IMPROVING COMPILER OPTIMIZATIONS BY EMPLOYING MACHINE LEARNING

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Compiler Heuristics

Metrics to decide which transformation / optimization to apply in what way

COMPILER HEURISTIC EXAMPLE

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if(ΔcodeSize*weight$_{size}$ < Δperformance*weight$_{perf}$) → doTransformation()

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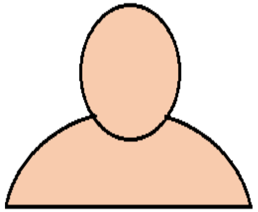

Compiler Expert

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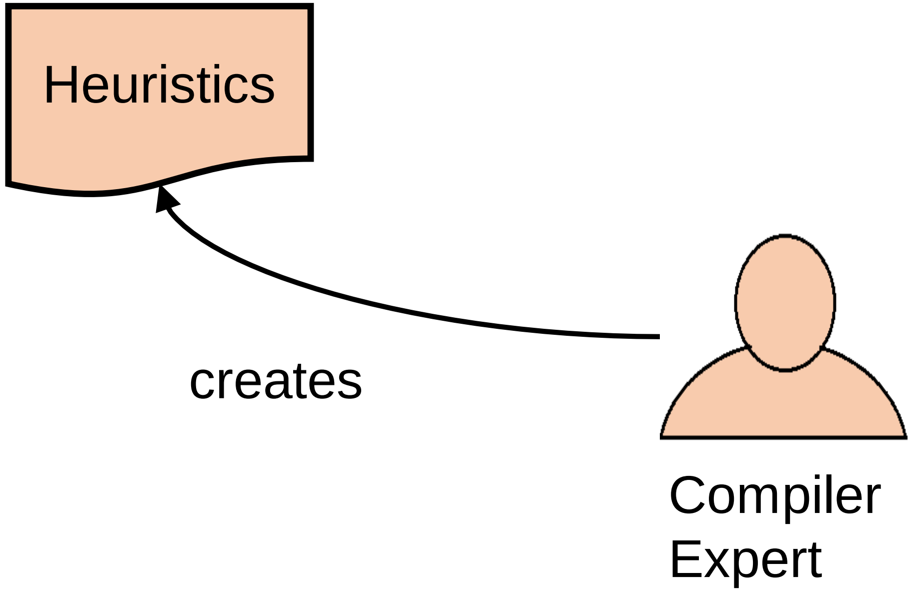

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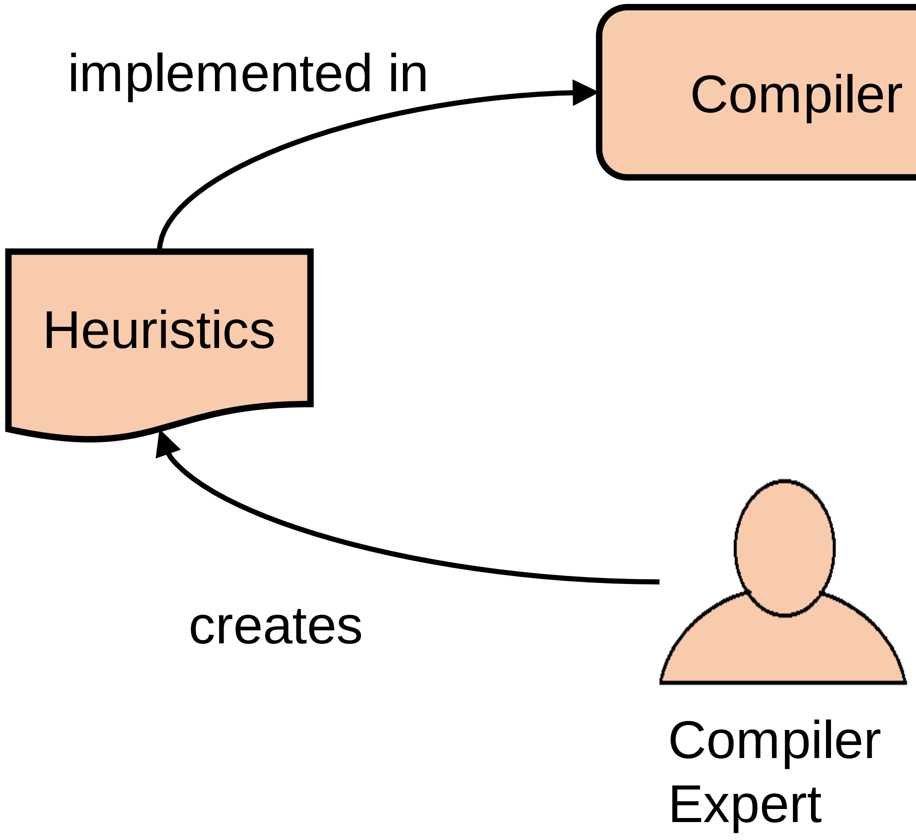

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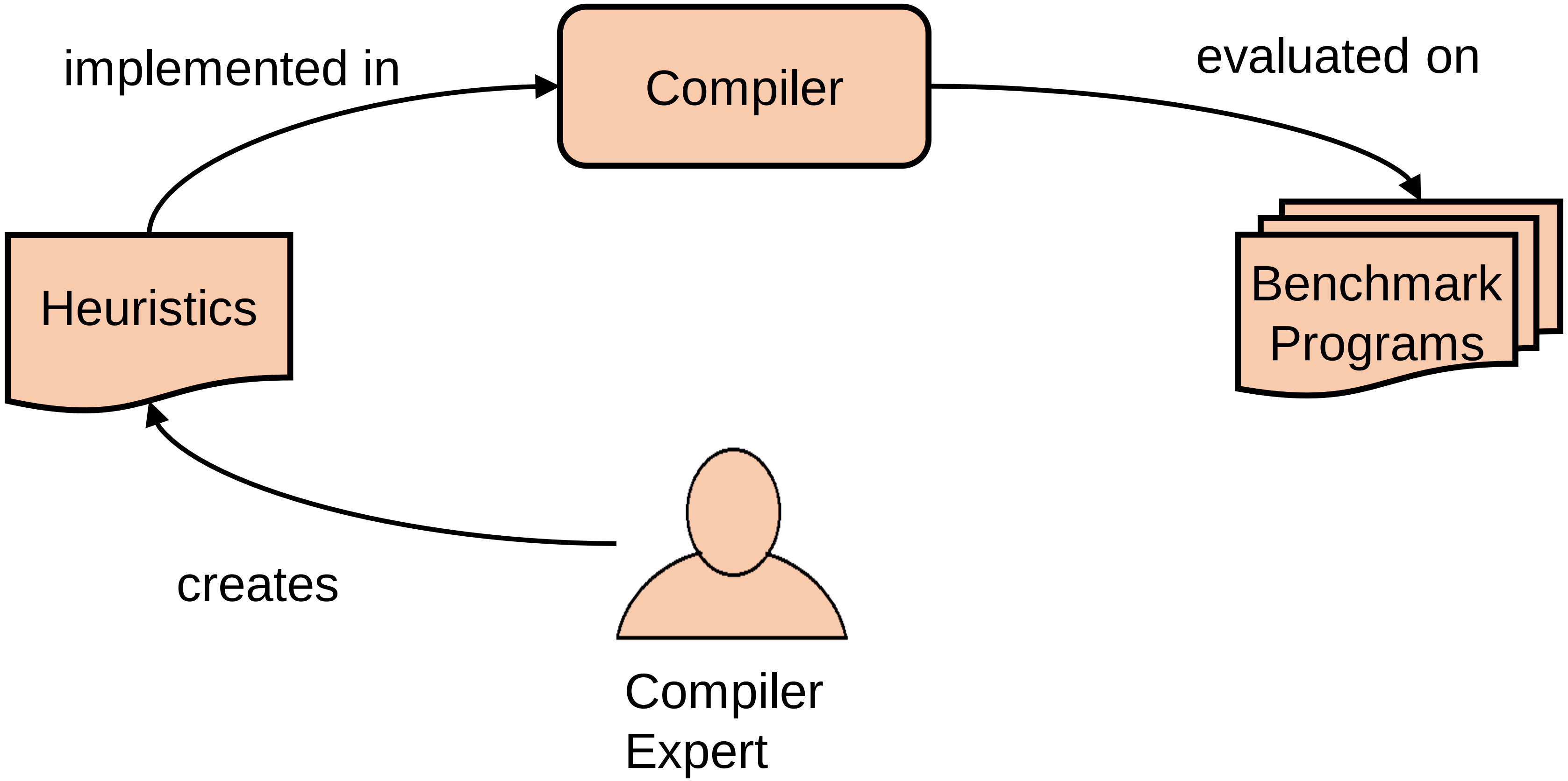

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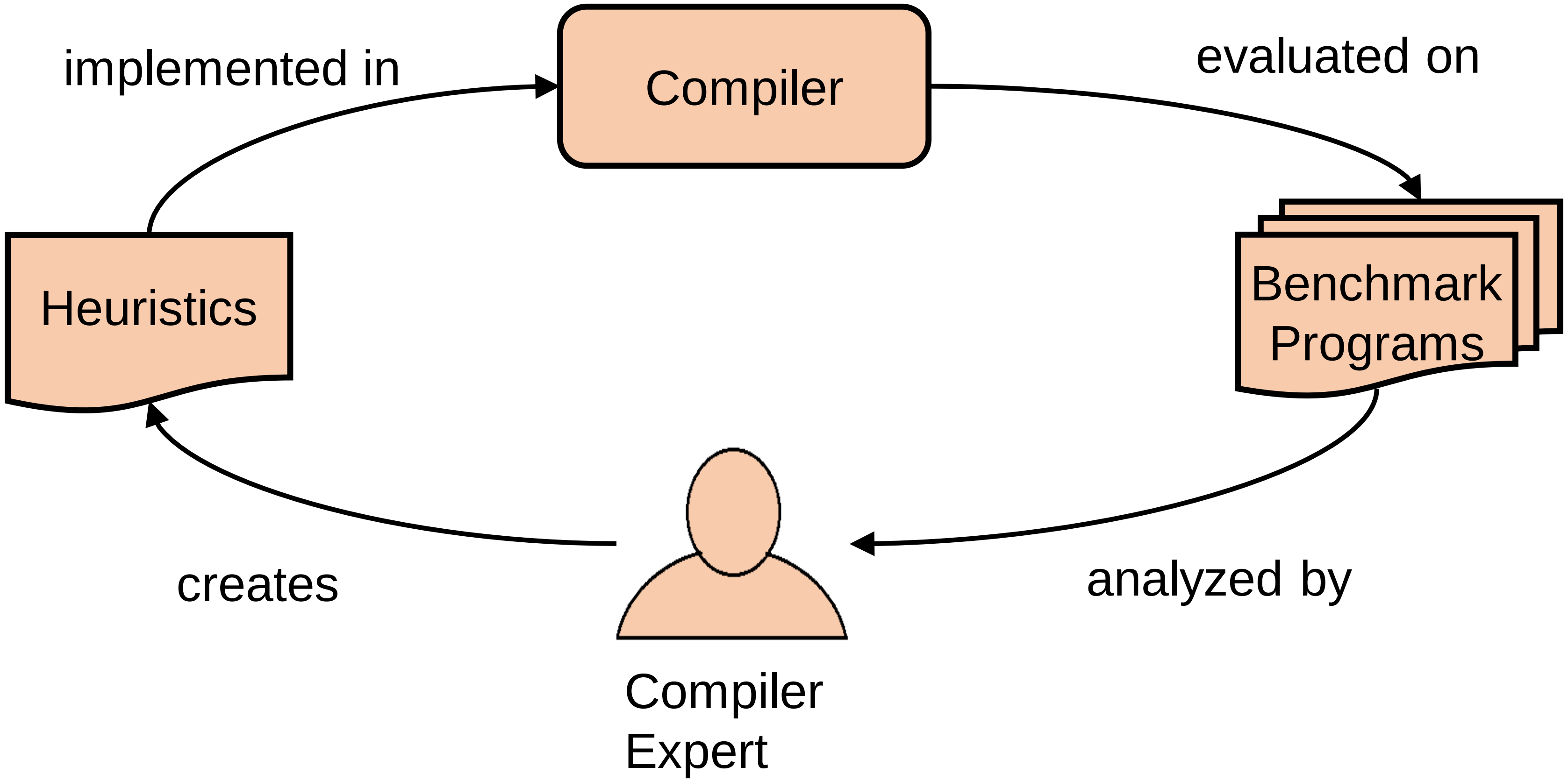

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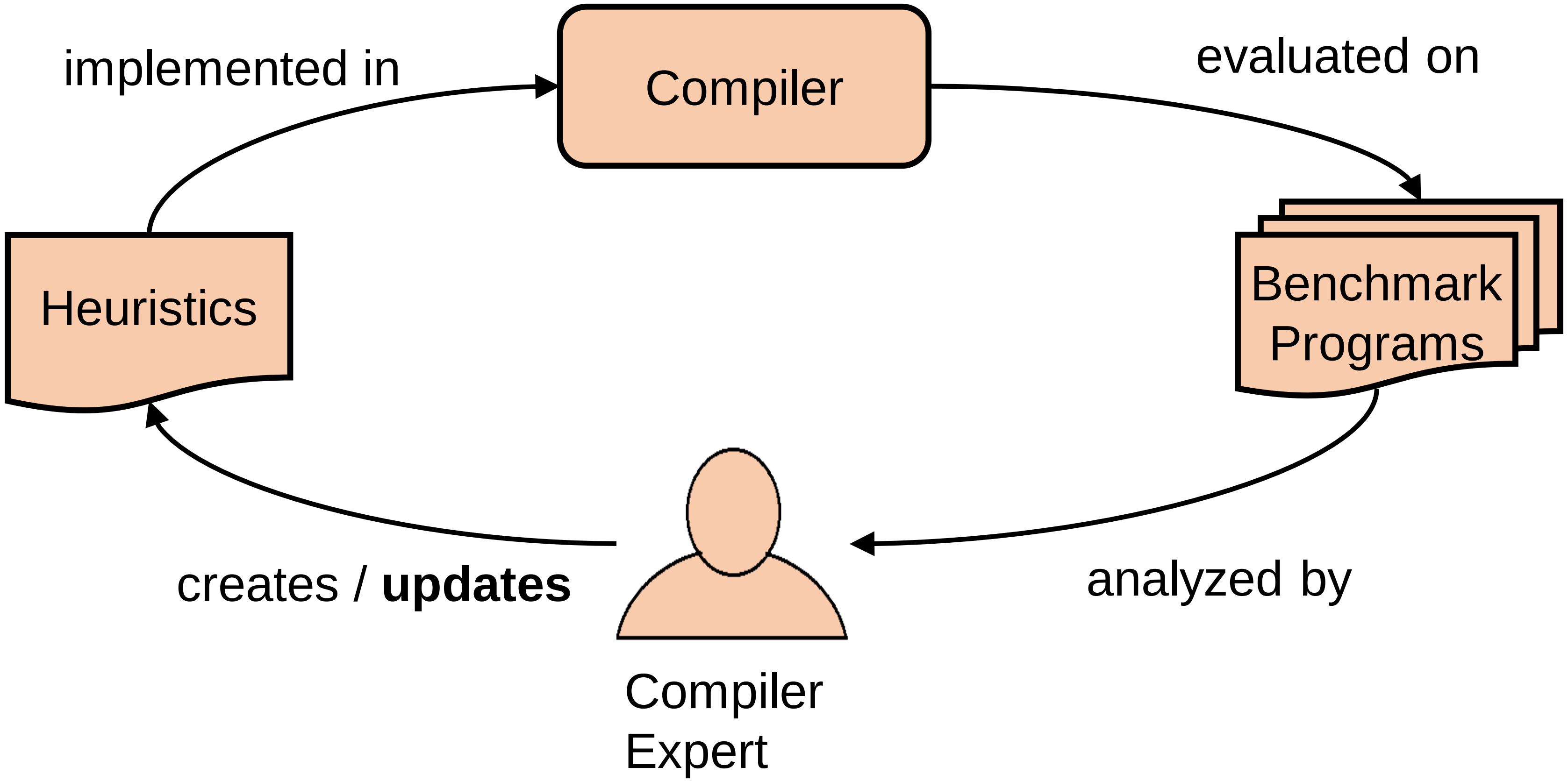
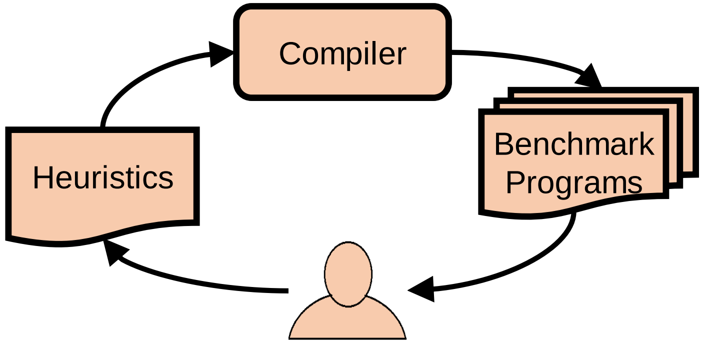


