban)
  (:requirements :typing )
  (:types thing location direction)
  (:predicates (move-dir ?v0 - location ?v1 - location ?v2 - direction)
  (is-nongoal ?v0 - location)
  (clear ?v0 - location)
  (is-stone ?v0 - thing)
  (at ?v0 - thing ?v1 - location)
  (is-player ?v0 - thing)
  (at-goal ?v0 - thing)
  (move ?v0 - direction)
  (is-goal ?v0 - location)
  )

  ; (:actions move)



  (:action move
    :parameters (?p - thing ?from - location ?to - location ?dir - direction)
    :precondition (and (move ?dir)
      (is-player ?p)
      (at ?p ?from)
      (clear ?to)
      (move-dir ?from ?to ?dir))
    :effect (and
      (not (at ?p ?from))
      (not (clear ?to))
      (at ?p ?to)
      (clear ?from))
  )
```

Figure 27: Sokoban Domain PDDL (Part 1)

```
; Sokoban domain (continued)

  (:action push-to-goal
    :parameters (?p - thing ?s - thing ?ppos - location ?from - location ?to -
location ?dir - direction)
    :precondition (and (move ?dir)
      (is-player ?p)
      (is-stone ?s)
      (at ?p ?ppos)
      (at ?s ?from)
      (clear ?to)
      (move-dir ?ppos ?from ?dir)
      (move-dir ?from ?to ?dir)
      (is-goal ?to))
    :effect (and
      (not (at ?p ?ppos))
      (not (at ?s ?from))
      (not (clear ?to))
      (at ?p ?from)
      (at ?s ?to)
      (clear ?ppos)
      (at-goal ?s))
  )


  (:action push-to-nongoal
    :parameters (?p - thing ?s - thing ?ppos - location ?from - location ?to -
location ?dir - direction)
    :precondition (and (move ?dir)
      (is-player ?p)
      (is-stone ?s)
      (at ?p ?ppos)
      (at ?s ?from)
      (clear ?to)
      (move-dir ?ppos ?from ?dir)
      (move-dir ?from ?to ?dir)
      (is-nongoal ?to))
    :effect (and
      (not (at ?p ?ppos))
      (not (at ?s ?from))
      (not (clear ?to))
      (at ?p ?from)
      (at ?s ?to)
      (clear ?ppos)
      (not (at-goal ?s)))
  )

)
```

Figure 28: Sokoban Domain PDDL (Part 2)

```
(define (problem sokoban-small)
  (:domain sokoban)
  (:objects
    dir-down - direction
    dir-left - direction
    dir-right - direction
    dir-up - direction
    player-01 - thing
    stone-01 - thing
    pos-1-1 - location
    pos-1-2 - location
    pos-1-3 - location
  )
  (:goal (and (at-goal stone-01)))
  (:init
    (at player-01 pos-1-1)
    (at stone-01 pos-1-2)
    (clear pos-1-3)
    (is-goal pos-1-3)
    (is-nongoal pos-1-1)
    (is-nongoal pos-1-2)
    (move dir-down)
    (move dir-left)
    (move dir-right)
    (move dir-up)
    (is-player player-01)
    (is-stone stone-01)
    (move-dir pos-1-1 pos-1-2 dir-right)
    (move-dir pos-1-2 pos-1-1 dir-left)
    (move-dir pos-1-2 pos-1-3 dir-right)
    (move-dir pos-1-3 pos-1-2 dir-left)
  )
)
```

Figure 29: Sokoban Problem PDDL

```
1. (push-to-goal player-01 stone-01 pos-1-1 pos-1-2 pos-1-3 dir-right)
```

Figure 30: Sokoban Plan

```
Domain Specification BlockStacking
Overview: Arrange blocks into stacks using actions that pick up, unstack, put down,
or stack blocks, adhering to constraints on hand state and block clarity.

Entity Types:
- block: Represents individual blocks that can be manipulated.

Predicates:
- HandEmpty: True when no block is being held.
- Holding(b: block): True when block b is in the hand.
- Clear(b: block): True when block b has no blocks on top of it and is not being
held.
- OnTable(b: block): True when block b is directly on the table.
- On(b: block, under: block): True when block b is immediately on top of block
under.

