HI-CFG:

Construction by Dynamic Binary Analysis, and Application to Attack Polymorphism

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Recovering Information

Knowledge of information (data) flow and control flow of an application crucial for analysis

- Current tools focus on just one type of flow

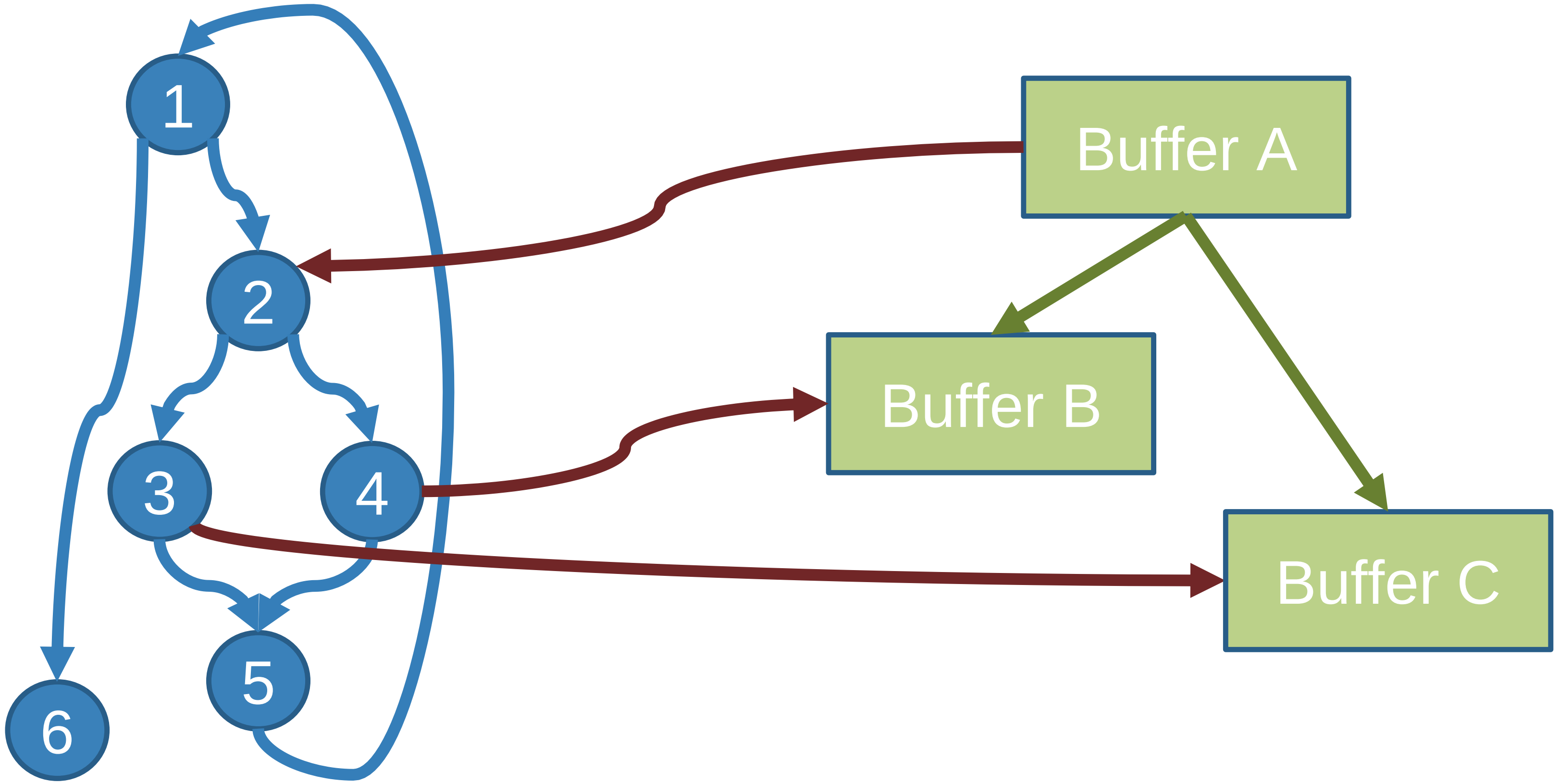
Combine information flow and control flow into high-level data structure