HUMAN-CRAFTED HEURISTICS



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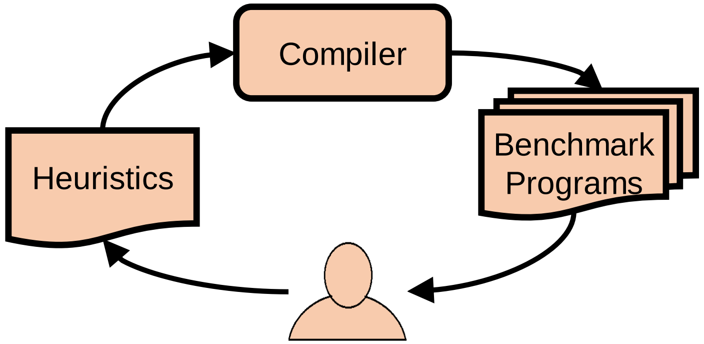

- Require domain expertise

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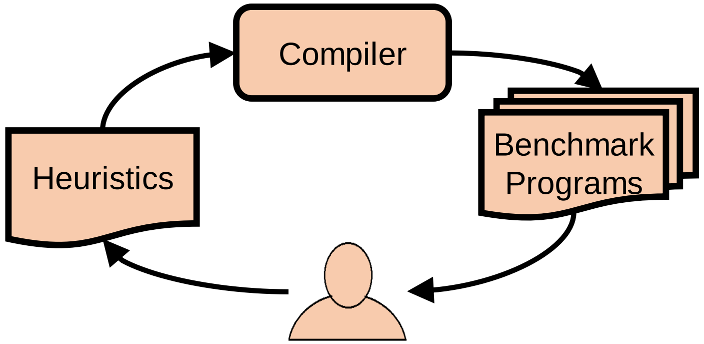

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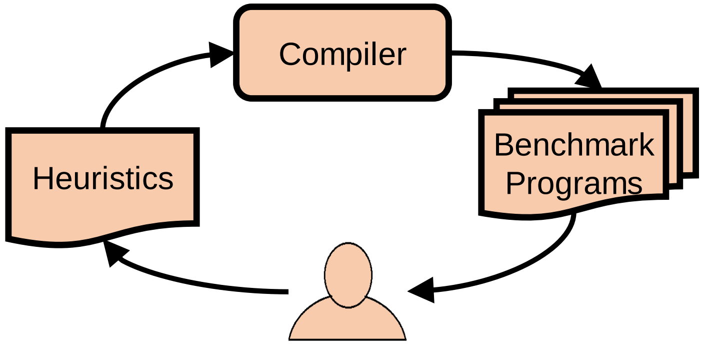

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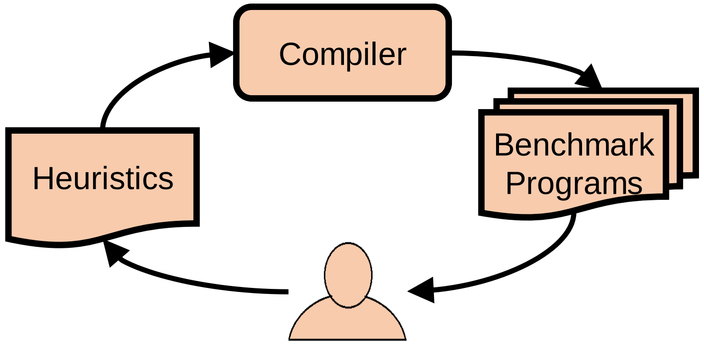

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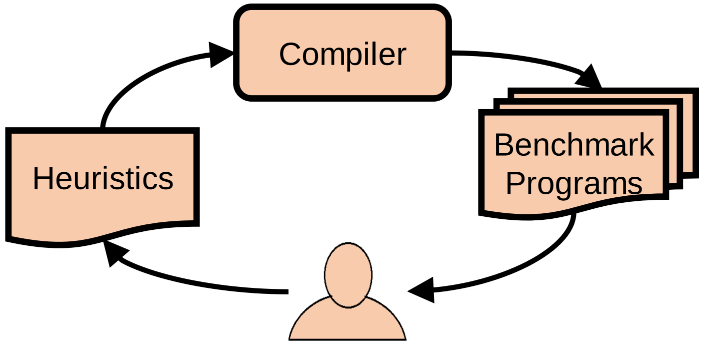

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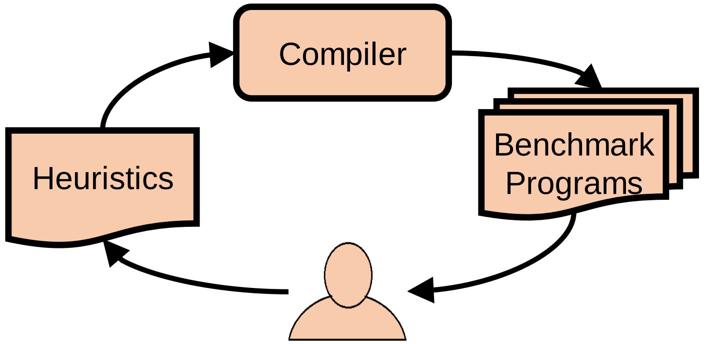

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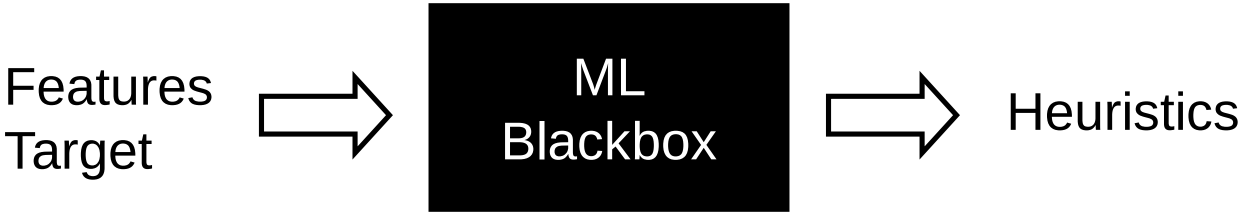
experience driven

MACHINE LEARNED HEURISTICS STATE-OF-THE-ART



Feature

A feature is a measurable property of an object of interest.
(e.g., #branches, #memoryOperations)

Target

The target is the feature to be predicted.
(e.g., best optimization decision)

ML MODELS IN COMPILERS STATE-OF-THE-ART

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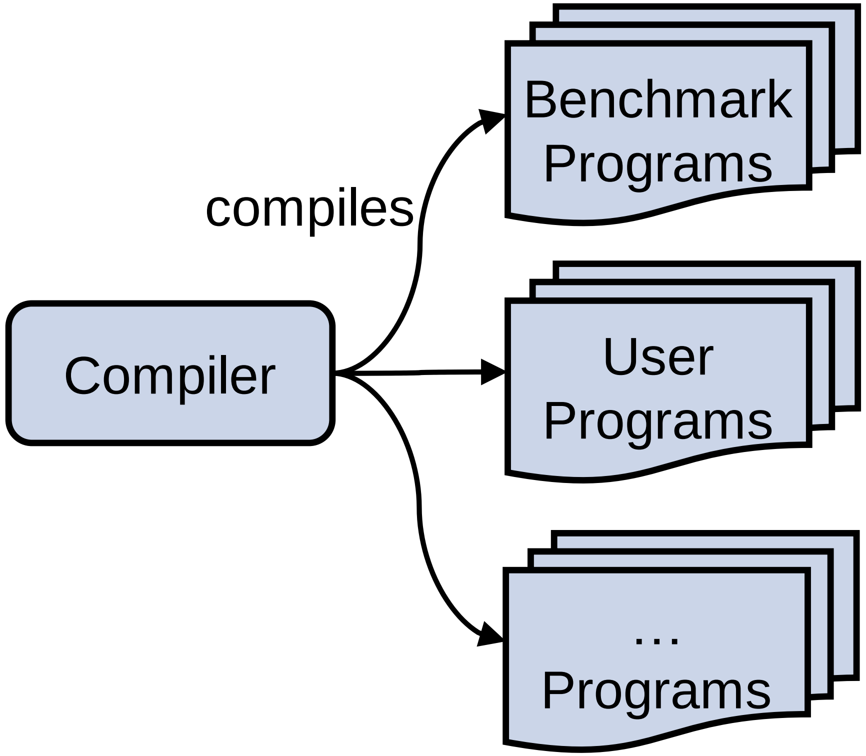

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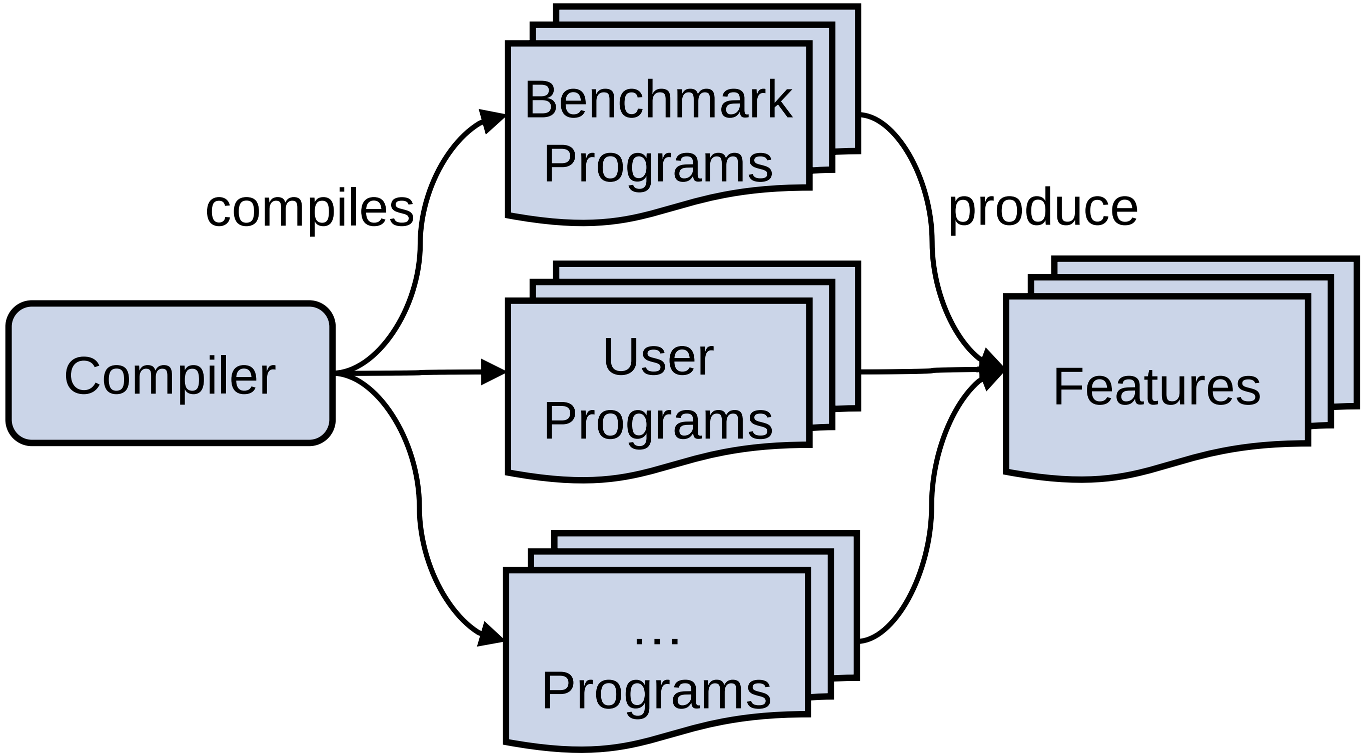

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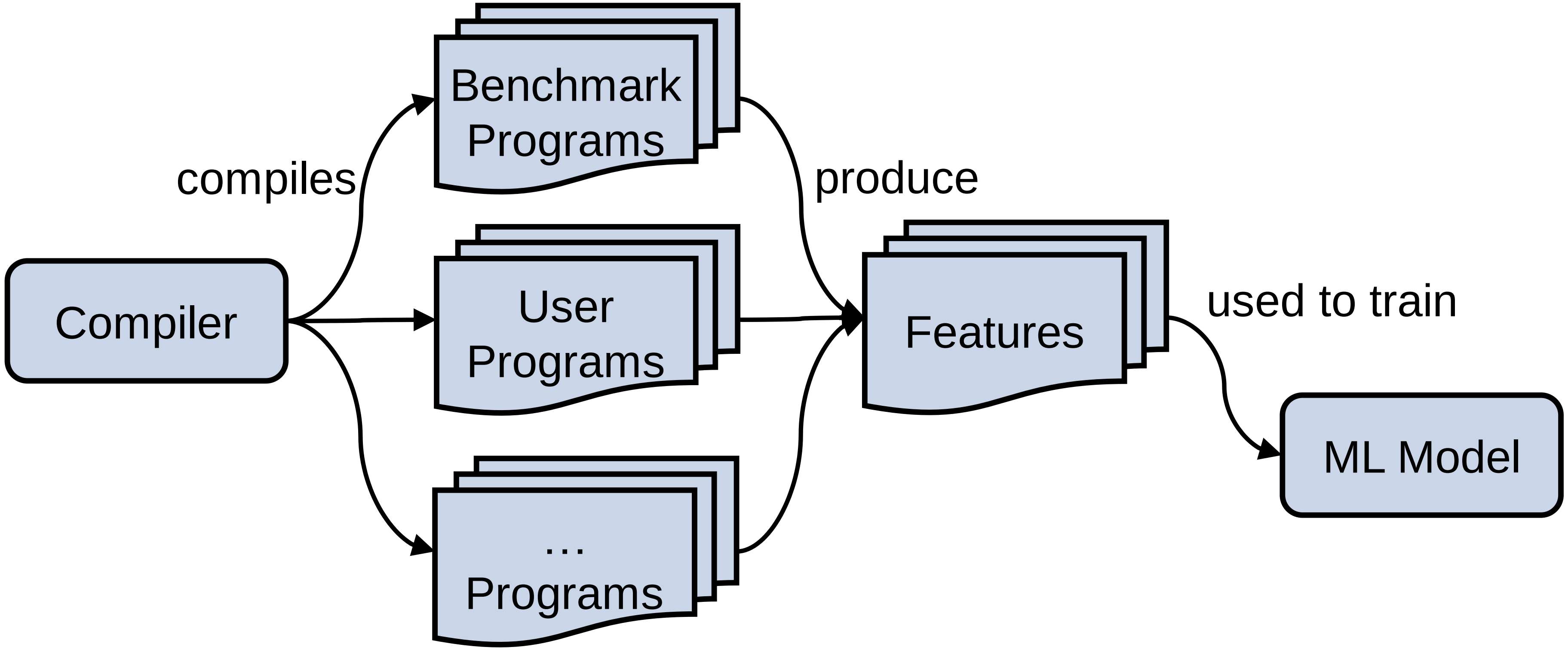