Actions:
Action: Pickup
Intent: Lift a single block from the table into the hand.
Parameters: b (block)
Preconditions:
- Positive: Clear(b), OnTable(b), HandEmpty
- Negative: None
Effects:
- Add: Holding(b)
- Delete: HandEmpty, OnTable(b), Clear(b)
- Conditional: None

Action: Unstack
Intent: Remove a block from on top of another block and hold it.
Parameters: b (block), under (block)
Preconditions:
- Positive: Clear(b), On(b, under), HandEmpty
- Negative: None
Effects:
- Add: Holding(b), Clear(under)
- Delete: On(b, under), HandEmpty, Clear(b)
- Conditional: None

Action: Putdown
Intent: Place a held block onto the table.
Parameters: b (block)
Preconditions:
- Positive: Holding(b)
- Negative: None
Effects:
- Add: OnTable(b), Clear(b), HandEmpty
- Delete: Holding(b)
- Conditional: None

Action: Stack
Intent: Place a held block onto another block.
Parameters: b (block), under (block)
Preconditions:
- Positive: Holding(b), Clear(under)
- Negative: None
Effects:
- Add: On(b, under), Clear(b), HandEmpty
- Delete: Holding(b), Clear(under)
- Conditional: None
```

Figure 31: NL-PDDL IR from the NL→PDDL pipeline.

```
Problem Specification BlockArrangement
Context: Rearrange the blocks from their initial configuration to a specified goal
state involving multiple stacks and table placements.

Objects:
- block: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Initial State:
- Clear(1) holds
- Clear(2) holds
- Clear(3) holds
- Clear(8) holds
- Clear(9) holds
- Clear(10) holds
- HandEmpty holds
- OnTable(1) holds
- OnTable(2) holds
- OnTable(4) holds
- OnTable(6) holds
- OnTable(8) holds
- OnTable(11) holds
- On(3, 6) holds
- On(5, 4) holds
- On(7, 11) holds
- On(9, 5) holds
- On(10, 7) holds
- Note: Blocks not explicitly listed as On or OnTable (e.g., block 5) are not on
the table unless stated. For example, OnTable(5) is false because it is on block 4.

Goal Conditions:
- On(1, 8) must hold
- On(2, 4) must hold
- On(6, 1) must hold
- On(9, 6) must hold
- OnTable(3) must hold
- OnTable(4) must hold
- OnTable(5) must hold
- OnTable(7) must hold
- OnTable(8) must hold
- OnTable(10) must hold
- OnTable(11) must hold
```

Figure 32: NL-PDDL IR from the NL→PDDL pipeline.

```python
from dataclasses import dataclass, field
from typing import Dict, Set, Optional, Union, Tuple, List, Iterable, frozenset

@dataclass(frozen=True)
class State:
    on: Dict[int, Union[str, int]]  # block -> 'table', another block, or 'held'
    clear: frozenset[int]  # blocks that are clear (no blocks on top and not held)
    held: Optional[int]  # the block being held, or None

class Action:
    def __init__(self, name: str, params: Tuple):
        self.name = name
        self.params = params

    def is_applicable(self, state: State) -> bool:
        raise NotImplementedError

    def apply(self, state: State) -> State:
        raise NotImplementedError

class PickupAction(Action):
    def __init__(self, block: int):
        super().__init__("pickup", (block,))
        self.block = block

    def is_applicable(self, state: State) -> bool:
        b = self.block
        return (state.on[b] == 'table' and
                b in state.clear and
                state.held is None)

    def apply(self, state: State) -> State:
        new_on = state.on.copy()
        new_on[self.block] = 'held'

        new_clear = set(state.clear)
        new_clear.remove(self.block)
        new_clear = frozenset(new_clear)

        new_held = self.block

        return State(new_on, new_clear, new_held)

class UnstackAction(Action):
    def __init__(self, block: int, under: int):
        super().__init__("unstack", (block, under))
        self.block = block
        self.under = under

    def is_applicable(self, state: State) -> bool:
        return (state.on[self.block] == self.under and
                self.block in state.clear and
                state.held is None)

    def apply(self, state: State) -> State:
        new_on = state.on.copy()
        new_on[self.block] = 'held'

        new_clear = set(state.clear)
        new_clear.remove(self.block)
```

Figure 33: PythonSim IR from the PythonSim→PDDL pipeline (Part 1 of 3).

