RLMEval: Evaluating Autoformalization on Research-Level Mathematics

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Abstract

Autoformalization, the automatic translation of unconstrained natural language into formal languages for proof assistants, has garnered significant attention due to its potential applications in theorem proving, formal verification, and LLM output checking. In this work, we present RLMEval, a framework to evaluate statement autoformalization methods on research-level mathematics.

Introduction Autoformalization is the task of automatically translating mathematical content from natural language into a formal language suitable for proof assistants. This capability promises to bridge human mathematical reasoning and machine-verifiable proofs, enabling large corpora of informal mathematics to be leveraged in formal systems. Recent advances in large language models (LLMs) have sparked interest in using LLMs for autoformalization. To measure progress, several benchmarks have been proposed such as MiniF2F [13] or ProofNet [3]. However, these benchmarks focus on competition-style or undergraduate-level problems and fail to test models on research-level content. This work presents RLMEval, a benchmark introduced in [10] and specifically designed to evaluate statement autoformalization methods on advanced mathematics formalized in Lean 4.

Benchmark Overview The core idea of RLMEval is to leverage existing Lean blueprint [7] projects, which align natural language mathematics with their formalized counterparts. These projects provide a high-quality source of parallel informal and formal statements. They are authored by domain experts and target advanced results, ensuring that both the informal input and formalization are precise and representative of real-world mathematical practice. We curated RLM25 using 6 projects we list in Table 1. To construct RLM25, we perform three steps: (1) we use plasTeX [1] to extract natural language statements from blueprint latex files along with the Lean labels, (2) we then use LeanDojo [11] to extract formal statements along with their context from the Lean files, and finally, (3) we align the natural language statements with their formal counterparts using the Lean labels in the latex files. The resulting dataset contains 619 aligned informal-formal pairs.

Evaluation Methodology Evaluating an autoformalization system on RLMEval involves checking both the correctness and faithfulness of generated formal statements. Given an informal statement, a model is expected to produce a Lean 4 statement that (a) is well-formed and type-checks in Lean, and (b) precisely captures the meaning of the original informal statement. Criterion (a) can be automatically verified by Lean's type checker. Criterion (b), semantic faithfulness, is more subtle: a statement can type-check but not correspond to the intended theorem. Currently, the most reliable evaluation for autoformalization is a manual evaluation by persons with sufficient understanding of the formal proof assistant and its library. This manual evaluation effort is an important bottleneck that limits the number of experiments that can be run. To approximate human judgment more efficiently, we introduced BEq+ in [10], a deterministic metric based on symbolic equivalence. BEq+ uses a combination of Lean

Project Name	# Theorems	Lean Version	First Commit
Carleson	111	4.14.0-rc2	20 Oct 2023
FLT	56	4.14.0-rc2	19 Nov 2023
FLT3	84	4.7.0-rc2	22 Mar 2024
PFR	145	4.14.0-rc3	13 Nov 2023
PrimeNumberTheoremAnd	99	4.14.0-rc2	9 Jan 2024
testing-lower-bounds	124	4.13.0-rc3	22 Feb 2024

Table 1: Lean 4 blueprint projects used in the RLMEval benchmark (RLM25). Each project formalizes advanced mathematical results and was first committed after the training data cutoff of current LLMs.

tactics to assess whether the predicted statement is semantically equivalent to the reference formalization, and has shown a high correlation with human evaluation.

For compatibility across projects using different Lean versions, we use LeanInteract [9], which backports the Lean REPL [2] across all versions from v4.7.0-rc1 to v4.19.0. It simplifies infrastructure for multi-version benchmarks like RLM25.

Results We evaluated four models: domain-specific Llemma-7B & 34B models [4], and general-purpose Llama3-8B-Instruct [5] and GPT-4o [8] models. To alleviate data contamination concerns, Table 1 includes the first commit date of each project[1], which come after the announced knowledge cut-off date of the models we use in this work: October 2023 for GPT-4o, March 2023 for LLama3 8B, and August 2023 as the release date of Llemma models.

Model	Training	Type-Check	BEq+
Llama3 8B	-	37.19	20.29
	MMA	41.73	19.24
Llemma 7B	-	55.96	24.16
	MMA	51.63	22.63
	Lean Workbook	53.89	23.55
Llemma 34B	-	**59.37**	**30.33**
GPT-4o	-	51.37	24.56

Table 2: Performance on RLM25 with in-file context prompting. Scores are reported as percentages for type-check success and BEq+ equivalence.

Providing in-file context, giving models access to relevant local definitions and hypotheses, improves performance across all models. As shown in Table 2, fine-tuning on existing autoformalization datasets, MMA [6] and Lean Workbook [12], yields no significant improvements over base models. Despite some progress, models still struggle to generate well-typed and semantically accurate statements, achieving at best a 59.37% type-check rate and 30.33% BEq+ score. These findings underscore the limitations of current methods and highlight the need for training datasets that better capture the contextual and semantic complexity of research-level mathematics. RLMEval provides a challenging and extensible testbed to drive progress on the next generation of autoformalization systems.

[1]The authors of the projects confirmed that the first commit dates correspond to the first public appearance of these projects.

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