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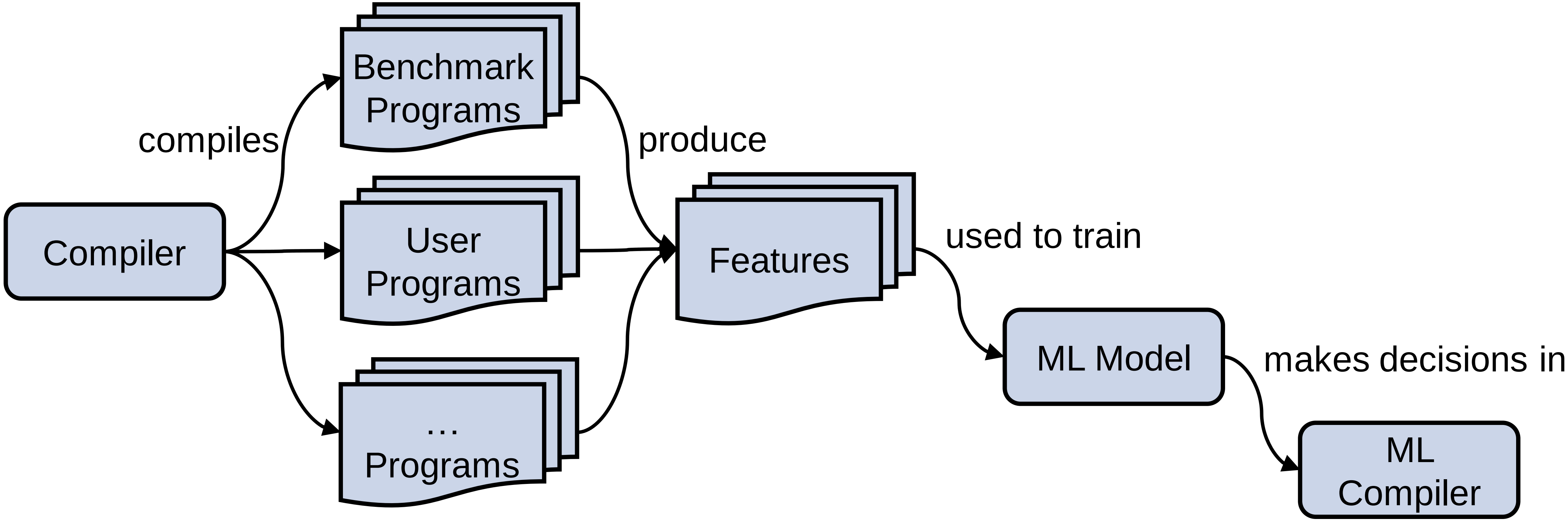

Compiler

compiles

Benchmark Programs

User Programs

… Programs

produce

Features

used to train

ML Model

makes decisions in

ML Compiler

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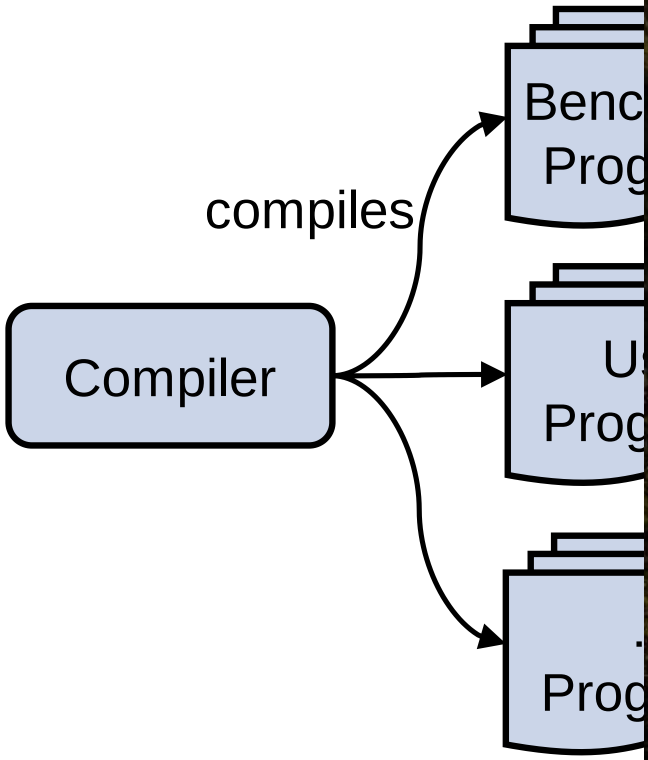
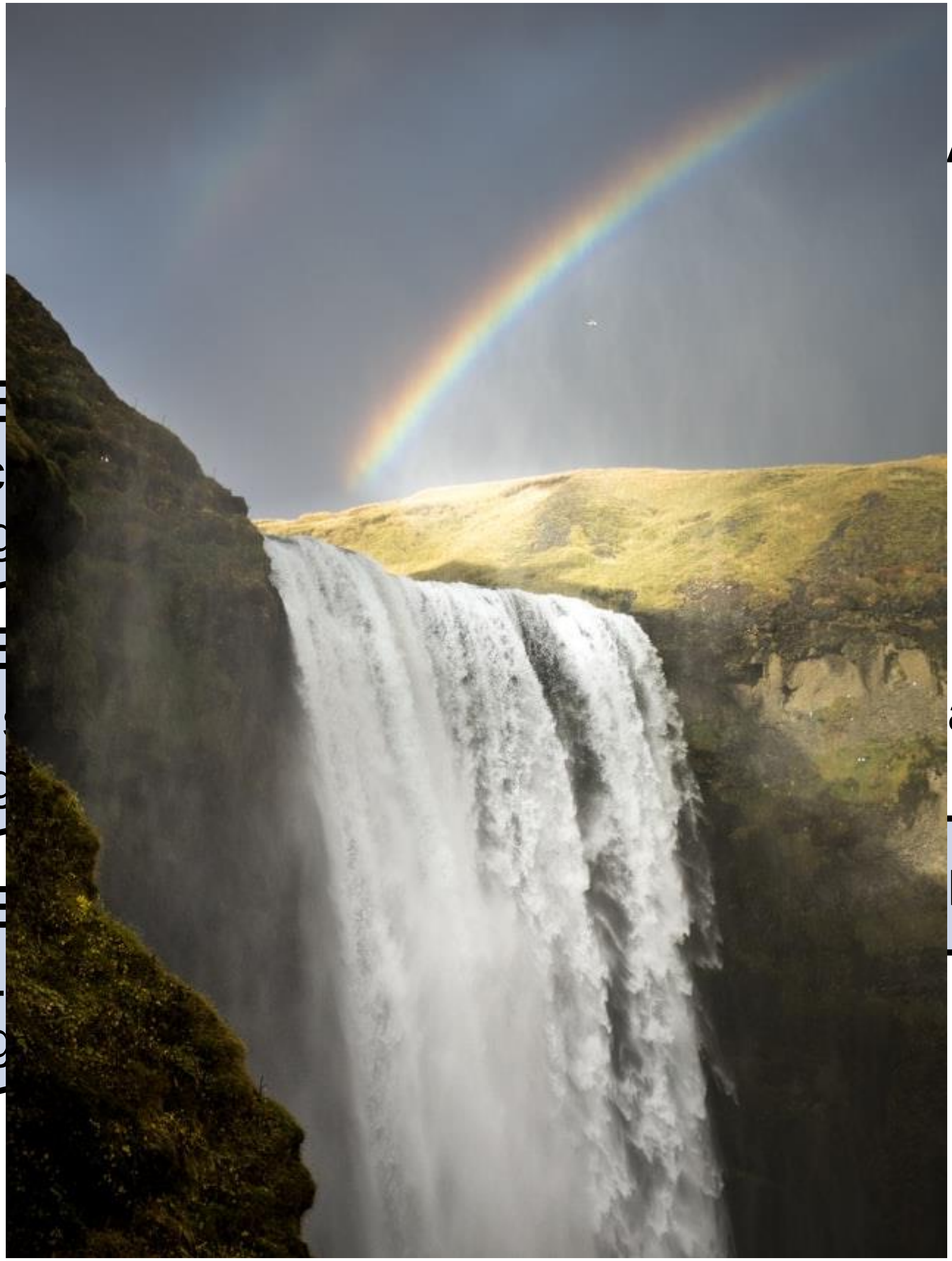




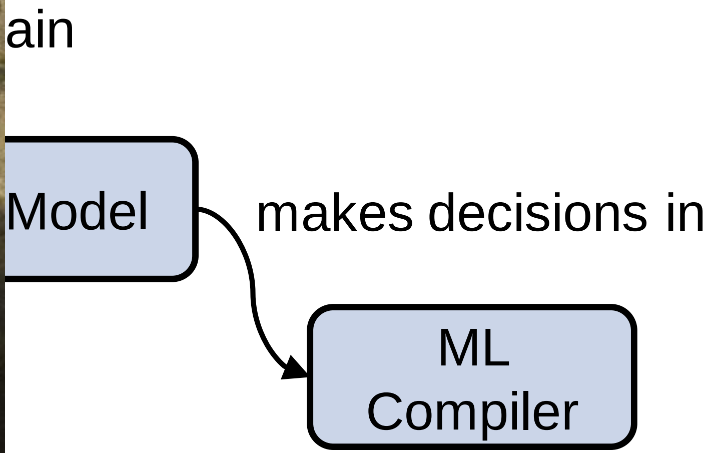
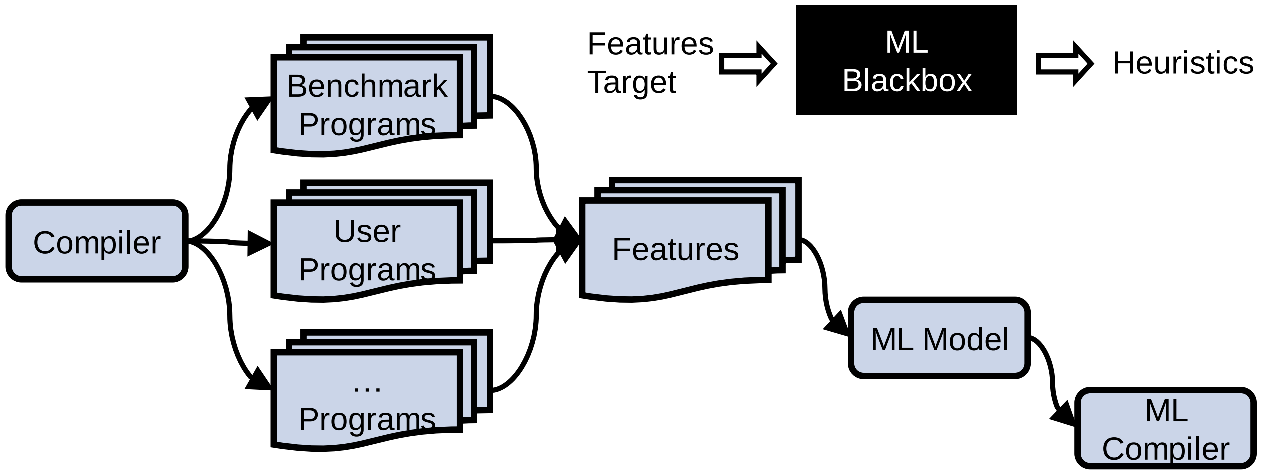


Photo by Dylan Gialanella on Unsplash

ML IN COMPILERS



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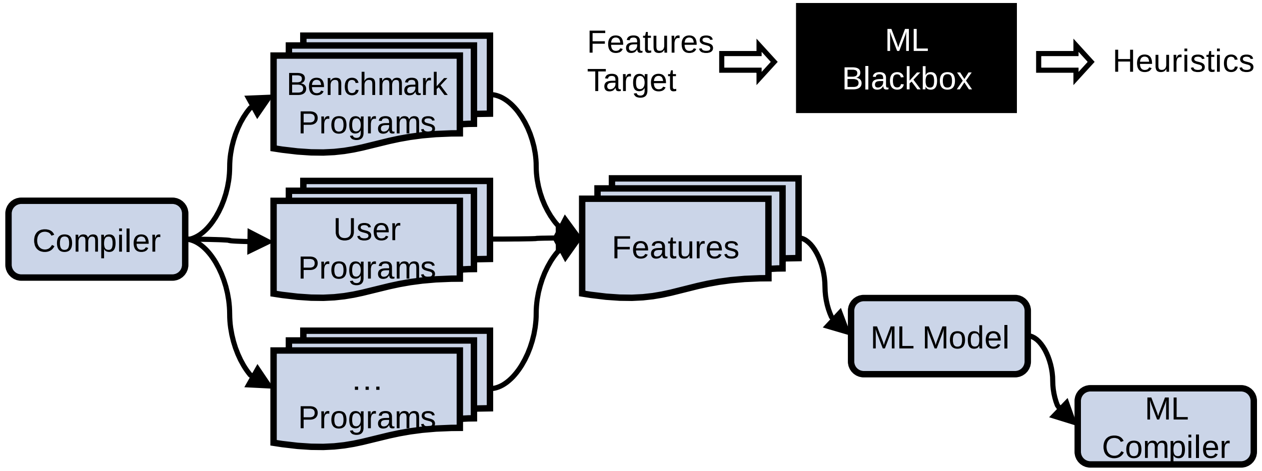

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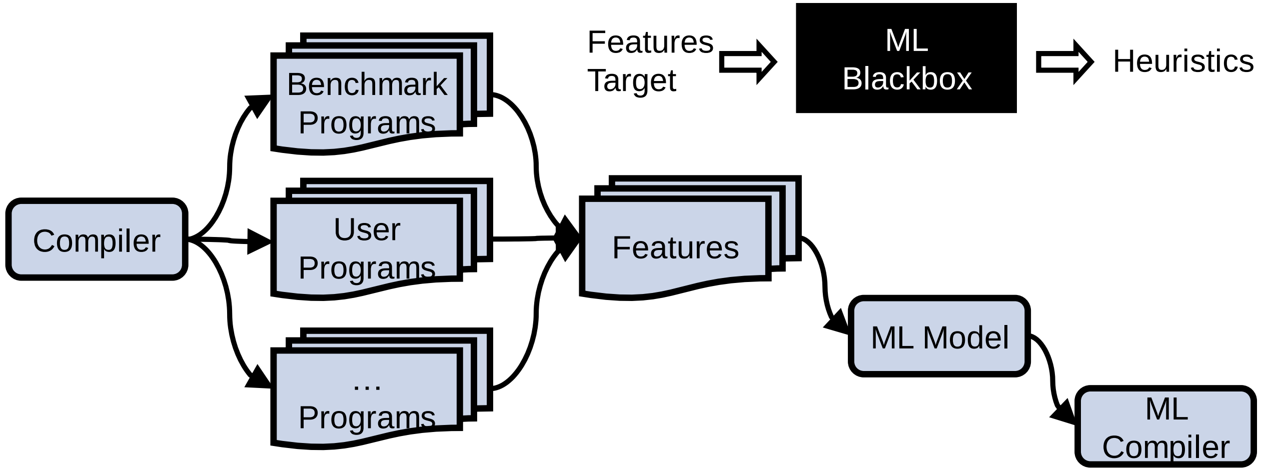