```
        new_clear.add(self.under)
        new_clear = frozenset(new_clear)

        new_held = self.block

        return State(new_on, new_clear, new_held)

class PutdownAction(Action):
    def __init__(self, block: int):
        super().__init__("putdown", (block,))
        self.block = block

    def is_applicable(self, state: State) -> bool:
        return state.held == self.block

    def apply(self, state: State) -> State:
        new_on = state.on.copy()
        new_on[self.block] = 'table'

        new_clear = set(state.clear)
        new_clear.add(self.block)
        new_clear = frozenset(new_clear)

        new_held = None

        return State(new_on, new_clear, new_held)

class StackAction(Action):
    def __init__(self, block: int, under: int):
        super().__init__("stack", (block, under))
        self.block = block
        self.under = under

    def is_applicable(self, state: State) -> bool:
        return (state.held == self.block and
                self.under in state.clear and
                self.block != self.under)

    def apply(self, state: State) -> State:
        new_on = state.on.copy()
        new_on[self.block] = self.under

        new_clear = set(state.clear)
        new_clear.remove(self.under)
        new_clear.add(self.block)
        new_clear = frozenset(new_clear)

        new_held = None

        return State(new_on, new_clear, new_held)

def available_actions(state: State) -> Iterable[Action]:
    actions = []

    # Pickup
    for b in state.on:
        if state.on[b] == 'table' and b in state.clear and state.held is None:
            actions.append(PickupAction(b))

    # Unstack
```

Figure 34: PythonSim IR from the PythonSim→PDDL pipeline (Part 2 of 3).

```
    for b in state.on:
        if state.on[b] not in ('table', 'held'):
            under = state.on[b]
            if b in state.clear and state.held is None:
                actions.append(UnstackAction(b, under))

    # Putdown
    if state.held is not None:
        actions.append(PutdownAction(state.held))

    # Stack
    if state.held is not None:
        b = state.held
        for under in state.clear:
            if under != b:
                actions.append(StackAction(b, under))

    return actions

def execute(action: Action, state: State) -> State:
    return action.apply(state)
```

Figure 35: PythonSim IR from the PythonSim→PDDL pipeline (Part 3 of 3).

```
from typing import List, Tuple

def initial_state() -> State:
    on = {
        1: 'table',
        2: 'table',
        3: 6,
        4: 'table',
        5: 4,
        6: 'table',
        7: 11,
        8: 'table',
        9: 5,
        10: 7,
        11: 'table'
    }
    clear = frozenset({1, 2, 3, 8, 9, 10})
    held = None
    return State(on, clear, held)

def is_goal(state: State) -> bool:
    return (state.held is None and
            state.on[1] == 8 and
            state.on[2] == 4 and
            state.on[6] == 1 and
            state.on[9] == 6 and
            state.on[3] == 'table' and
            state.on[4] == 'table' and
            state.on[5] == 'table' and
            state.on[7] == 'table' and
            state.on[8] == 'table' and
            state.on[10] == 'table' and
            state.on[11] == 'table')

def solve(limit: int = 1024) -> List[Action]:
    from collections import deque

    frontier = deque()
    frontier.append((initial_state(), []))
    visited = set()

    while frontier and len(frontier) < limit:
        state, plan = frontier.popleft()
        if is_goal(state):
            return plan
        if state in visited:
            continue
        visited.add(state)
        for action in available_actions(state):
            next_state = execute(action, state)
            frontier.append((next_state, plan + [action]))
    return []
```

Figure 36: PythonSim IR from the PythonSim→PDDL pipeline.

