Genetic Improvement in the Shackleton Framework for Optimizing LLVM Pass Sequences

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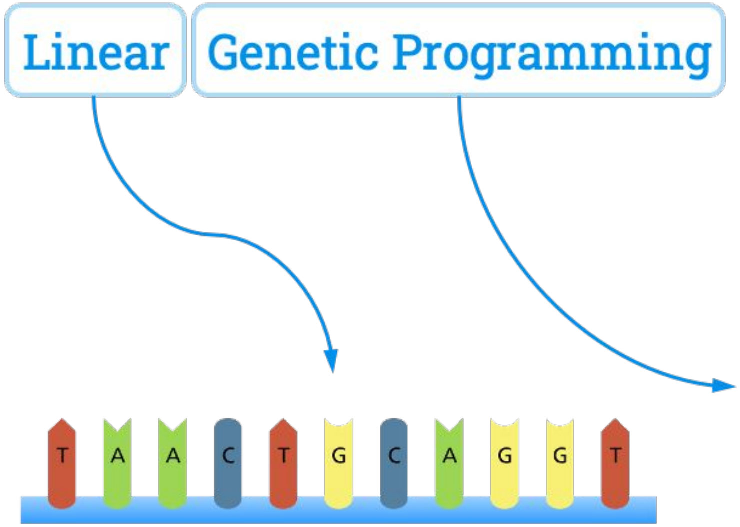
https://arxiv.org/abs/2204.13261

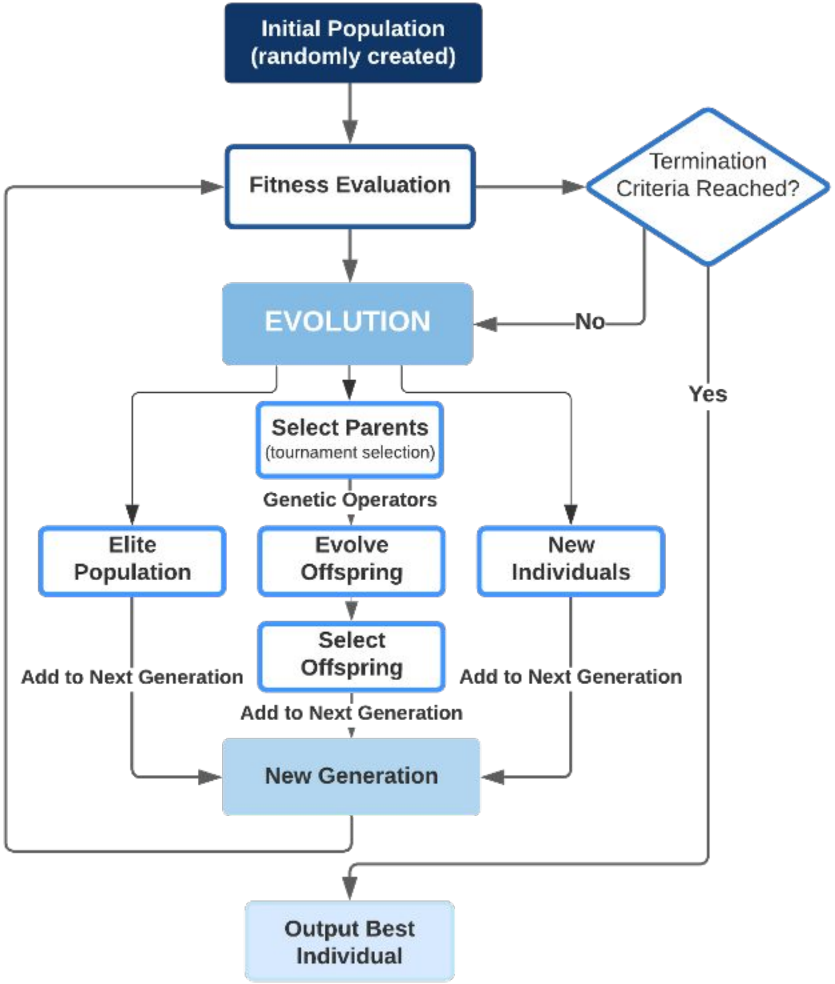
Key Points

- Using genetic improvement to find optimized LLVM Pass sequences
- Automatic way to find a problem-specific optimization sequence
  - Without expert domain knowledge
- 3.7% runtime improvement (good in compiler world)