- Hybrid, Information- and Control-Flow-Graph (HI-CFG) using binary analysis

HI-CFG Overview

CFG view

Data flow view



Outline

Motivation

Attack Polymorphism

Dynamic HI-CFG Construction

Evaluation

Conclusion

HI-CFG: Attack Polymorphism

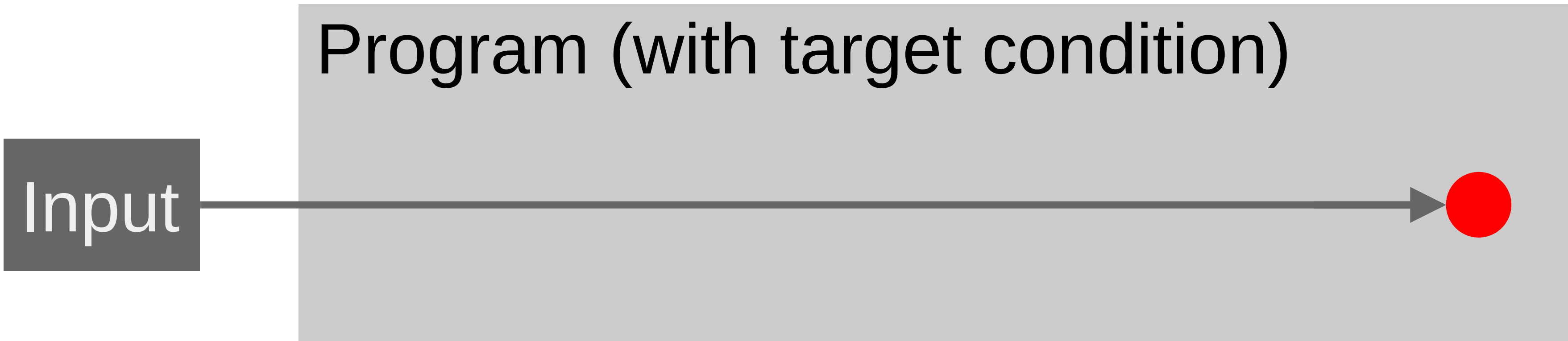
Step one: phase partitioning

- Divide a computation into steps that transform data from an original input to an internal format
- Based on HI-CFG buffers, information-flow and producer/consumer edges

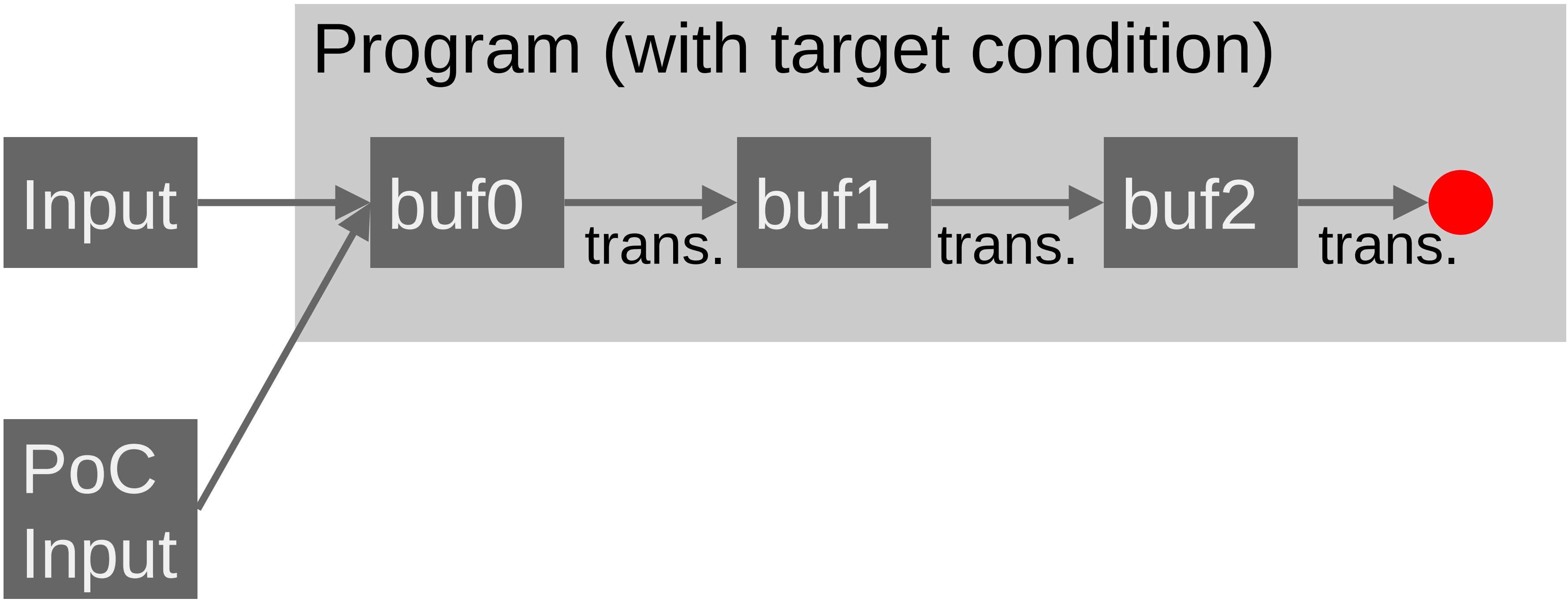
Step two: phase aware input generation

- Aim is to produce an input that triggers a vulnerability deep within a program
- Use phase structure to divide and conquer
- Symbolic execution with search pruning