```
from py2pddl import Domain, create_type
from py2pddl import predicate, action

class BlocksWorldDomain(Domain):
    Block = create_type("block")

    @predicate(Block)
    def clear(self, b):
        """Block is clear (no blocks on top and not held)"""

    @predicate(Block, Block)
    def on(self, b, under):
        """Block b is on top of block under"""

    @predicate(Block)
    def on_table(self, b):
        """Block is on the table"""

    @predicate(Block)
    def holding(self, b):
        """Block is being held"""

    @predicate()
    def hand_empty(self):
        """Hand is empty"""

    @action(Block)
    def pickup(self, b):
        precond = [
            self.hand_empty(),
            self.clear(b),
            self.on_table(b)
        ]
        effect = [
            ~self.hand_empty(),
            self.holding(b),
            ~self.on_table(b),
            ~self.clear(b)
        ]
        return precond, effect

    @action(Block, Block)
    def unstack(self, b, under):
        precond = [
            self.hand_empty(),
            self.clear(b),
            self.on(b, under)
        ]
        effect = [
            ~self.hand_empty(),
            self.holding(b),
            ~self.on(b, under),
            ~self.clear(b),
            self.clear(under)
        ]
        return precond, effect

    @action(Block)
    def putdown(self, b):
        precond = [
```

Figure 37: PyPDDL IR from the PyPDDL→PDDL pipeline (Part 1 of 2).

```
            self.holding(b)
        ]
        effect = [
            ~self.holding(b),
            self.hand_empty(),
            self.on_table(b),
            self.clear(b)
        ]
        return precond, effect

    @action(Block, Block)
    def stack(self, b, under):
        precond = [
            self.holding(b),
            self.clear(under)
        ]
        effect = [
            ~self.holding(b),
            self.hand_empty(),
            self.on(b, under),
            ~self.clear(under),
            self.clear(b),
            ~self.on_table(b)
        ]
        return precond, effect
```

Figure 38: PyPDDL IR from the PyPDDL→PDDL pipeline (Part 2 of 2).

```
from py2pddl import init, goal

class BlocksWorldProblem(BlocksWorldDomain):
    def __init__(self):
        super().__init__()
        self.blocks = self.Block.create_objs(range(1, 12), prefix="block")

    @init
    def init(self):
        clear = [
            self.clear(self.blocks[0]),  # block1
            self.clear(self.blocks[1]),  # block2
            self.clear(self.blocks[2]),  # block3
            self.clear(self.blocks[7]),  # block8
            self.clear(self.blocks[8]),  # block9
            self.clear(self.blocks[9]),  # block10
        ]

        hand_empty = [self.hand_empty()]

        on_relations = [
            self.on(self.blocks[2], self.blocks[5]),  # block3 on block6
            self.on(self.blocks[4], self.blocks[3]),  # block5 on block4
            self.on(self.blocks[6], self.blocks[10]), # block7 on block11
            self.on(self.blocks[8], self.blocks[4]),  # block9 on block5
            self.on(self.blocks[9], self.blocks[6]),  # block10 on block7
        ]

        on_table = [
            self.on_table(self.blocks[0]),  # block1
            self.on_table(self.blocks[1]),  # block2
            self.on_table(self.blocks[3]),  # block4
            self.on_table(self.blocks[5]),  # block6
            self.on_table(self.blocks[7]),  # block8
            self.on_table(self.blocks[10]), # block11
        ]

        return clear + hand_empty + on_relations + on_table

    @goal
    def goal(self):
        goals = [
            self.on(self.blocks[0], self.blocks[7]),  # block1 on block8
            self.on(self.blocks[1], self.blocks[3]),  # block2 on block4
            self.on(self.blocks[5], self.blocks[0]),  # block6 on block1
            self.on(self.blocks[8], self.blocks[5]),  # block9 on block6
            self.on_table(self.blocks[2]),            # block3 on table
            self.on_table(self.blocks[3]),            # block4 on table
            self.on_table(self.blocks[4]),            # block5 on table
            self.on_table(self.blocks[6]),            # block7 on table
            self.on_table(self.blocks[7]),            # block8 on table
            self.on_table(self.blocks[9]),            # block10 on table
            self.on_table(self.blocks[10]),           # block11 on table
        ]
        return goals
```

Figure 39: PyPDDL IR from the PyPDDL→PDDL pipeline.