Overview

I. The Shackleton Framework

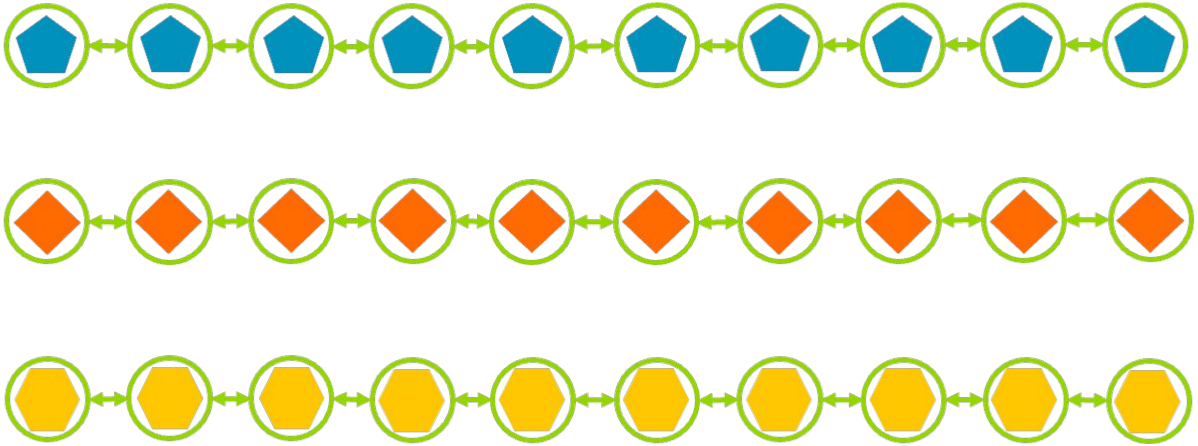




Osaka List Structure

Generalized linear representation of objects that unifies:

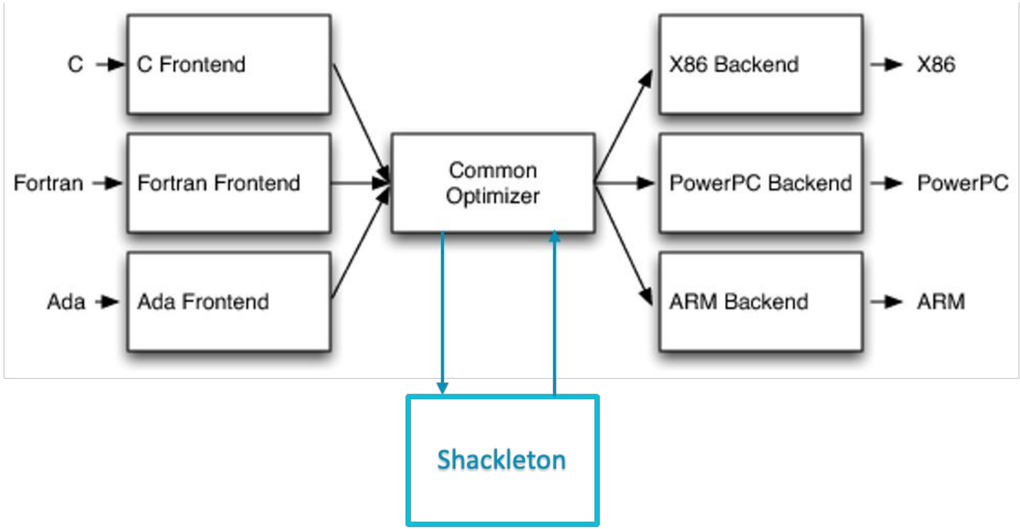
- Initialization
- Selection
- Crossover
- Mutation



- Customized fitness

II. LLVM Optimization Passes

- New target application, mostly unrelated to GA
- Variety of possible injection points for GA
  - Common Optimizer
  - Transitions from frontend to middle, middle to backend
- Open source
  - Easily accessible, popular