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  - □ Waterfall

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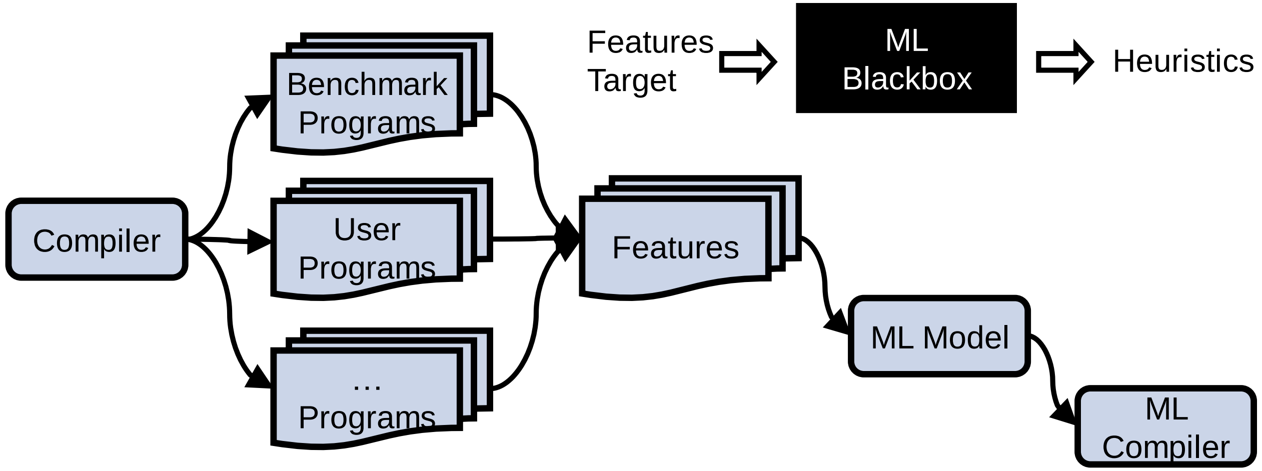

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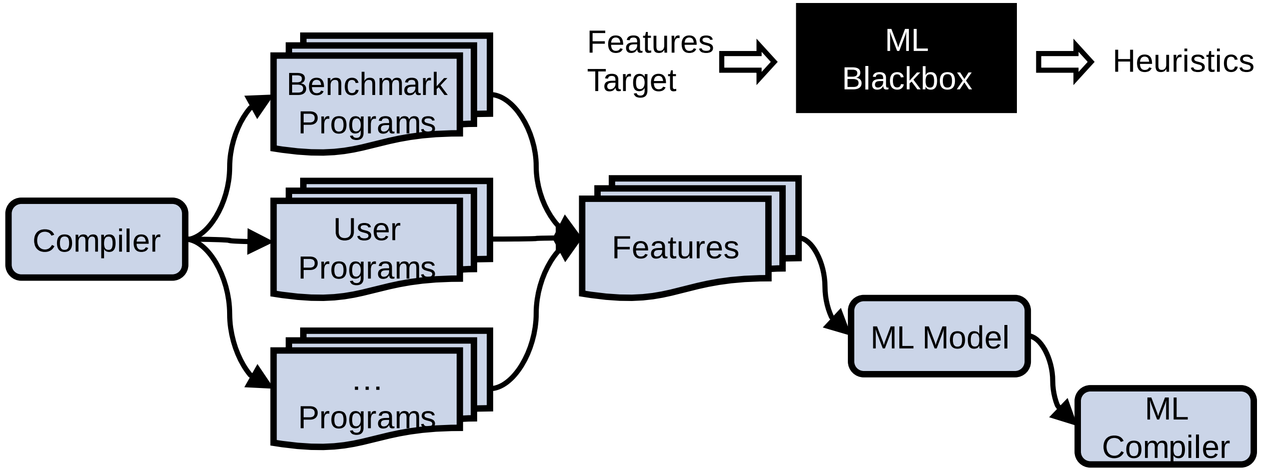

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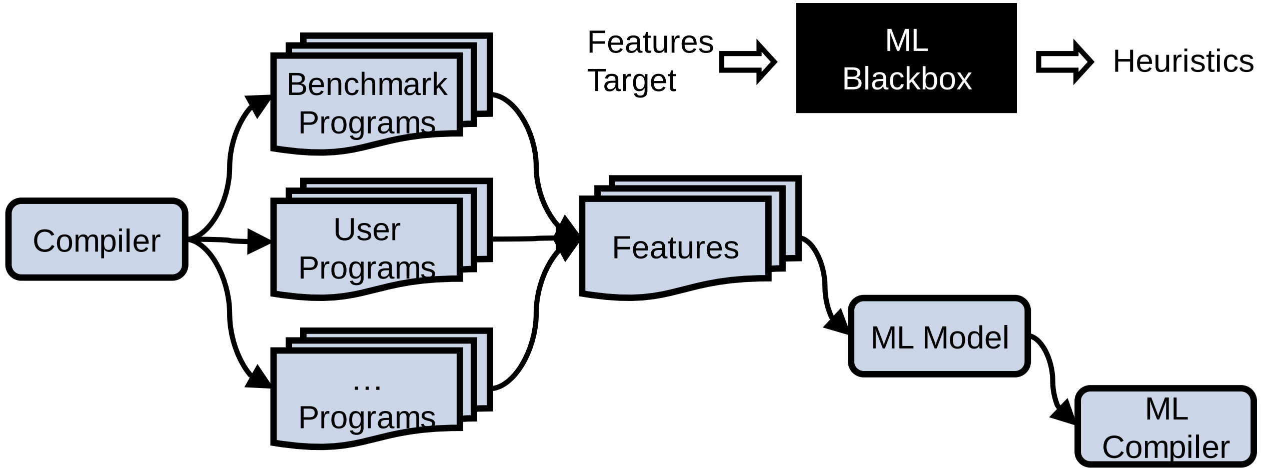

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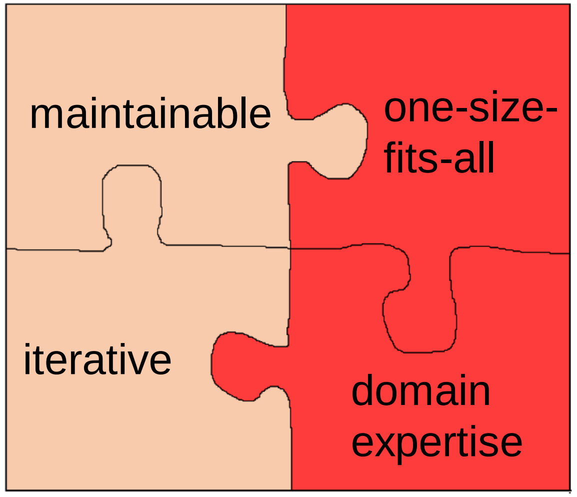
data driven

UTILIZE MACHINE LEARNING ASSISTIVELY



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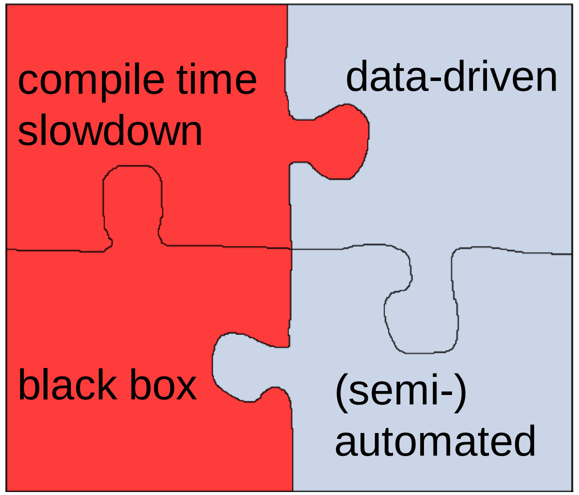

machine learned heuristics

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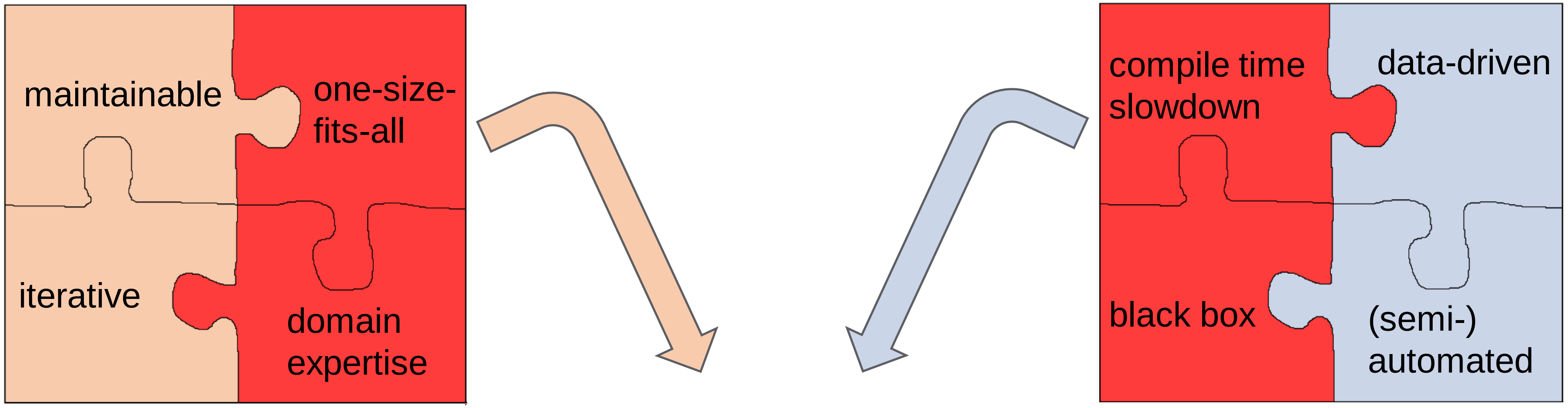

maintainable

one-size-fits-all

iterative

domain expertise

compile time slowdown

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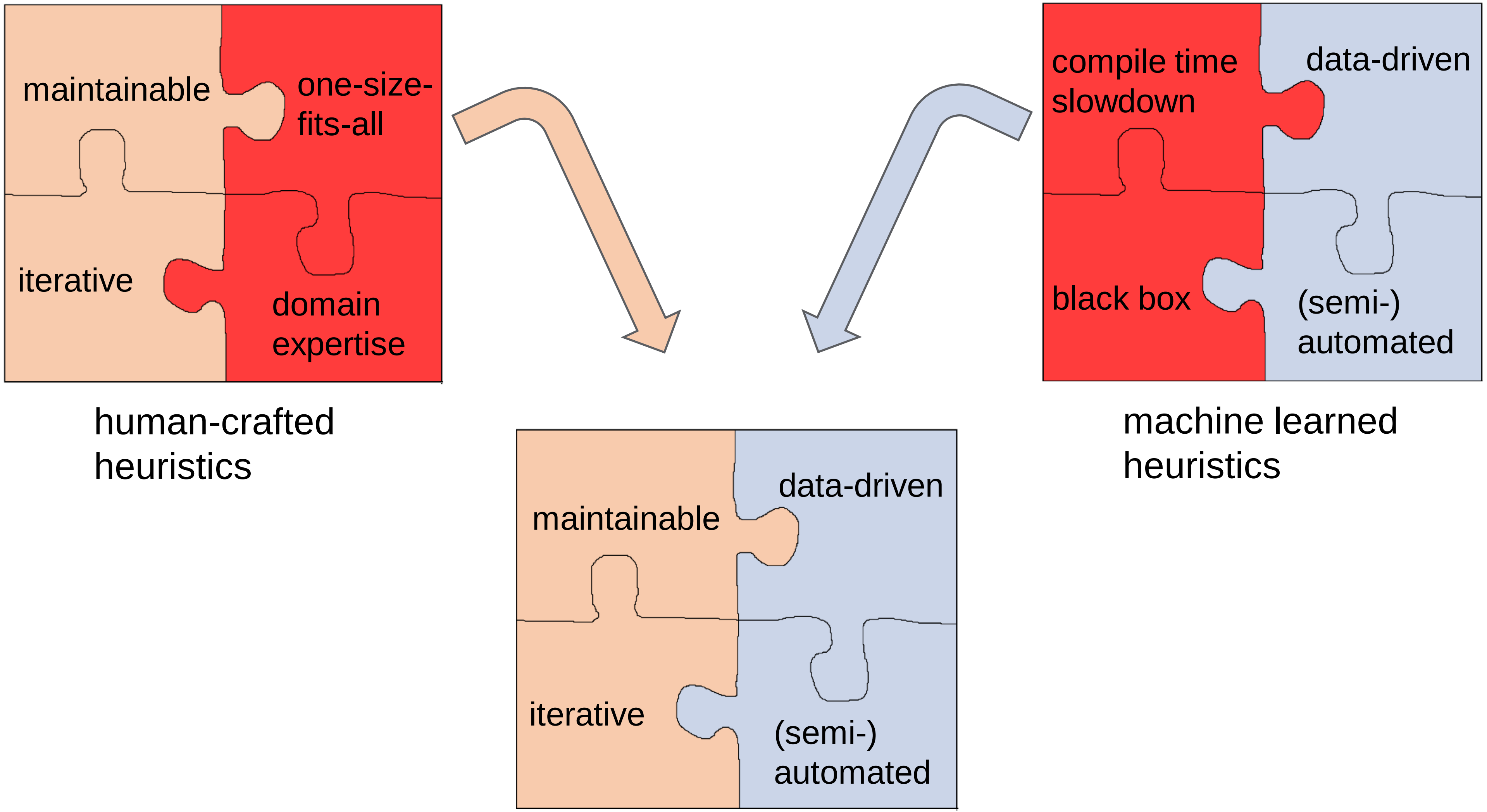

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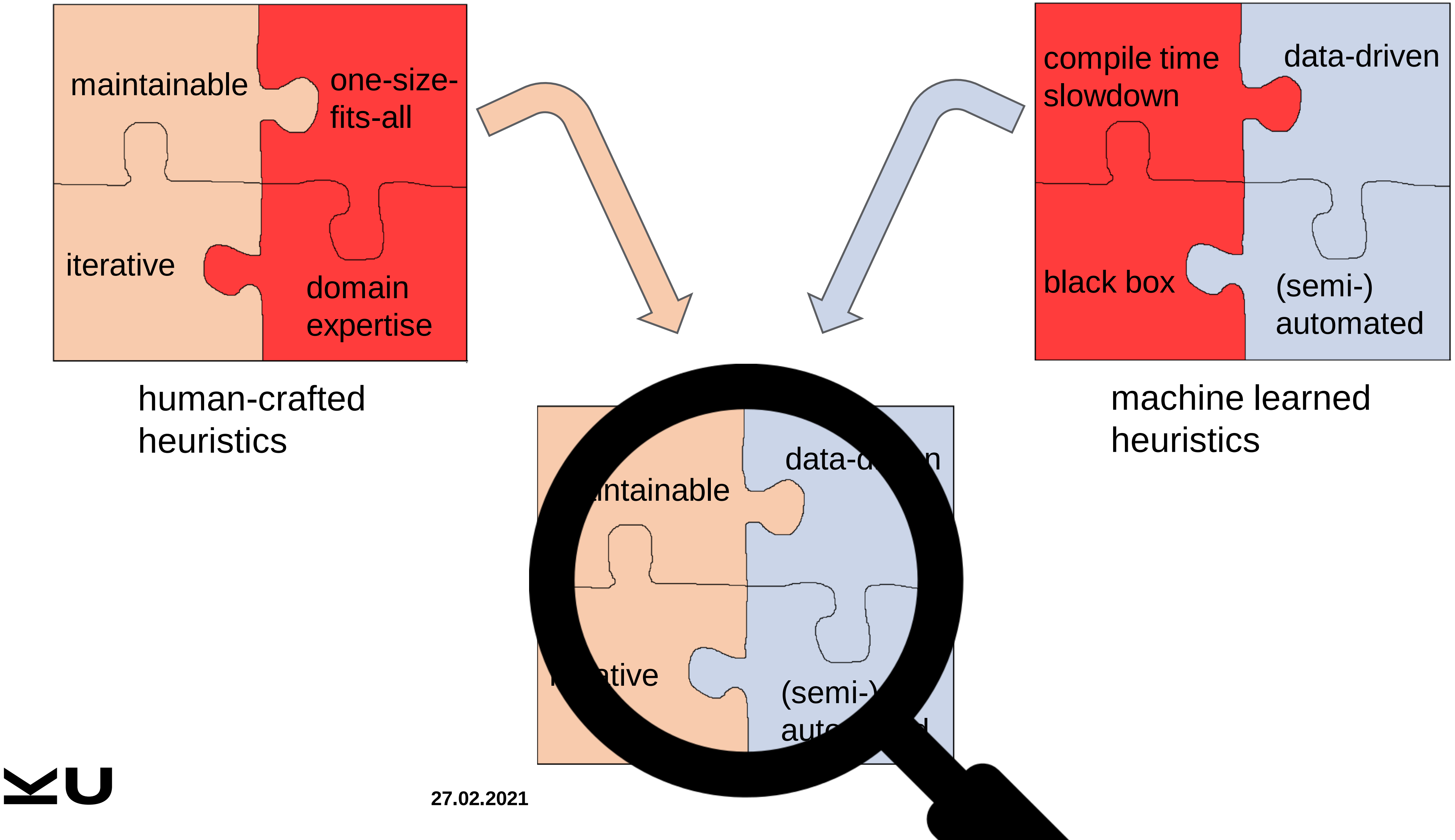