```
(define
  (domain blocks-world)
  (:requirements :strips :typing)
  (:types block)
  (:predicates
    (clear ?b - block)
    (on ?b - block ?x - block)
    (ontable ?b - block)
    (holding ?b - block)
    (handempty)
  )
  (:action pickup
    :parameters (?b - block)
    :precondition (and (clear ?b) (ontable ?b) (handempty))
    :effect (and (holding ?b) (not (clear ?b)) (not (handempty)) (not (ontable ?b)))
  )
  (:action unstack
    :parameters (?b ?under - block)
    :precondition (and (clear ?b) (on ?b ?under) (handempty))
    :effect (and (holding ?b) (clear ?under) (not (on ?b ?under)) (not (handempty))
(not (clear ?b)))
  )
  (:action putdown
    :parameters (?b - block)
    :precondition (holding ?b)
    :effect (and (ontable ?b) (handempty) (clear ?b) (not (holding ?b)))
  )
  (:action stack
    :parameters (?b ?under - block)
    :precondition (and (holding ?b) (clear ?under))
    :effect (and (on ?b ?under) (handempty) (not (clear ?under)) (not (holding ?b))
(not (ontable ?b)))
  )
)
```

Figure 40: PDDL IR from the PDDL→PDDL pipeline.

```
(define
  (problem block_problem)
  (:domain blocks-world)
  (:objects block1 block2 block3 block4 block5 block6 block7 block8 block9 block10
block11 - block)
  (:init
    (clear block1) (clear block2) (clear block3) (clear block8) (clear block9)
(clear block10)
    (on block3 block6) (on block5 block4) (on block7 block11) (on block9 block5)
(on block10 block7)
    (ontable block1) (ontable block2) (ontable block4) (ontable block6) (ontable
block8) (ontable block11)
    (handempty)
  )
  (:goal
    (and
      (on block1 block8) (on block2 block4) (on block6 block1) (on block9 block6)
      (ontable block3) (ontable block4) (ontable block5) (ontable block7) (ontable
block8) (ontable block10) (ontable block11)
    )
  )
)
```

Figure 41: PDDL IR from the PDDL→PDDL pipeline.

```
You are an expert automated planner. Your task is to read a natural-language domain description and a
corresponding problem description, reason through the objects, actions, and goals, and output a valid plan.

Recall the distinctions:
- The **domain description** explains the general world: available action schemas, predicates, and object
types.
- The **problem description** gives the concrete instance: specific objects, the initial state, and the
goals for this planning episode.

Planning output requirements:
- Think aloud inside <think>...</think> to lay out objects, preconditions, effects, and progress toward the
goals.
- Produce the final plan inside <plan>...</plan>. Each action must be on its own line in classical PDDL
plan syntax, e.g. `(move robot1 roomA roomB)`.
- Maintain the execution order from top to bottom. Do not include step numbers, timestamps, or
probabilities.
- Only emit actions that are applicable given the initial state and that eventually achieve the goals.
- After the closing </plan> tag, do not add extra commentary.

Example format (replace names with the task-specific details):
<think>
... reasoning about applicable actions ...
</think>
<plan>
(pick-up block1 hand)
(stack block1 block2)
(move robot room1 room2)
</plan>

Follow this template for every problem. EOF
```

Figure 42: Base instruction `plan_instruction`.

```
PDDL domain file contains domain name, requirements, types of objects in the domain, predicates, and
actions.
Based on the natural language domain description, identify the actions that are possible.
Identify action sematics i.e. understand the preconditions under which that action could be done and the
effects of the action.
Then identify appropriate predicates that could enable action semantics i.e. preconditions and effects.
PDDL domain file has a definitive syntax that must be followed for any domain. An abstract example PDDL
domain file is given below:

<domain_file>
(define
  (domain domain_name)
  (:requirements :strips :typing)
  (:types
    type1
    type2
  )
  (:predicates
    (predicate1 ?arg1 - type1 ?arg2 - type2)
    (predicate2 ?arg1 - type1 ?arg2 - type2)
  )
  (:action action1
    :parameters (?arg1 - type1 ?arg2 - type2 ?arg3 - type2)
    :precondition (predicate1 ?arg1 ?arg2)
    :effect (and (predicate1 ?arg1 ?arg2) (predicate2 ?arg1 ?arg3))
  )
  (:action action2
    :parameters (?arg1 - type1 ?arg2 - type2 ?arg3 - type2)
    :precondition (and (predicate1 ?arg1 ?arg2) (predicate2 ?arg1 ?arg3))
    :effect (predicate2 ?arg1 ?arg3)
  )
)
</domain_file>