A bit more about LLVM - default optimization levels

-O0: compiles the fastest and generates the most debuggable code

-O1: in between -O0 and -O2

-O2: moderate level of optimization which enables most optimizations

-O3: -O2 plus optimizations that take longer to perform or that may generate larger code (in an attempt to make the program run faster)

-O4: adds link-time optimization

-Os: -O2 with extra optimizations to reduce code size

-Oz: -Os (and thus -O2) but reduces code size further

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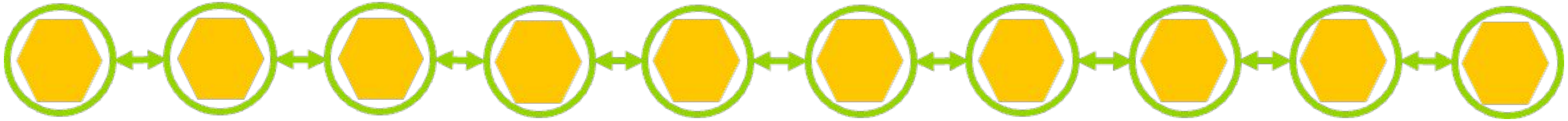
III. Genetic “Edit” Rules

1. Deletion
2. Insertion
3. Replacement

Inside an “Edit”:

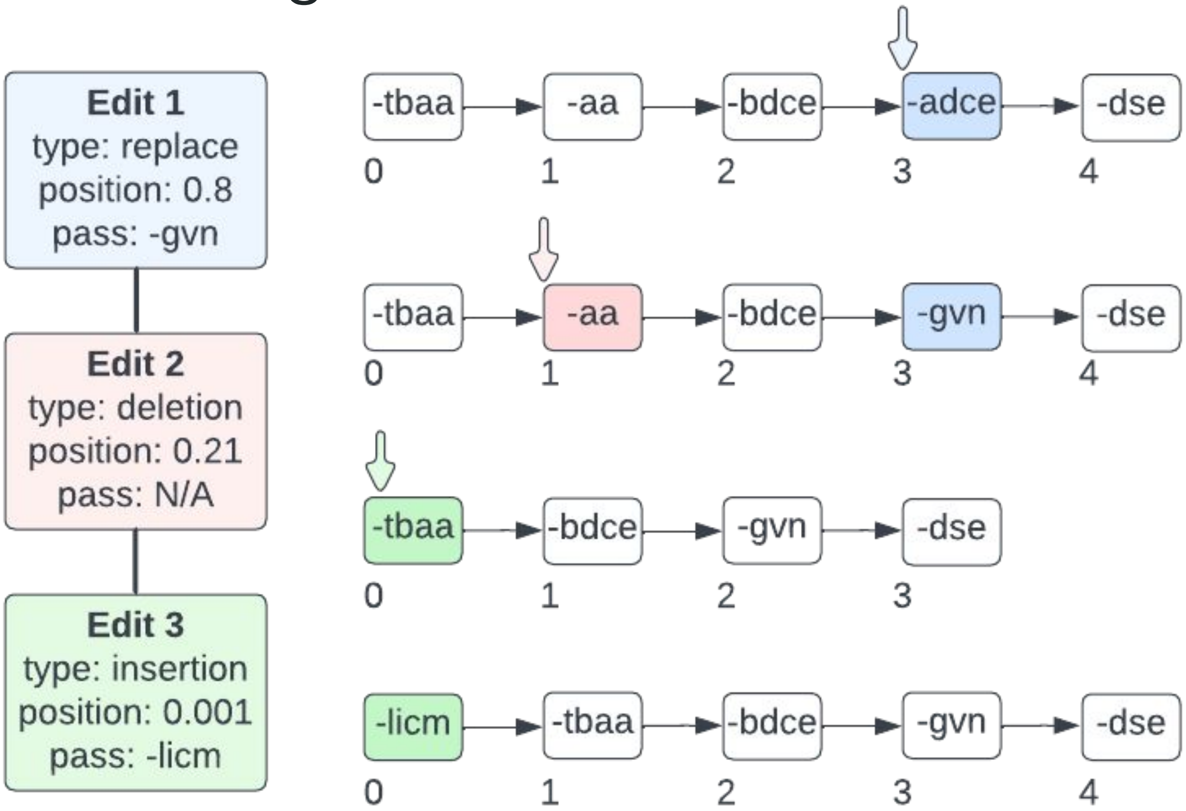
1. Edit type
2. Position
3. New Pass (null for deletion)

