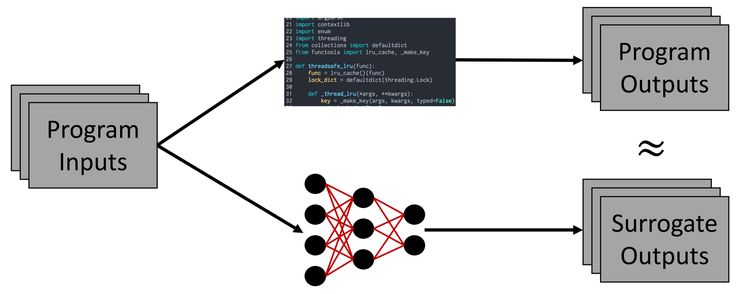
Programming with Neural Surrogates of Programs

Alex Renda, Yi Ding, Carbin
{renda, ding1, mcarbin}@csail.mit.edu

Surrogates of Programs

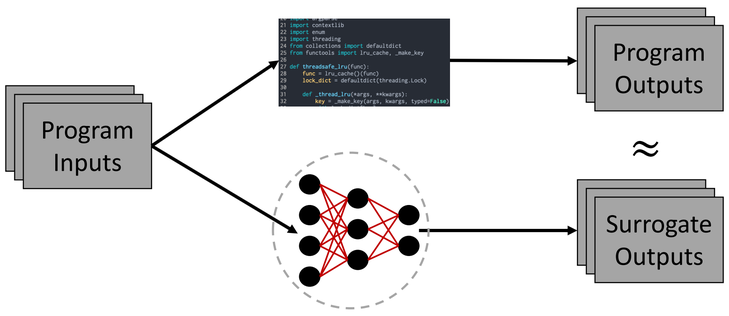
- Models of the behavior of program
- Implemented with machine learning models (e.g., neural networks)
- Trained with input-output examples of the program



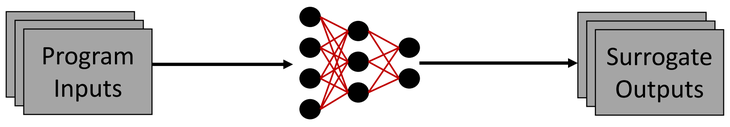
Surrogate-Based Design Patterns

Surrogate Compilation

1. Develop a surrogate of a program



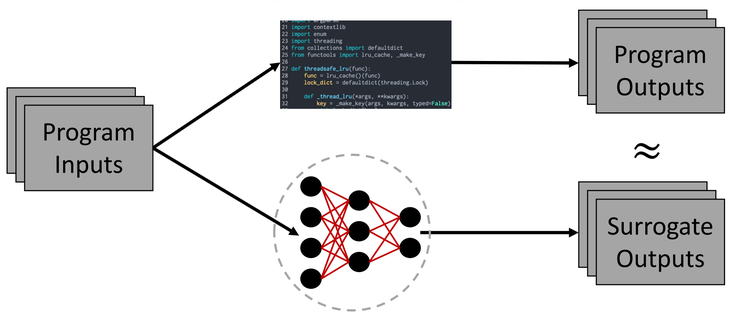
2. Deploy the surrogate to end-users



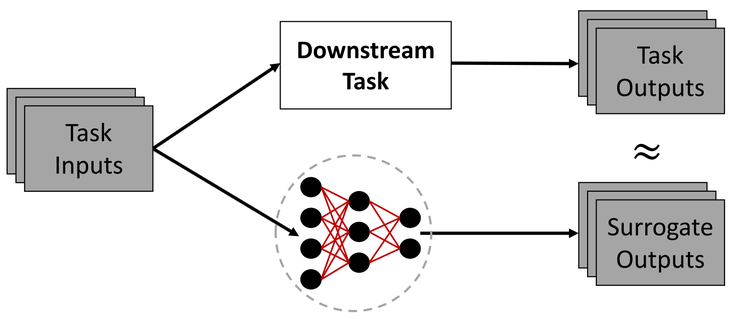
Surrogate executes faster than the program:
- Surrogate implementation can be more optimized
- Surrogate can execute on different hardware
- Surrogate can have different complexity