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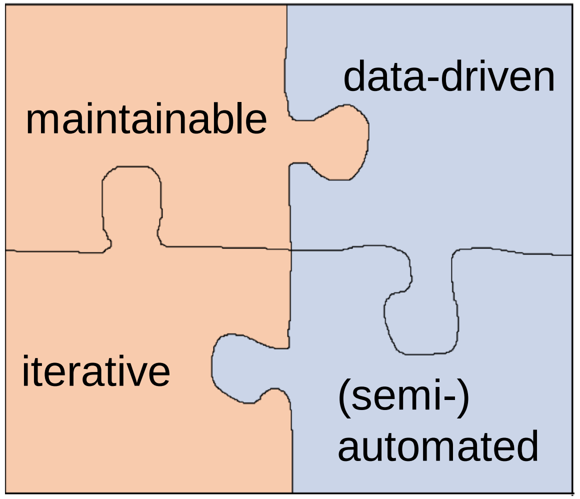

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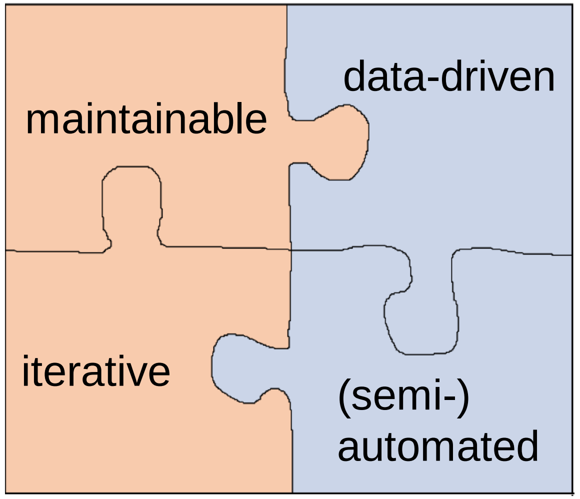

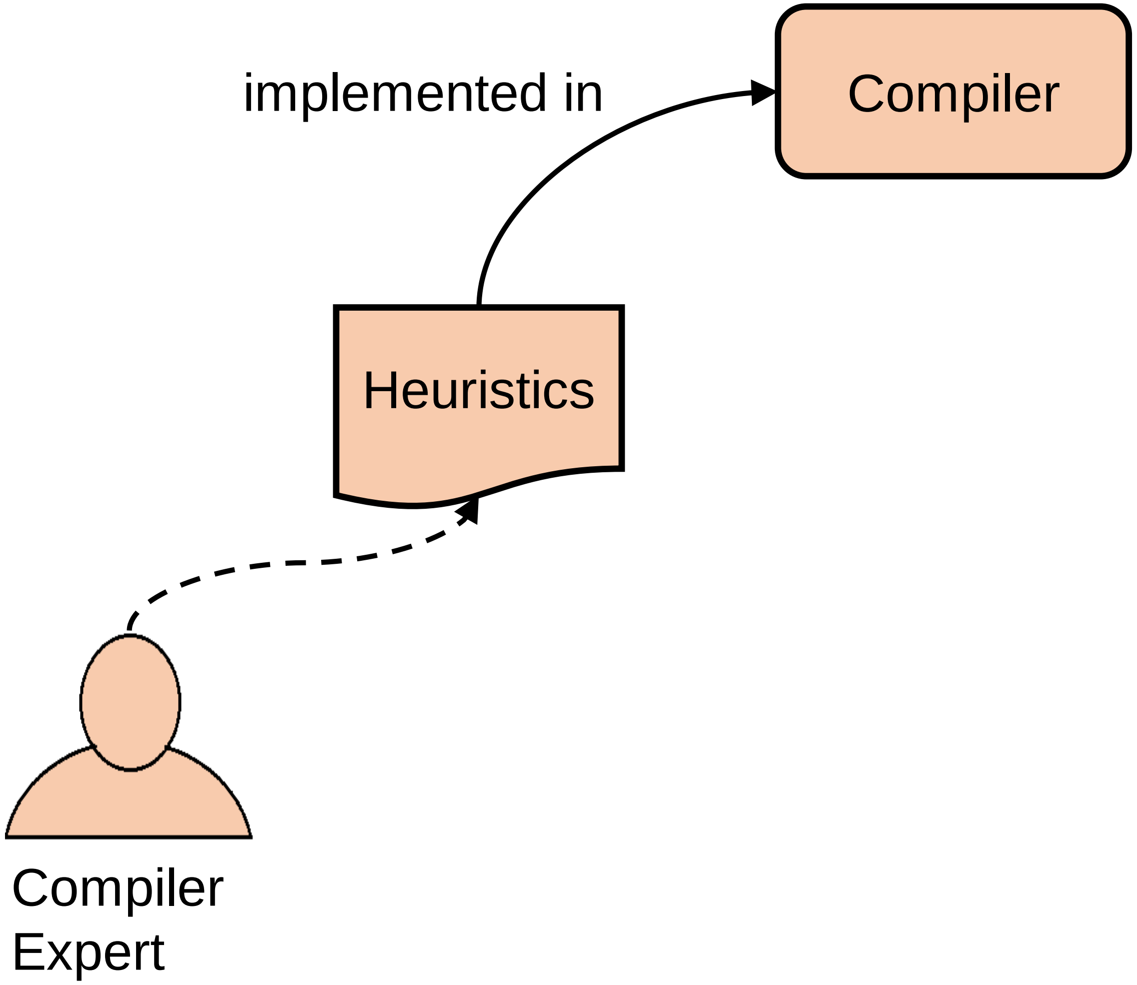

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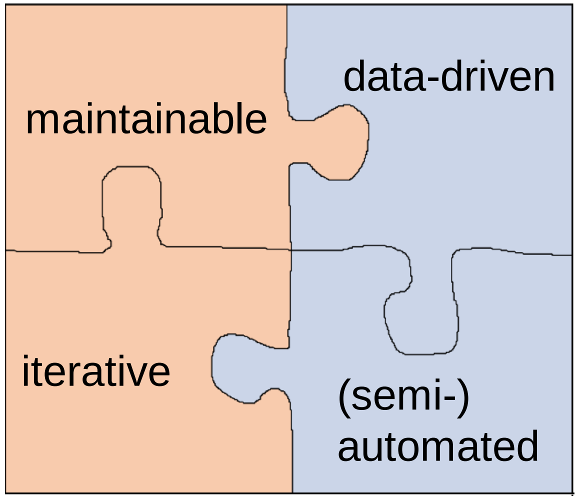

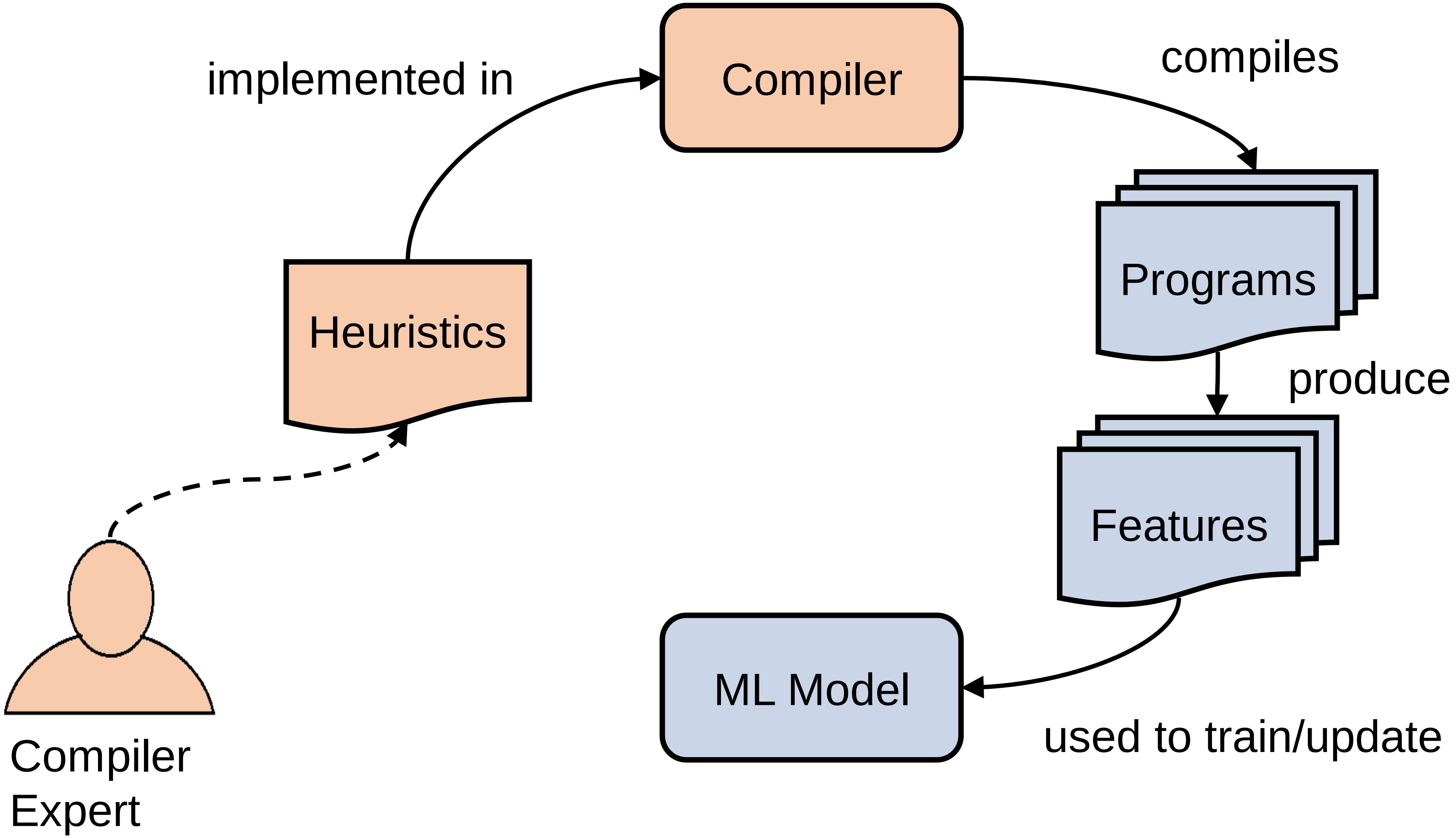

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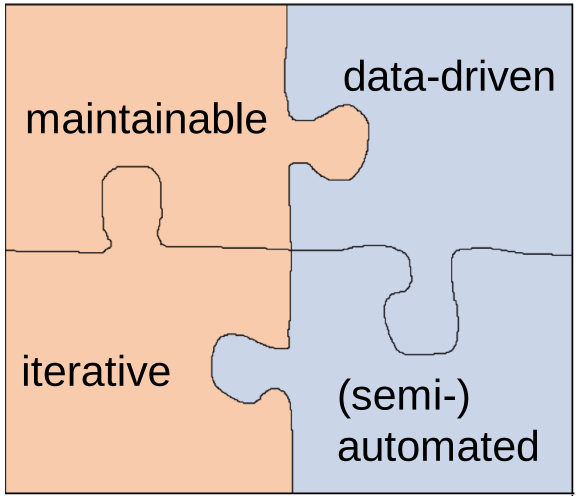

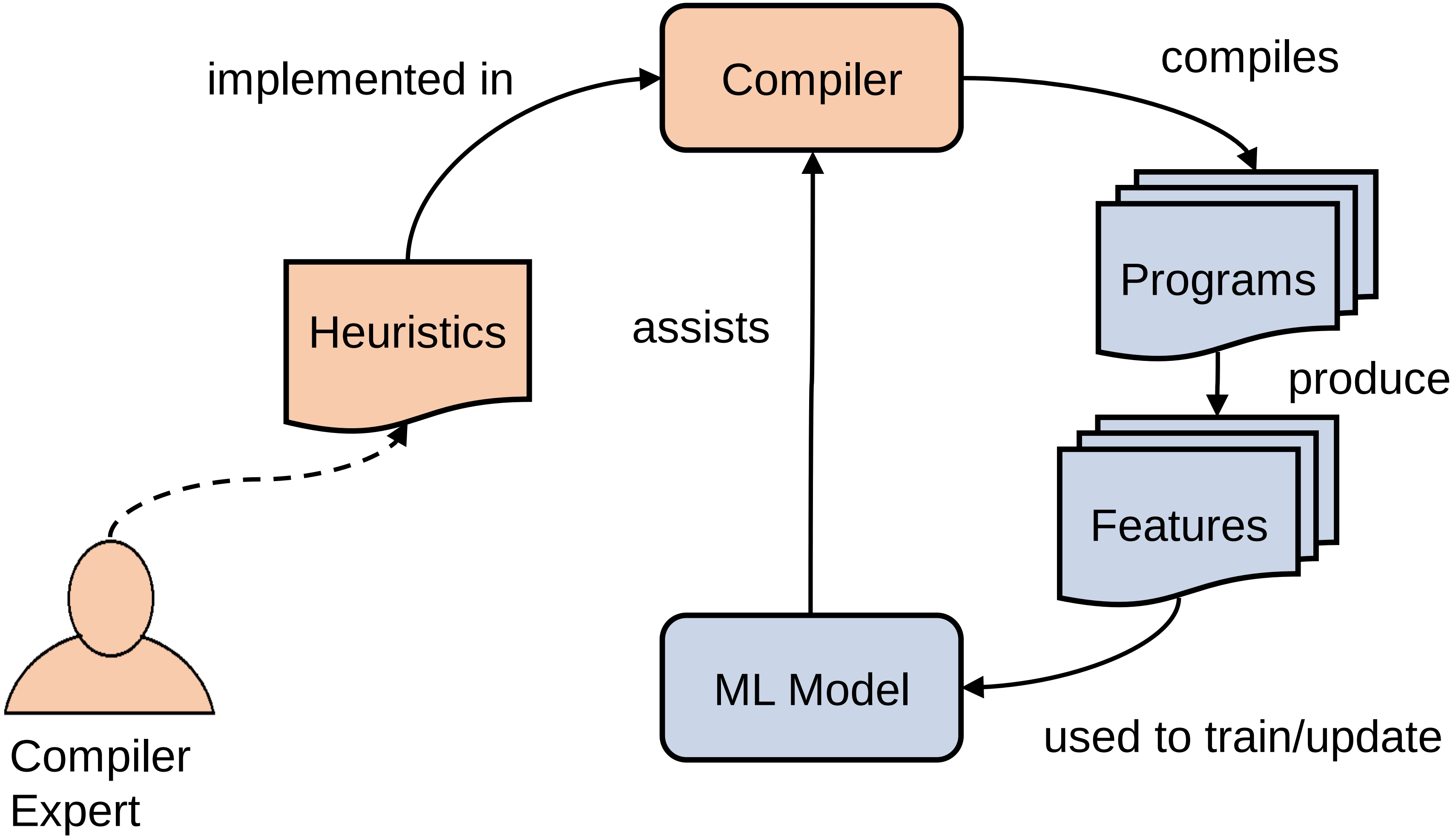

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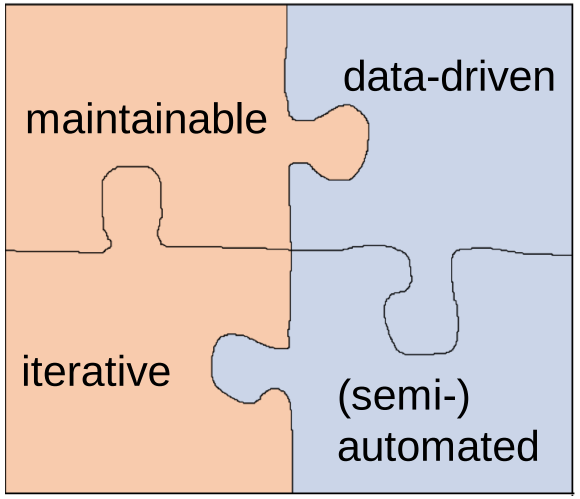

