

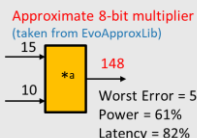
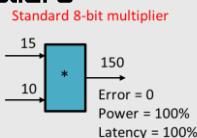
MOTIVATION

Approximate circuits trade a small loss in accuracy for reductions in power, area, or latency. Designing them is a challenging multi-objective optimization problem: manual design does not scale, while CGP (the current state-of-the-art automated approach) is computationally expensive and has already driven the approximate circuits in reference libraries such as EvoApproxLib close to their design limits. LLM-based approaches are not sufficiently explored.

Approximate multipliers

An approximate multiplier is a combinational digital circuit which performs arithmetic operation multiplication inexactly.

It trades accuracy for lower power consumption, reduced latency, or smaller chip area. It can be used in error-resilient applications, such as deep neural networks.



Experiments

Comparison of 7B models

- Falcon3-7B-Instruct
- Qwen2.5-Math-7B
- Qwen2.5-Coder-7B-Instruct
- OpenReasoning-Nemotron-7B

Experiments with various number of examples in a prompt

Qwen2.5-Coder-7B-Instruct fine-tuning

- Measurement of temperature value influence
- A neural network layer transformation

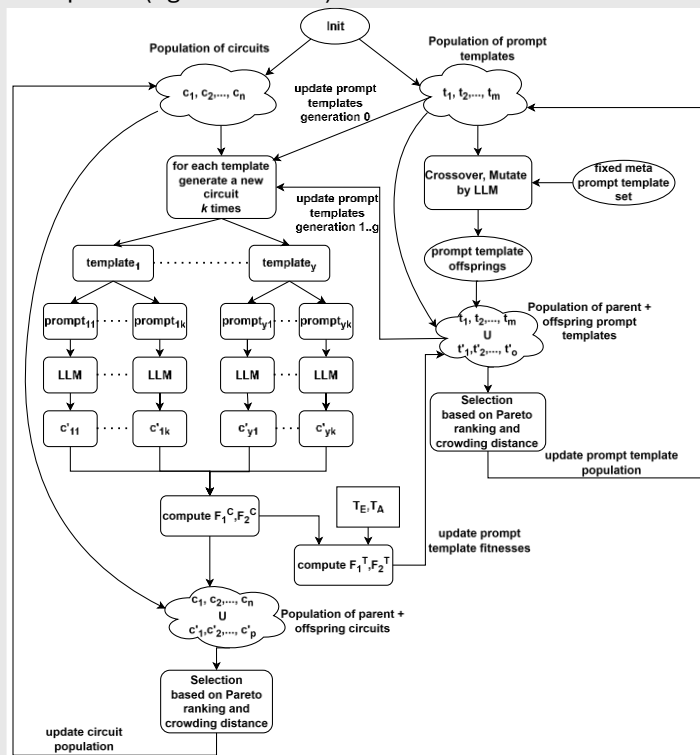
LLM integration into a cycle

Evolution with a fine-tuned model

Coevolution with an off-the-shelf LLM

COEVOLUTION OF CIRCUITS AND MODIFICATION TEMPLATES

The proposed circuit approximation method that utilizes a co-evolutionary algorithm evolving a population of circuits (left-hand side) and a population of circuit producing templates (right-hand side).



Circuit fitness functions

$$F_1^C = \text{MSE or WCE}$$

$$F_2^C = \text{area estimate}$$

$$\text{MSE} = \frac{\sum_{i=1}^{n_{\text{inp}}} (O_{\text{approx}}^i - O_{\text{accurate}}^i)^2}{2n_{\text{inp}}}$$

$$\text{WCE} = \frac{\max_i |O_{\text{approx}}^i - O_{\text{accurate}}^i|}{O_{\text{accurate}}^i}$$

n_{inp} - number of inputs
 O_{approx}^i and O_{accurate}^i - approximate and accurate i -th decimal output

Template fitness functions

$$F_1^T = 1 - \left(\frac{\text{valid}}{\max(\text{circuit_cnt}, 1)} \right)$$

$$F_2^T = \frac{1}{\sum_{i=1}^{\text{valid}} |T_E - \text{Error}_{\text{c}[i]}|}$$

T_E - target error (MSE/WCE)
 $\text{Error}_{\text{c}[i]}$ - error of circuit i (MSE/WCE)
 valid - number of valid circuits generated by a given template
 circuit_cnt - number of circuits generated by a given template

Circuit Approximation Prompt Example

Following equations describe approximate multiplier.

Example:

Mean Squared Error (MSE) = {src_random_mse}

Area = {src_random_area} μm^2

The circuit: {src_random_design}

Please, design a new approximate multiplier circuit with parameters:

Mean Squared Error (MSE) = {target_mse}

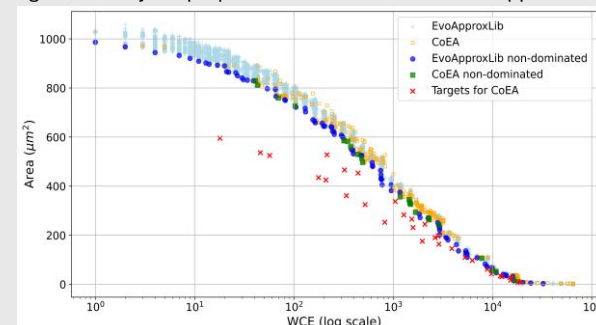
Area = {target_area} μm^2

Generate only the new circuit, without any comments.

The new circuit:

RESULTS

The WCE-Area trade-offs for 8-bit approximate multipliers generated by the proposed CoEA or taken from EvoApproxLib.



The method produced 24 circuits with new WCE-area tradeoffs and 23 MSE-area trade-offs on the global Pareto front.

CoEA produced 70 approximate multipliers exhibiting new trade-offs between WCE and area that are not present in EvoApproxLib. It produced 63 designs with new MSE-area trade-offs.

PUBLICATION

Tomašovič, M., Sekanina, L. (2027). Multi-objective Coevolution of Prompts and Templates for Circuit Approximation. In: Iacca, G., et al. Parallel Problem Solving from Nature – PPSN XIX. PPSN 2026. Lecture Notes in Computer Science, vol 16989. Springer, Cham. https://doi.org/10.1007/978-3-032-36217-9_19