Surrogate Adaptation

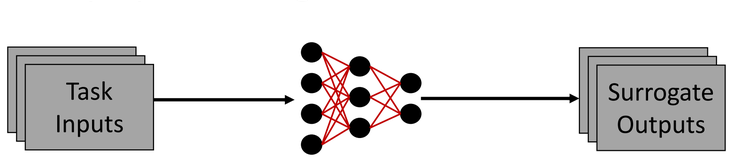
1. Develop a surrogate of a program



2. Fine-tune the surrogate on a downstream task



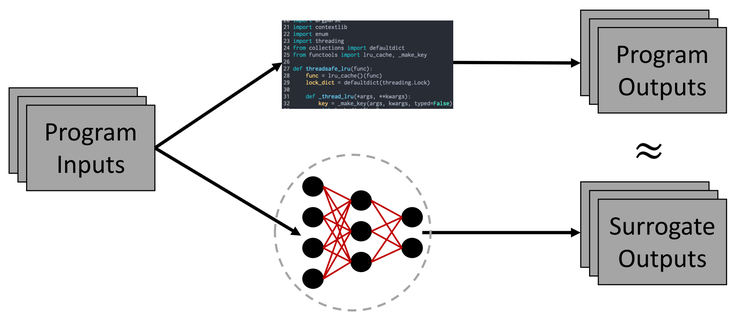
3. Deploy the surrogate to end-users



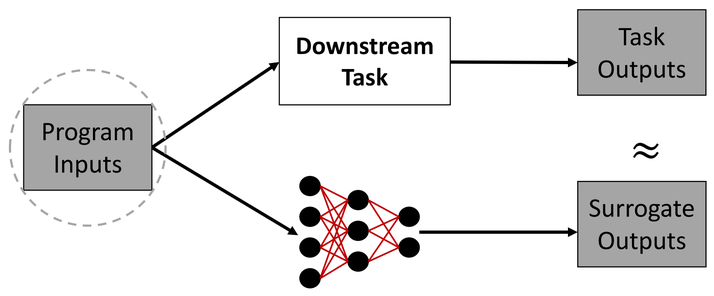
Changes the semantics of the program to accomplish a downstream task:
- Surrogate is more accurate than the program on the downstream task
- Requires less data than training a network from scratch on the downstream task

Surrogate Optimization

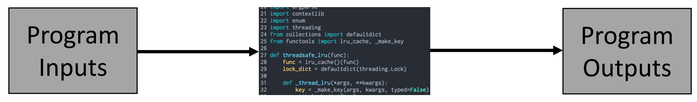
1. Develop a surrogate of a program



2. Optimize inputs of the surrogate



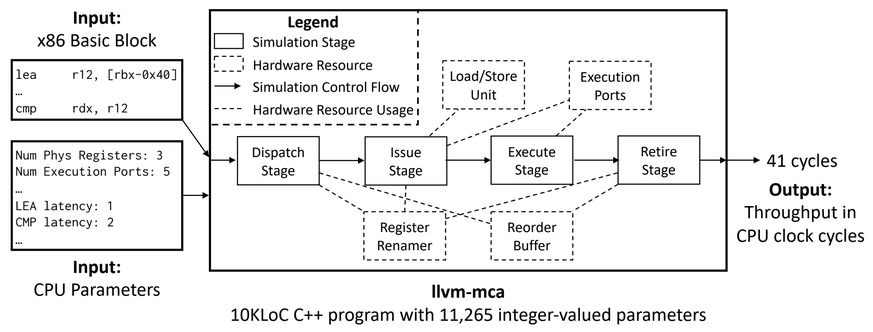
3. Plug the inputs back into the original program



Optimizes inputs faster than optimizing against the original program:
- Surrogate is differentiable allowing for using gradient descent
- Surrogate can execute faster than the program

Case Study: llvm-mca

CPU Simulator included in the LLVM compiler infrastructure.
- Predicts the execution time of x86 basic blocks
- >10,000 lines of C++
- 25% error against ground-truth timings



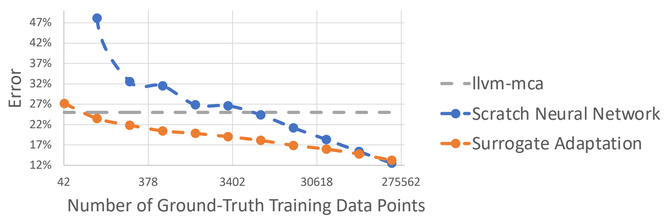
Surrogate Compilation

Accelerates llvm-mca's execution speed by 1.6x with <10% loss in accuracy

Approach	Execution Speed	Error
llvm-mca -O3	1742 BBs/second	25.0%
Surrogate	2820 BBs/second	27.1%

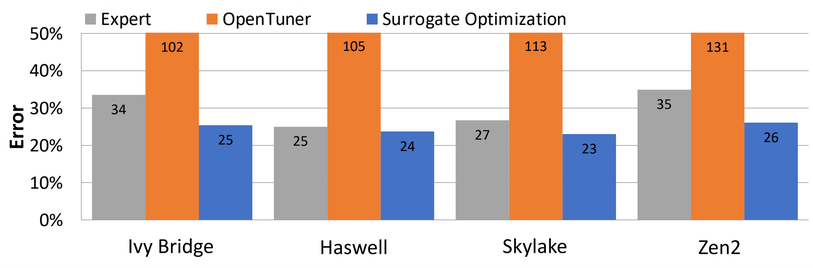
Surrogate Adaptation

Decreases llvm-mca's error by up to 50% with less data than training a network from scratch



Surrogate Optimization

Finds simulation parameters that decrease llvm-mca's error relative to expert-set parameters given the same budget as a surrogate-free technique, Opentuner



Neural Surrogate Programming Methodology

Design

- What neural network architecture topology does the surrogate use?
- How do you scale the surrogate's capacity to represent the original program?

Training

- What training data does the surrogate use?
- What loss function does the surrogate use?
- How long do you train the surrogate?

Deployment

- What hardware does the surrogate use?
- What software execution environment does the surrogate use?