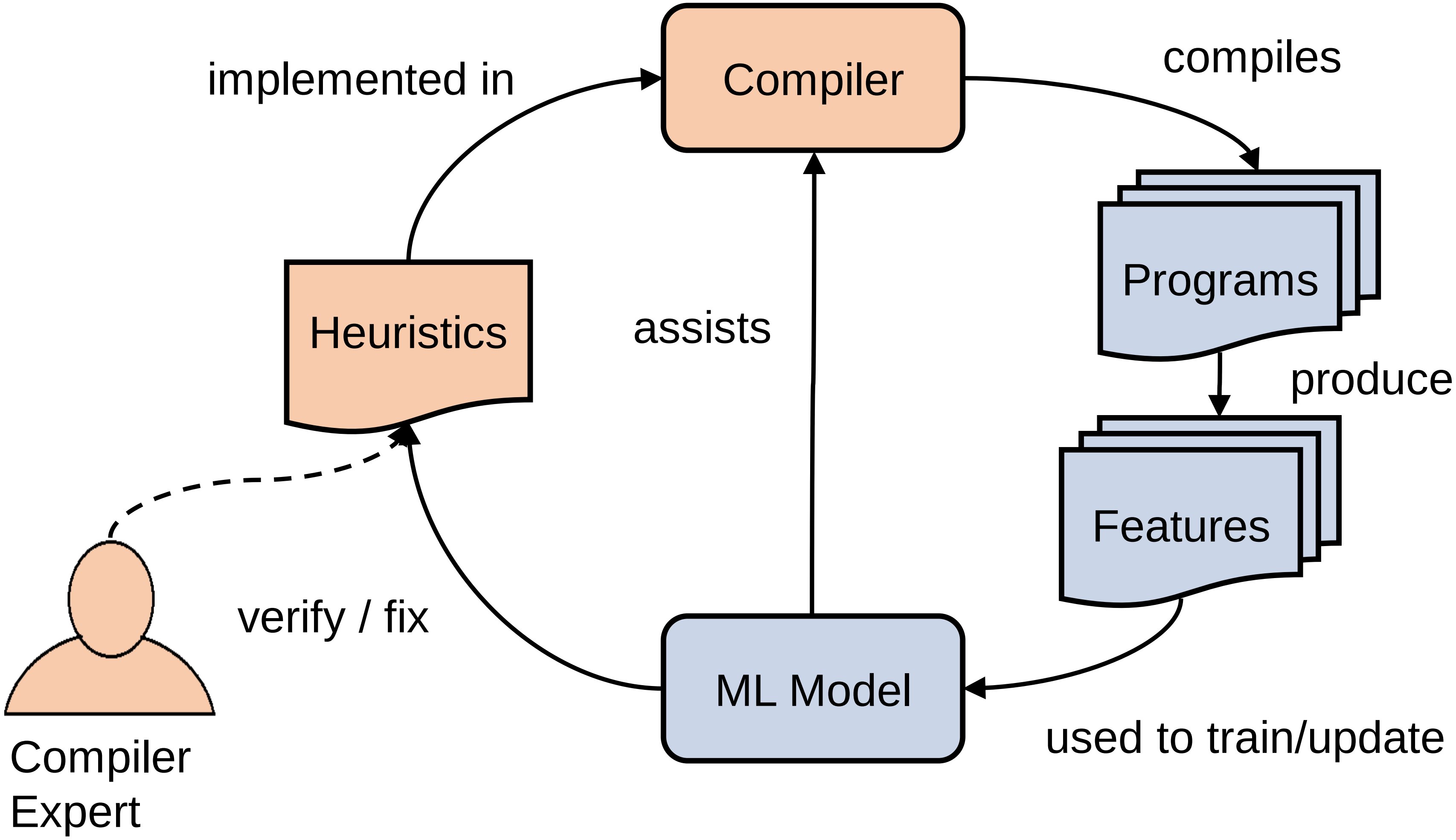

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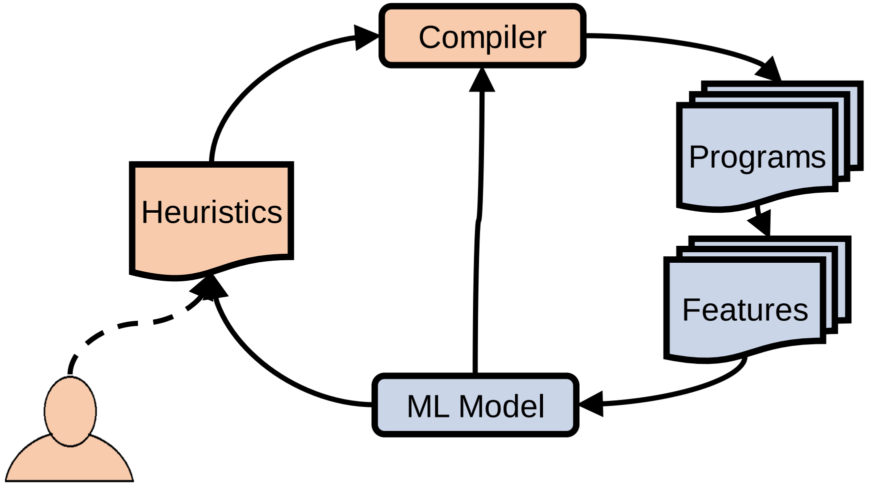

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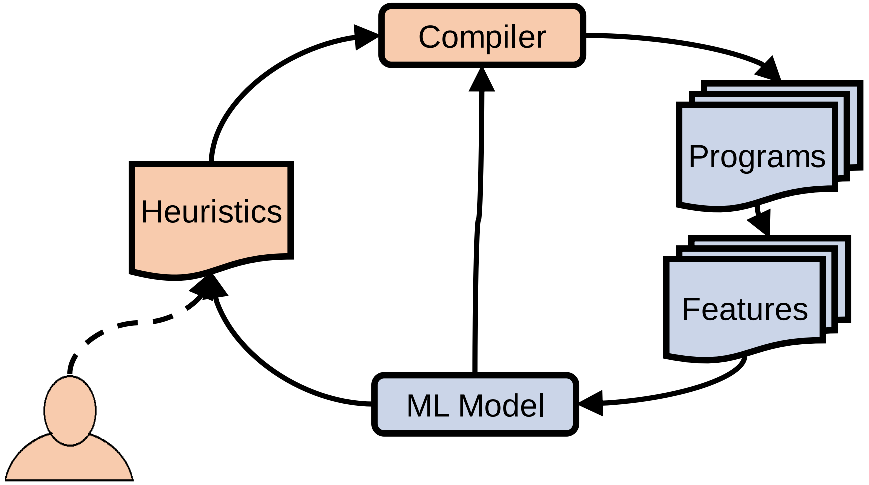

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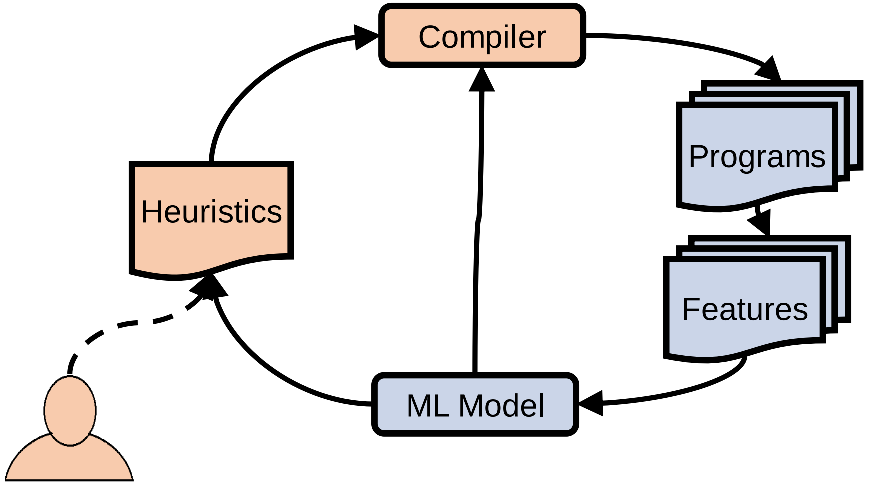

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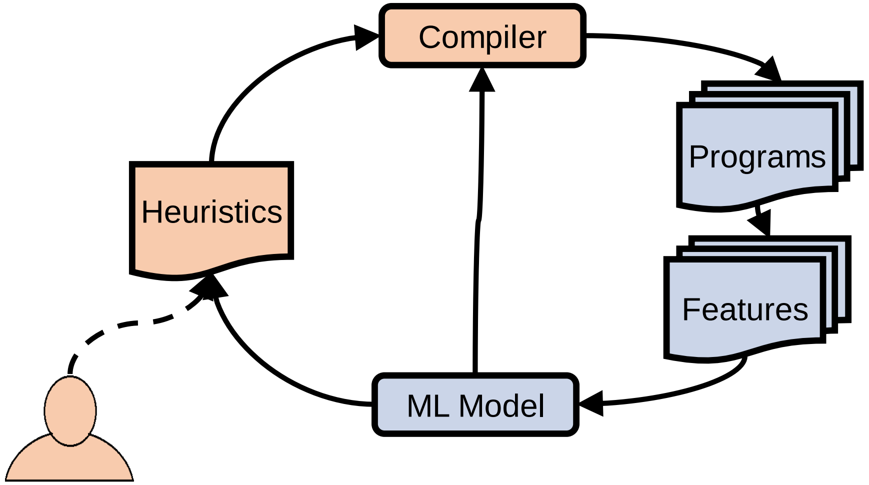

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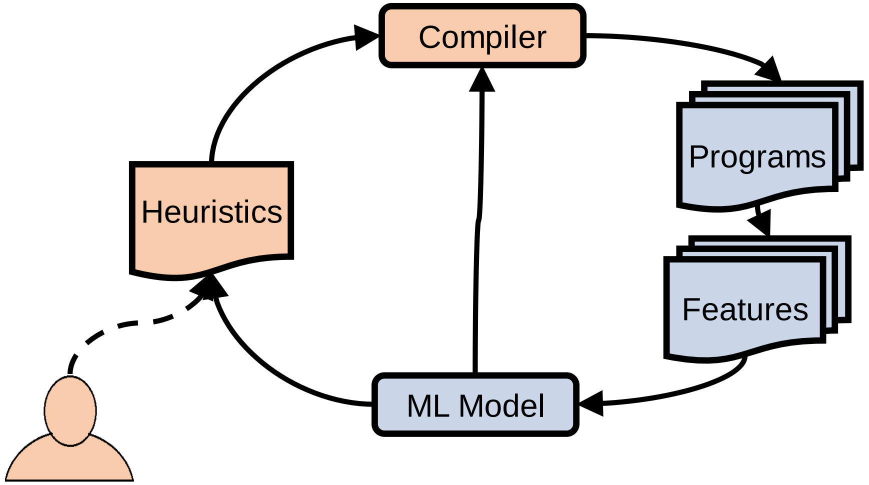

data guided

CASE STUDY:
DUPLICATION IN THE GRAAL COMPILER

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… to enable further optimizations.

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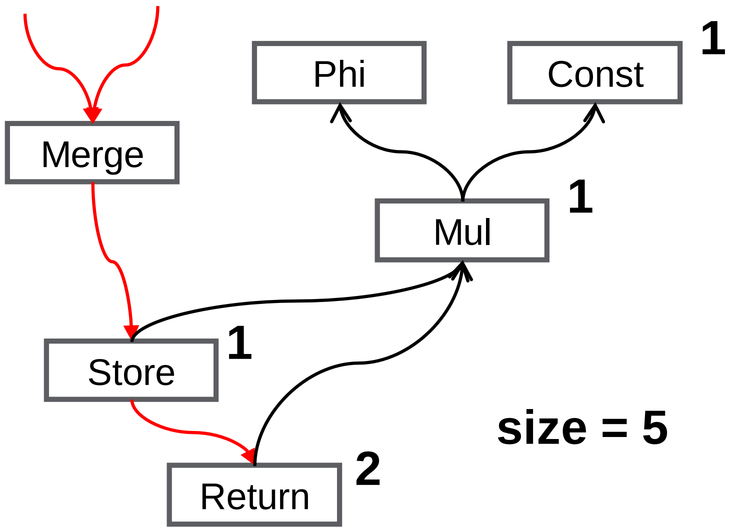

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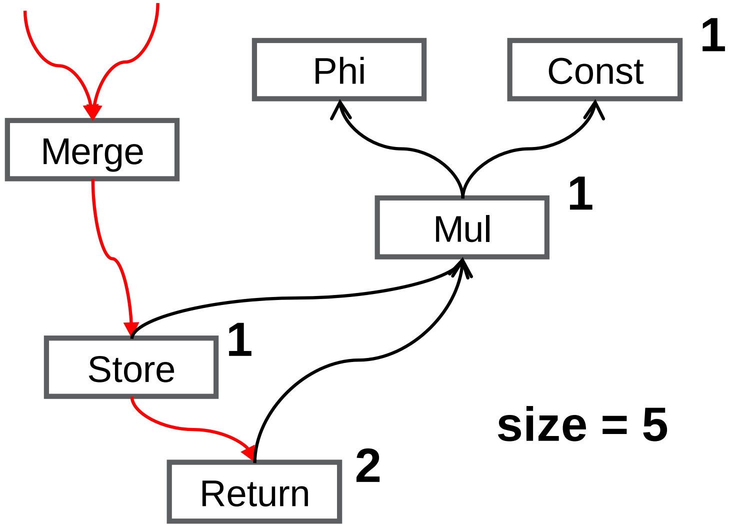
  - □ Execution cycles



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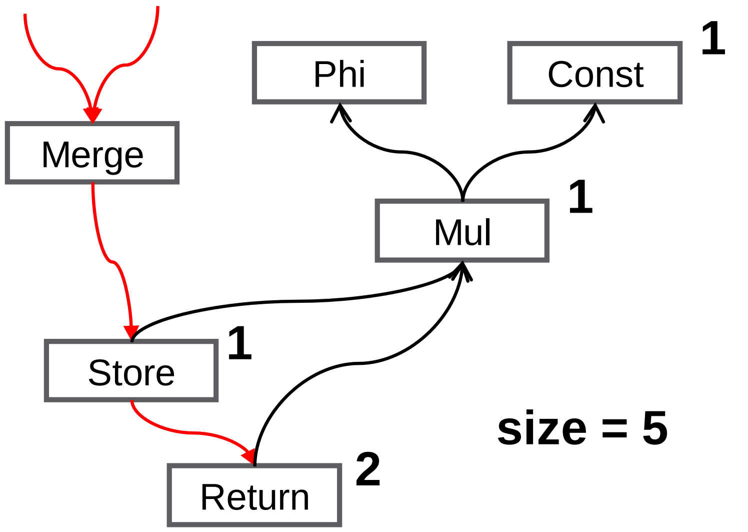