Notes for generating domain file:
- type1 & type2 are only representative and should be replaced with appropriate types. There could be any
number of types.
- predicate1 & predicate2 are only representative and should be replaced with appropriate predicates. There
could be any number of predicates.
- action1 & action2 are only representative and should be replaced with appropriate actions. There could be
any number of actions.
- arg1 & arg2 are only representative and should be replaced with appropriate arguments for predicates and
in preconditions and effects.
- predicates with proper arguments could be combined to combine complex boolean expression to represent
predicondition and effect
The braces should be balanced for each section of the PDDL program
- Use predicates with arguments of the right type as declared in domain file
- All the arguments to any :precondition or :effect of an action should be declared in :parameters as input
arguments


PDDL problem file contains problem name, domain name, objects in this problem instance, init state of
objects, and goal state of objects.
Based on the natural language problem description, identify the relevant objects for this problems with
their names and types.
Represent the initial state with the appropriate predicates and object arguments. Represent the goal state
with the appropriate predicates and object arguments.
PDDL problem file has a definitive syntax that must be followed for any problem. An abstract example PDDL
problem file is given below.

<problem_file>
(define
  (problem problem_name)
  (:domain domain_name)
  (:objects
    obj1 obj2 - type1
    obj3, obj4 - type2
  )
  (:init (predicate1 obj1 obj3) (predicate2 obj2 obj3))
  (:goal (and (predicate1 obj1 obj4) (predicate2 obj2 obj3)))
)
</problem_file>

Notes for generating problem file:
- obj1, obj2, ... are only representative and should be replaced with appropriate objects. There could be
any number of obects with their types.
- init state with predicate1 & predicate2 is only representative and should be replaced with appropriate
predicates that define init state
- goal state with predicate1 & predicate2 is only representative and should be replaced with appropriate
predicates that define goal state
- predicates with proper arguments could be combined to combine complex boolean expression to represent
init and goal states
- The braces should be balanced for each section of the PDDL program
- Use predicates with arguments of the right type as declared in domain file
- All the objects that would be arguments of predicates in init and goal states should be declared in
:objects
```

Figure 43: Base instruction `only_pddl_instruction`.

```
Natural language planning specifications serve as a blueprint for generating the exact PDDL domain and
problem files. Write in clear prose, but ensure every detail required for a faithful PDDL reconstruction is
present and testable.

Overall guidance:
- Organize the specification with labeled sections so the structure is obvious without PDDL syntax.
- Use precise terminology and consistent naming; anything omitted here cannot appear in the final PDDL.
- State facts, conditions, and effects explicitly. Avoid implication, ambiguity, or narrative fluff.

Domain description must include:
- Domain title and a one-sentence overview of the scenario.
- Complete list of entity types, subtyping relations when relevant, and the role each type plays.
- Exhaustive catalog of predicates. For each predicate, name every parameter, state its type, and clarify
exactly what the predicate means when true.
- Exhaustive catalog of actions. For each action, provide:
  * Action title and concise intent.
  * Parameter list with names and types, including any constraints or distinctness requirements.
  * Preconditions broken out as positive conditions (facts that must hold) and negative conditions (facts
that must not hold), both referencing the predicates above.
  * Effects split into add effects (facts that become true) and delete effects (facts that cease to hold).
Mention conditional effects separately if they exist.
  * Any invariants or notes needed to enforce the same logical behavior as PDDL.

Problem description must include:
- Problem title and one-sentence context linking it to the domain.
- Exhaustive list of objects, grouped by type, using the exact type names from the domain section.
- Initial state described as bullet points or sentences, each mapping directly to a predicate instance that
should hold initially. Include explicit mention of facts that are false if the domain relies on them.
- Goal conditions stated explicitly, each tied to predicate instances. Distinguish between conjunctive and
disjunctive goals if applicable.