“Edit” Representations in Osaka List Structure



Edit ↔ Gene

Example Walk-through



Experimental Outline

a. Target program: Backtracker Algorithm for the Subset Sum Problem (SSP)

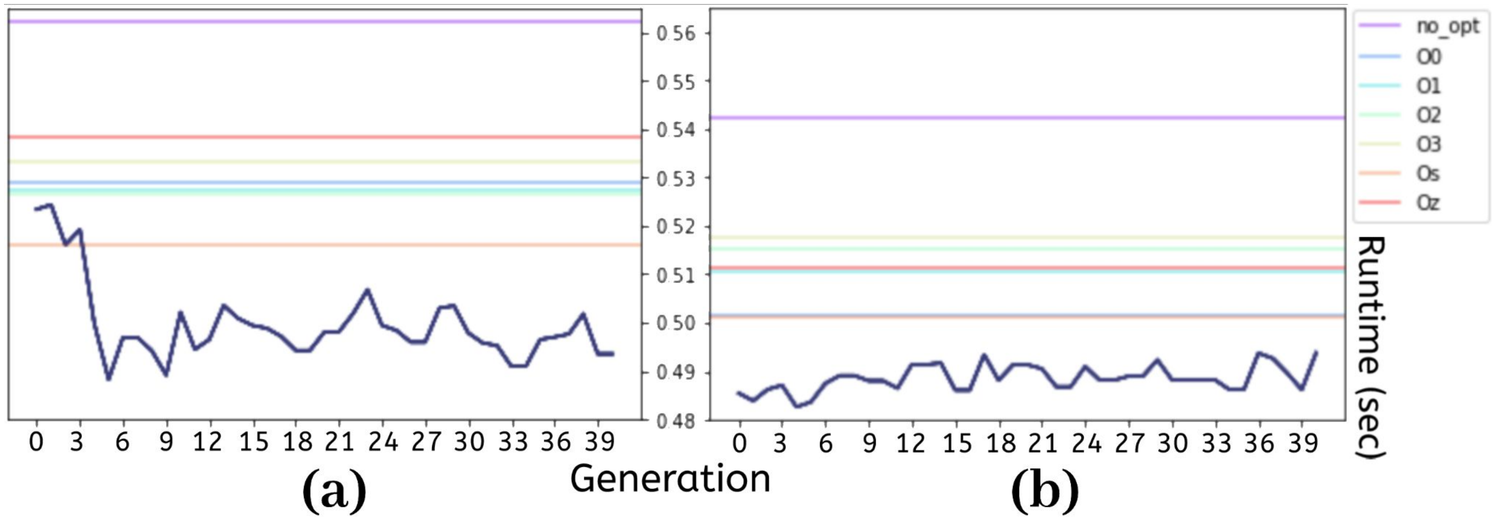
b. Hyperparameters:

num_generations	50
population_size	40
percent_crossover	60
percent_mutation	80
percent_elite	10
tournament_size	4
nest_size	6
individual_size	0 (this means random length)

c. 8 repeated runs

Results

Runtime Improvement: 3.7% (±0.8768)



Hoste, Kenneth and Eeckhout, Lieven (2008): 3.1%
Ashouri, Amir Hossein et. al. (2016): 4%, 2%
Ashouri, Amir Hossein et. al. (2017): 5%
Wang, Zheng and O'Boyle, Michael (2018): 5%

Efficiency Analysis

Entire search space: 10^167 ➜ would take decades!

Genetic Improvement: start from known solution (-O3) ➜ a few hours

Conclusions

- Don’t need domain expertise
- Problem-specific
- Efficient search process
- 3.7% runtime improvement

Future Directions

- Hyperparameter tuning specific for GI
- More test cases & standard benchmarks

thanks for listening!

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