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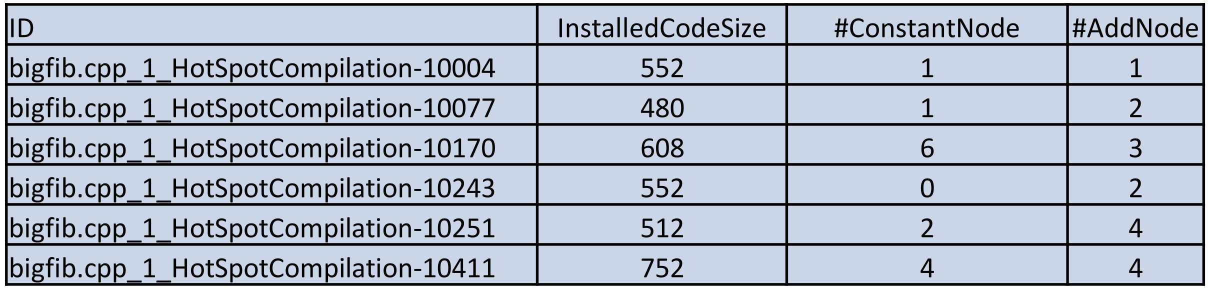
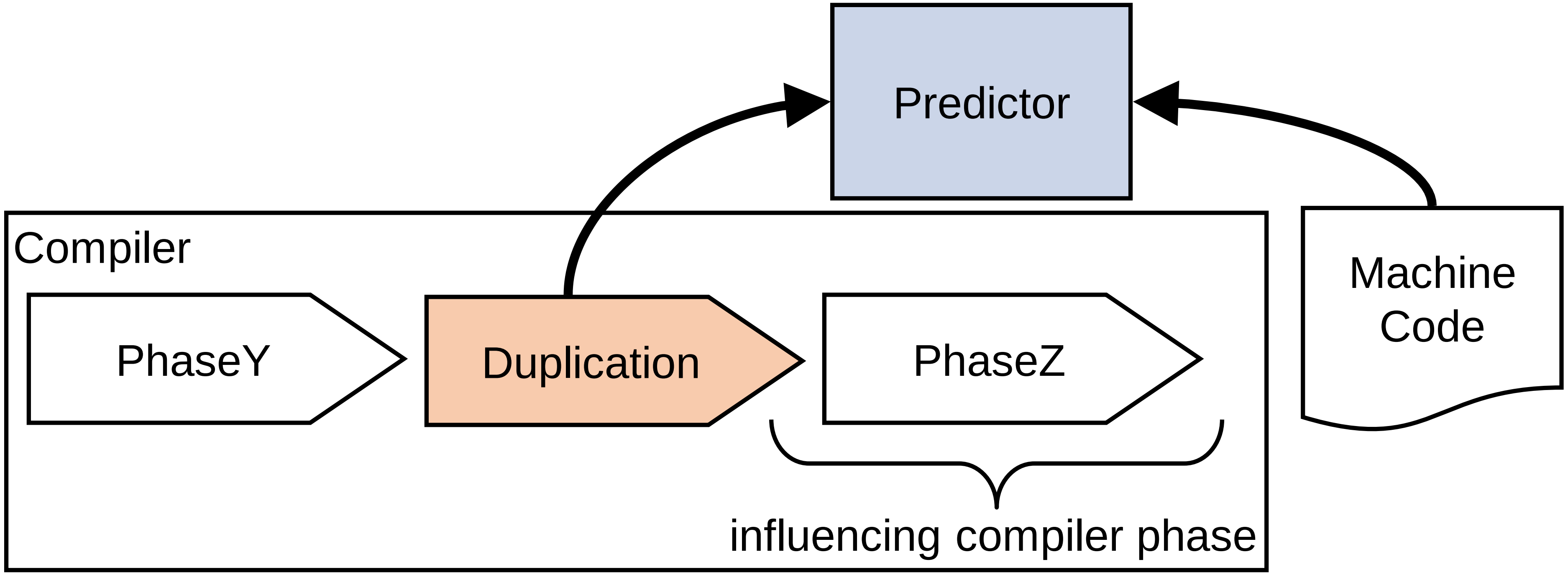
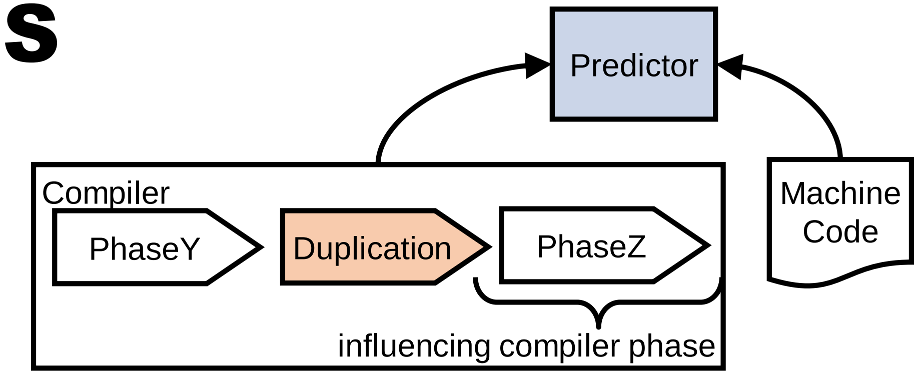


ID	InstalledCodeSize	#ConstantNode	#AddNode
bigfib.cpp_1_HotSpotCompilation-10004	552	1	1
bigfib.cpp_1_HotSpotCompilation-10077	480	1	2
bigfib.cpp_1_HotSpotCompilation-10170	608	6	3
bigfib.cpp_1_HotSpotCompilation-10243	552	0	2
bigfib.cpp_1_HotSpotCompilation-10251	512	2	4
bigfib.cpp_1_HotSpotCompilation-10411	752	4	4

PROBLEM: SUBSEQUENT COMPILER PHASES



PROBLEM: SUBSEQUENT COMPILER PHASES



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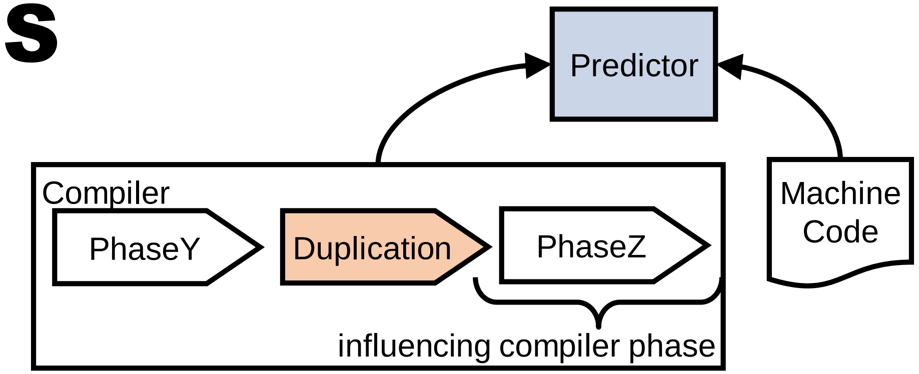
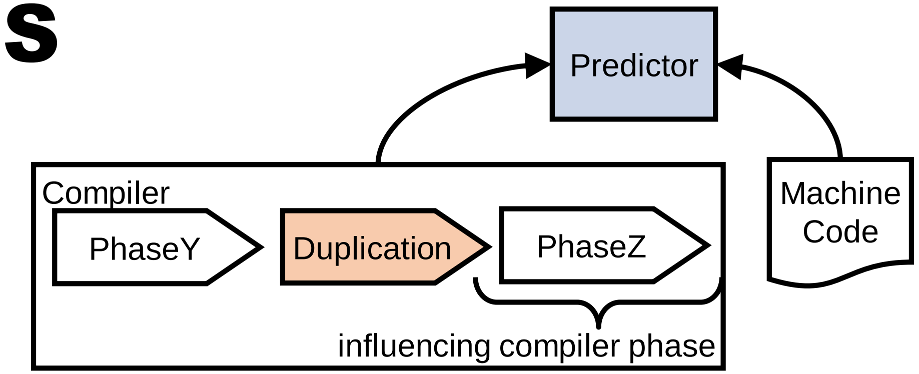


- Transformations on IR level wreck linear relation between nodes and final code size

PROBLEM:
SUBSEQUENT COMPILER PHASES



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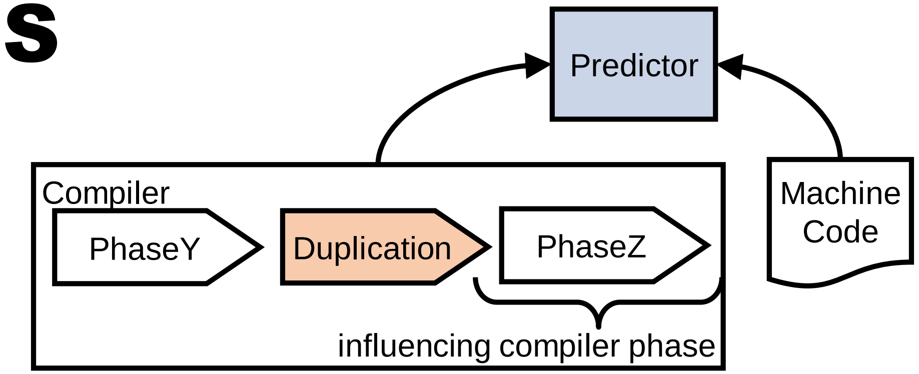
- Linear regression model mispredicts code size impact

PROBLEM: SUBSEQUENT COMPILER PHASES



- Transformations on IR level wreck linear relation between nodes and final code size
- Linear regression model mispredicts code size impact
- Requires non-linear predictor to account for intermediate compiler phases

ANN PREDICTOR

- Trained a simple ANN on benchmarks
  - dacapo, scala-dacapo, octane, jetstream, renaissance

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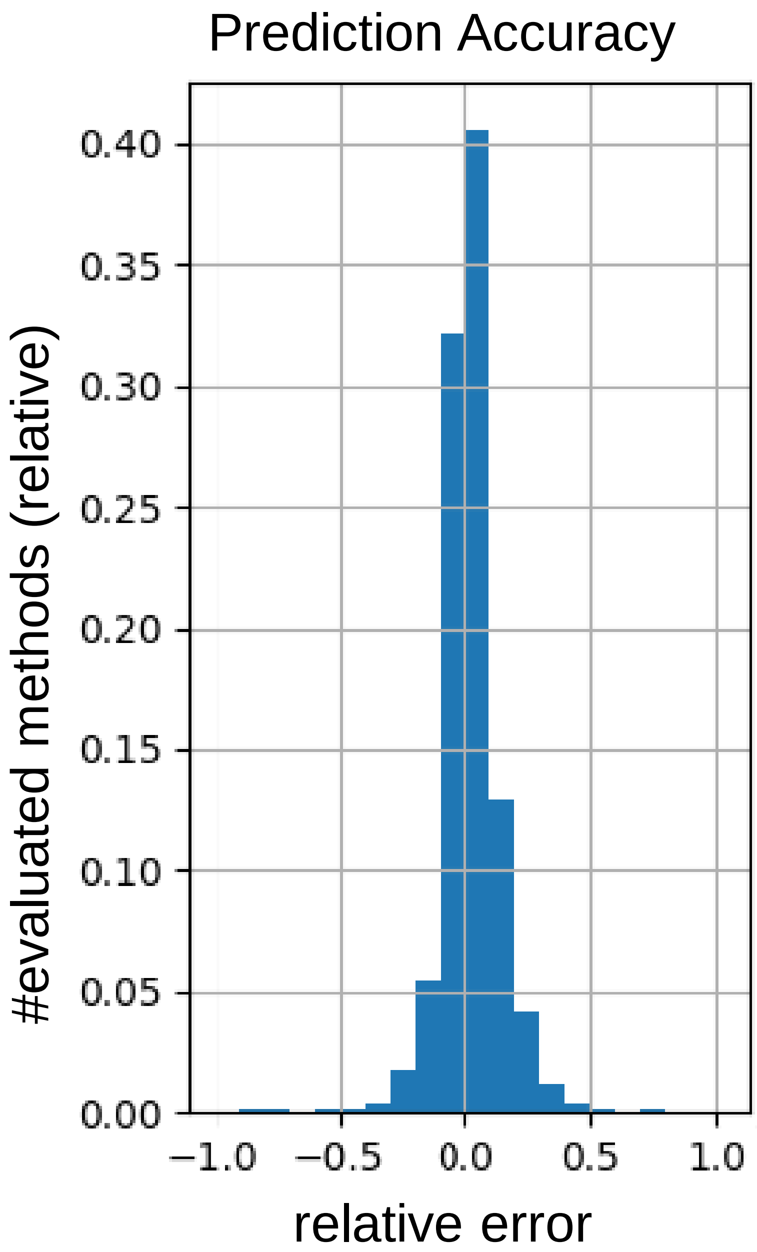

ANN PREDICTOR

- Trained a simple ANN on benchmarks
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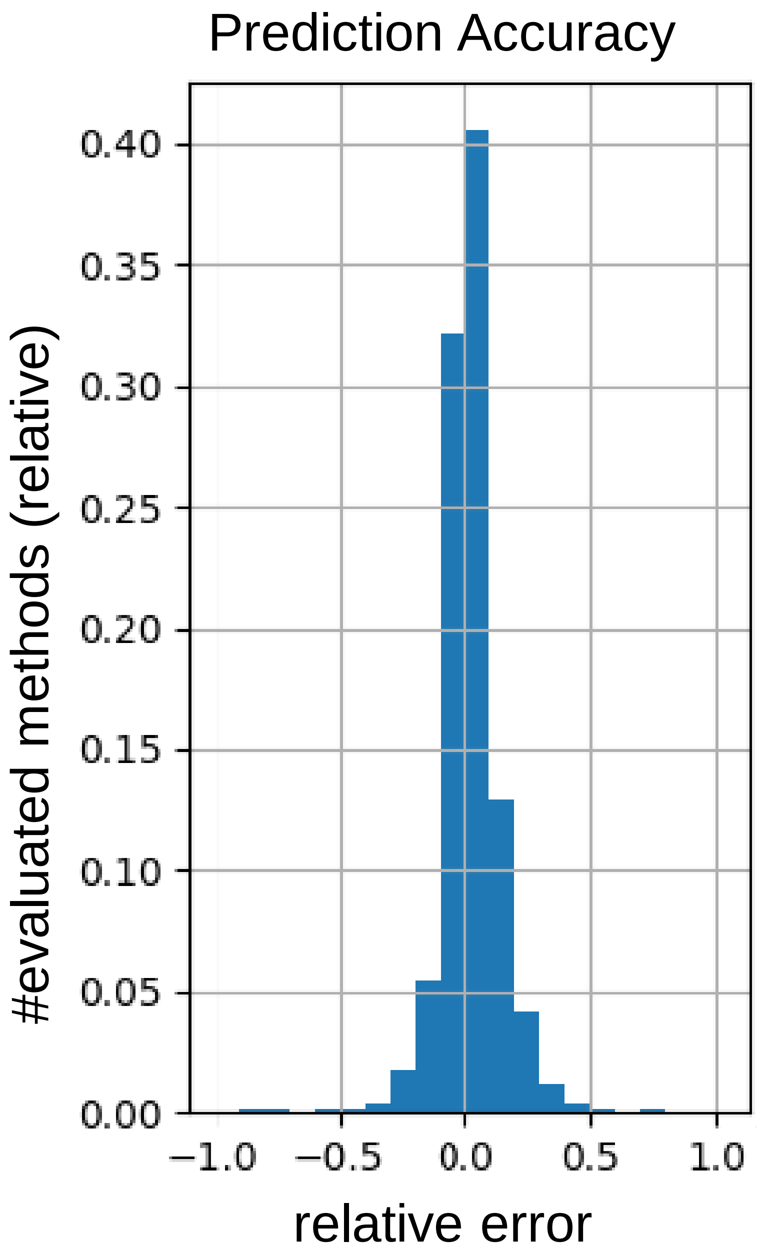
- Accurately predicts code size impact
  - 3 out of 4 predictions have **errors <10%**