Formatting conventions:
- Stick to full sentences or crisp bullet points-no raw PDDL, no code blocks, no decorative markup.
- Maintain consistent vocabulary between domain and problem sections so predicates, actions, and objects
align exactly.
- If numeric fluents, temporal elements, or other advanced PDDL features are present, describe their roles,
bounds, and update rules explicitly.
- The specification must be sufficient for a separate model to regenerate the original PDDL without
guessing.

Abstract example (replace placeholders with the concrete content for the task at hand):
Domain Specification - DomainName
Overview: A single sentence summarizing the planning scenario.
Entity Types:
- Type1: Explanation of entities of this type and any subtype relationships.
- Type2: Explanation of entities of this type.
Predicates:
- predicate1(entity1: Type1, entity2: Type2): Meaning of the fact when true.
- predicate2(entity: Type2): Meaning of the fact when true.
Actions:
Action: Action1
Intent: Brief purpose of the action.
Parameters: entity1: Type1, entity2: Type2 (include distinctness constraints if required).
Preconditions:
- Positive: predicate1(entity1, entity2) must hold.
- Negative: predicate2(entity2) must not hold.
Effects:
- Add: predicate2(entity2) becomes true.
- Delete: predicate1(entity1, entity2) ceases to hold.
- Conditional: Describe any conditional effects explicitly, including their triggering conditions.
Action: Action2
Intent: Another representative action with its parameters, preconditions, and effects fully spelled out.

Problem Specification - ProblemName
Context: One sentence linking the problem to the domain.
Objects:
- Type1: obj1, obj2 (brief descriptions optional).
- Type2: obj3, obj4.
Initial State:
- predicate1(obj1, obj3) holds because ...
- predicate2(obj4) is false (state explicitly if the domain depends on this).
Goal Conditions:
- Conjunctive goal requiring predicate2(obj3) and predicate2(obj4) to hold.
- Note disjunctions or temporal ordering if the problem includes them.
```

Figure 44: Base instruction `nl_instruction`.

```
{{plan_instruction}}

### Domain description
{{domain_description}}

### Problem description
{{problem_description}}
Generate the plan for this instance following the required format.
```

Figure 45: Prompt template for `plan_gen` plan generation.

```
{{only_pddl_instruction}}

You are an expert PDDL engineer.
Create syntactically correct and mutually consistent domain and problem files using the information below.

### Original domain description
{{domain_description}}

### Original problem description
{{problem_description}}

Wrap only the final domain PDDL in <domain_file>...</domain_file> and the final problem PDDL in
<problem_file>...</problem_file>.
```

Figure 46: Prompt template for `pddl`.

```
{{nl_instruction}}

Use the following natural-language descriptions to craft a complete planning specification in prose. Follow
the layout described above.

### Original domain description
{{domain_description}}

### Original problem description
{{problem_description}}

Wrap the final structured prose in <nl_summary>...</nl_summary>. Begin your reasoning with <think> so we
can inspect the chain of thought.
Do not emit any PDDL or code yet.
```

Figure 47: Stage-one prompt for `nl_pddl`.

```
{{only_pddl_instruction}}

You are an expert PDDL engineer.
Leverage the structured natural-language planning specification, along with the original descriptions, to
produce consistent domain and problem files. Always ground your final answer in the original domain and
problem descriptions shown below.

### Original domain description
{{domain_description}}

### Original problem description
{{problem_description}}

### Natural-language planning specification
{{nl_summary}}

Output syntactically correct PDDL. Wrap only the domain file in <domain_file>...</domain_file> and the
problem file in <problem_file>...</problem_file>.
```

Figure 48: Stage-two prompt for `nl_pddl`.

```
{{python_sim_instruction}}

### Domain description
{{domain_description}}

### Problem description
{{problem_description}}

Synthesise the Python planning simulator. Wrap the reusable domain code in <domain_file>...</domain_file>
and the problem-specific code in <problem_file>...</problem_file>.
```

Figure 49: Stage-one prompt for pythonsim_pddl.

```
{{only_pddl_instruction}}

You are an expert PDDL engineer. Using the natural-language descriptions and the Python simulator below,
produce syntactically correct and mutually consistent domain/problem PDDL files. Your answer must stay
aligned with the original domain and problem descriptions referenced above.

### Original domain description
{{domain_description}}

### Original problem description
{{problem_description}}

### Python simulator \- domain module
```python
{{python_domain_module}}
```

Python simulator \- problem module
```python
{{python_problem_module}}
```

Wrap only the final domain PDDL in <domain_file>...</domain_file> and the final problem PDDL in
<problem_file>...</problem_file>.
```

Figure 50: Stage-two prompt for pythonsim_pddl.

```
{{pypddl_instruction}}

### Domain description
{{domain_description}}

### Problem description
{{problem_description}}

Write the PyPDDL domain and problem classes. Wrap the domain in <domain_file>...</domain_file> and the
problem in <problem_file>...</problem_file>.
```

Figure 51: Stage-one prompt for pypddl_pddl.

```
{{only_pddl_instruction}}

You are an expert PDDL engineer. Using the natural-language descriptions and the PyPDDL program below,
produce syntactically correct, mutually consistent domain and problem PDDL files. Keep the original
descriptions in mind throughout your answer.

### Original domain description
{{domain_description}}

### Original problem description
{{problem_description}}

### PyPDDL domain class
```python
{{pypddl_domain_code}}
```

PyPDDL problem class
```python
{{pypddl_problem_code}}
```

Wrap only the final domain PDDL in <domain_file>...</domain_file> and the final problem PDDL in
<problem_file>...</problem_file>.
```

Figure 52: Stage-two prompt for pypddl_pddl.

```
{{pddl_instruction}}

Domain description:
{{domain_description}}

Problem description:
{{problem_description}}
Write the domain and problem files in minimal PDDL.

Wrap the domain inside <domain_file>...</domain_file> and the problem inside
<problem_file>...</problem_file>.
```

Figure 53: Stage-one prompt for pddl_pddl.

```
{{pddl_instruction}}

Domain description:
{{domain_description}}

Problem description:
{{problem_description}}
Write the domain and problem files in minimal PDDL.

To aid the revision, the original natural-language descriptions are repeated above.
------ Previous attempt start ------
[DOMAIN FILE]
{{stage1_domain_file}}

[PROBLEM FILE]
{{stage1_problem_file}}
------ Previous attempt end --------

Feedback from the planning solver:
{{stage1_solver_feedback}}

Revise the domain and problem to fix the issues. Output only the new domain wrapped in
<domain_file>...</domain_file> and the new problem wrapped in <problem_file>...</problem_file>.
```

Figure 54: Stage-two prompt for pddl_pddl.

```
{{pddl_instruction}}

Domain description:
{{domain_description}}

Problem description:
{{problem_description}}
Write the domain and problem files in minimal PDDL.

Wrap the domain inside <domain_file>...</domain_file> and the problem inside
<problem_file>...</problem_file>.
```

Figure 55: Stage-one prompt for pddl_pddl_pddl.

```
{{pddl_instruction}}

Domain description:
{{domain_description}}

Problem description:
{{problem_description}}
Write the domain and problem files in minimal PDDL.

To aid the revision, the original natural-language descriptions are repeated above.
------ Previous attempt start ------
[DOMAIN FILE]
{{stage1_domain_file}}

[PROBLEM FILE]
{{stage1_problem_file}}
------ Previous attempt end --------

Solver feedback:
{{stage1_solver_feedback}}

Revise the domain and problem to fix the issues. Output only the new domain wrapped in
<domain_file>...</domain_file> and the new problem wrapped in <problem_file>...</problem_file>.
```

Figure 56: Stage-two prompt for pddl_pddl_pddl.

````
{{pddl_instruction}}

Domain description:
{{domain_description}}

Problem description:
{{problem_description}}
Write the domain and problem files in minimal PDDL.

Review the latest PDDL below together with the solver feedback and produce a final corrected version.

### Previous domain.pddl
```pddl
{{stage2_domain_file}}
```

### Previous problem.pddl
```pddl
{{stage2_problem_file}}
```

### Solver feedback
{{stage2_solver_feedback}}

Wrap the refined domain in <domain_file>...</domain_file> and the refined problem in
<problem_file>...</problem_file>.
````

Figure 57: Stage-three prompt for `pddl_pddl_pddl`.