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- Accurately predicts code size impact
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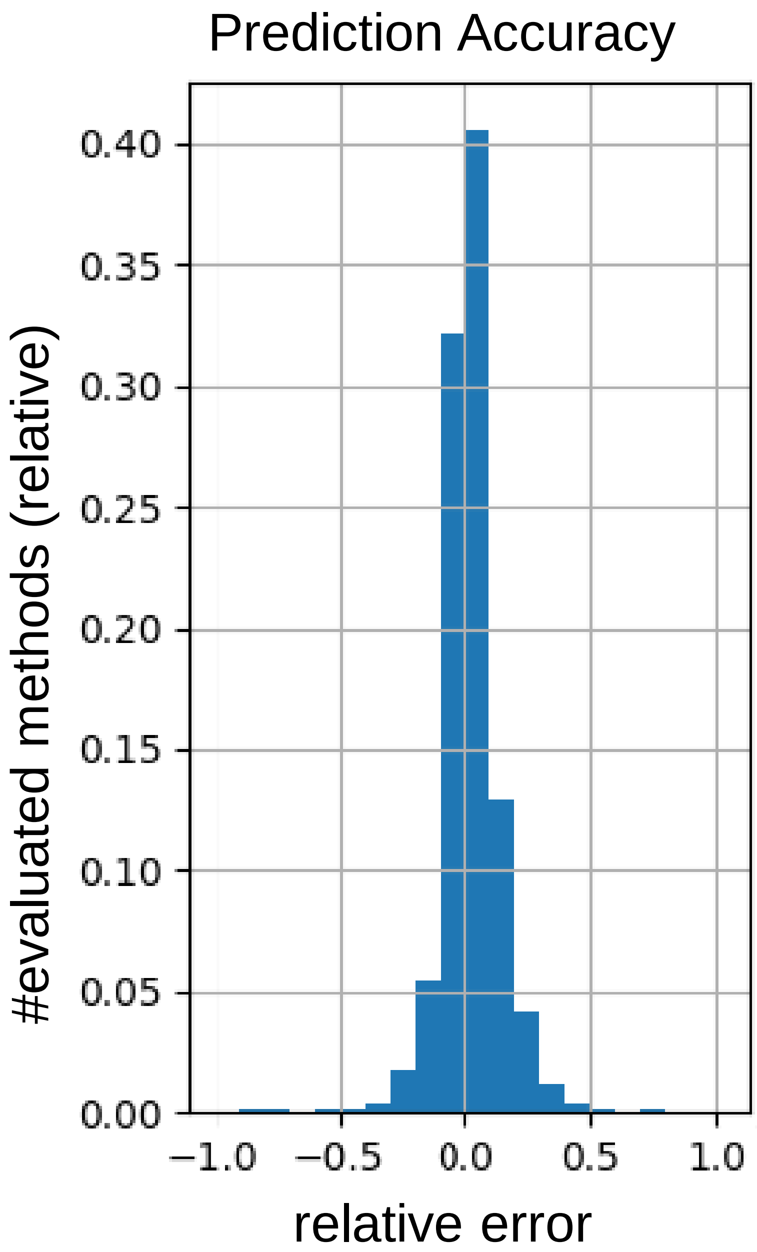
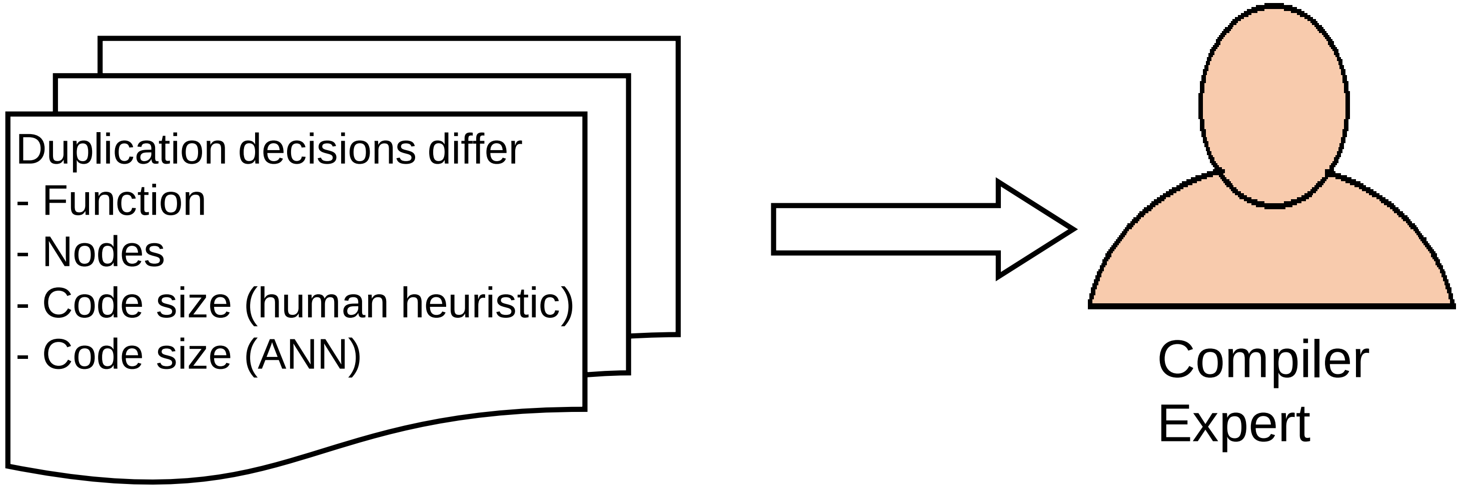
- Implemented a prototype predictor in the Graal compiler



PRODUCING HELPFUL OUTPUT

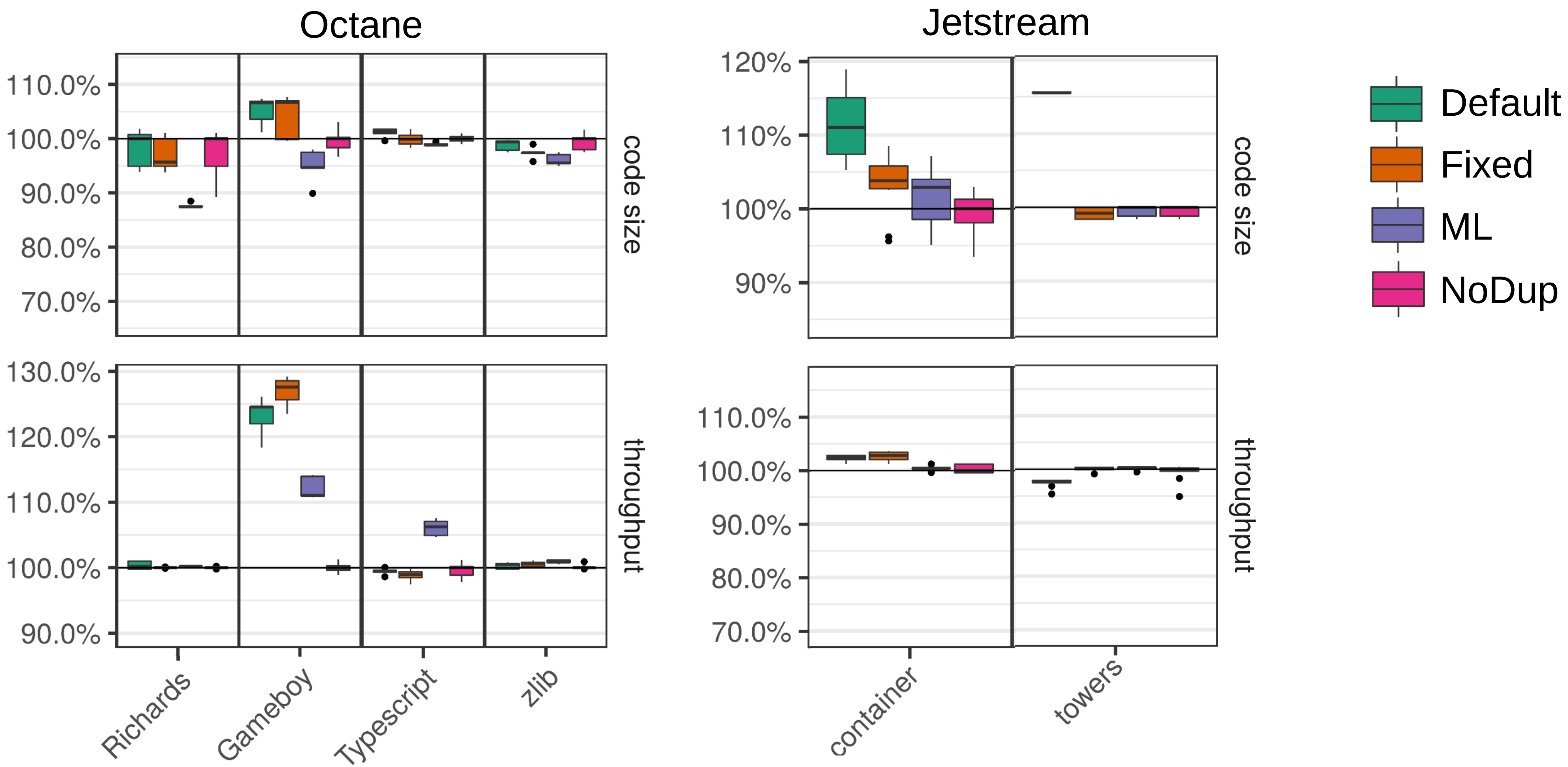
- Analysis mode in Graal
  - Prints differences in duplication decisions based on human model vs. learned model
  - Results provided to compiler expert



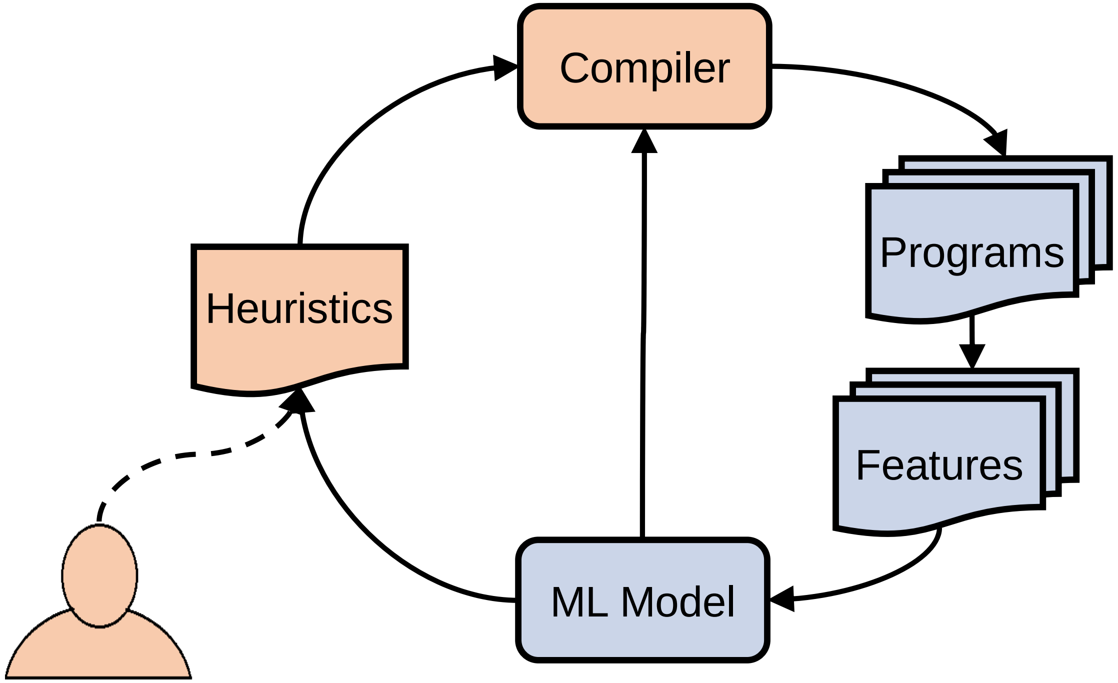
Duplication decisions differ
- Function
- Nodes
- Code size (human heuristic)
- Code size (ANN)

Compiler
Expert

BENCHMARK PERFORMANCE (SELECTION)



IMPROVING COMPILER OPTIMIZATIONS BY EMPLOYING MACHINE LEARNING



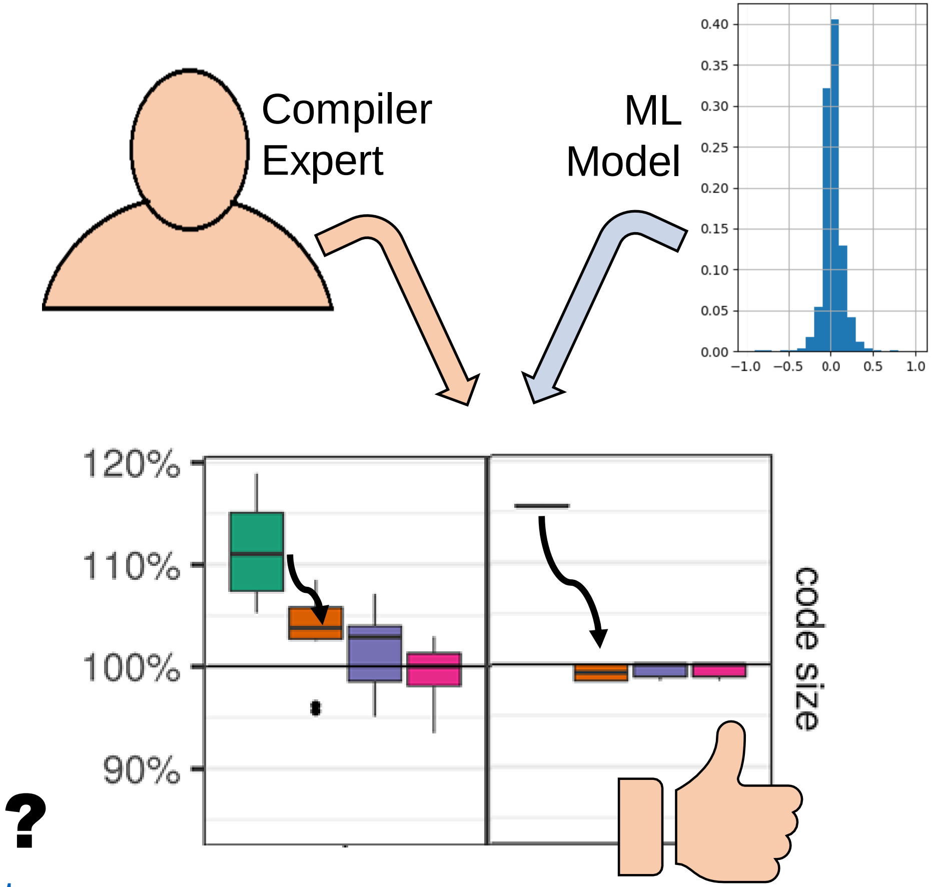
Compiler

Programs

Features

ML Model

Heuristics



Compiler Expert

ML Model

QUESTIONS ?

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