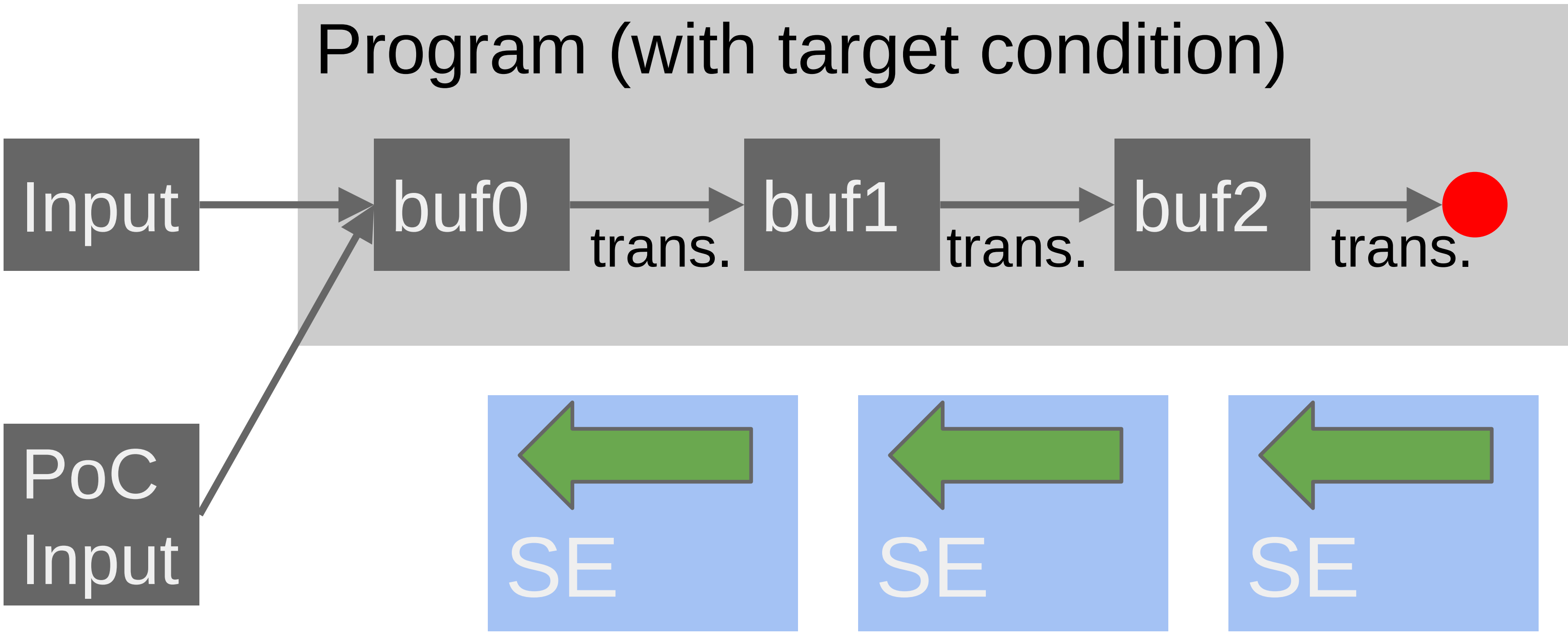
HI-CFG: Attack Polymorphism



HI-CFG: Attack Polymorphism



HI-CFG: Attack Polymorphism



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HI-CFG: trace-based construction 1/3

Trace enables us to recover both control-flow and information-flow of an application using some concrete input

1. Start with specific input data
2. Collect an instruction level trace (TEMU)
3. Process the traces to create a HI-CFG

HI-CFG: trace-based construction 2/3

Work through the execution trace and group "***related***" memory accesses

- Categorize buffers hierarchically
- Conservative and taint-based information flow

Grouping heuristics

- Instructions use same base pointer
- Temporally and spatially correlated memory accesses

HI-CFG: trace-based construction 3/3

Apply graph partitioning algorithms to divide the HI-CFG at "***natural***" boundaries to separate code and data structures

- Extract functionality into separate modules for reuse or transformation

No source info needed, except addresses of `malloc/calloc/free`

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- Scalable Symbolic Execution
- Poppler Case Study

Conclusion

Scalable SE is key

Vulnerability detection

- Both in malware and legit applications

Model extraction

- Automatically learn security-relevant models

Binary code reuse

- Identify interface and extract components

Evaluation setup

Simple transformation

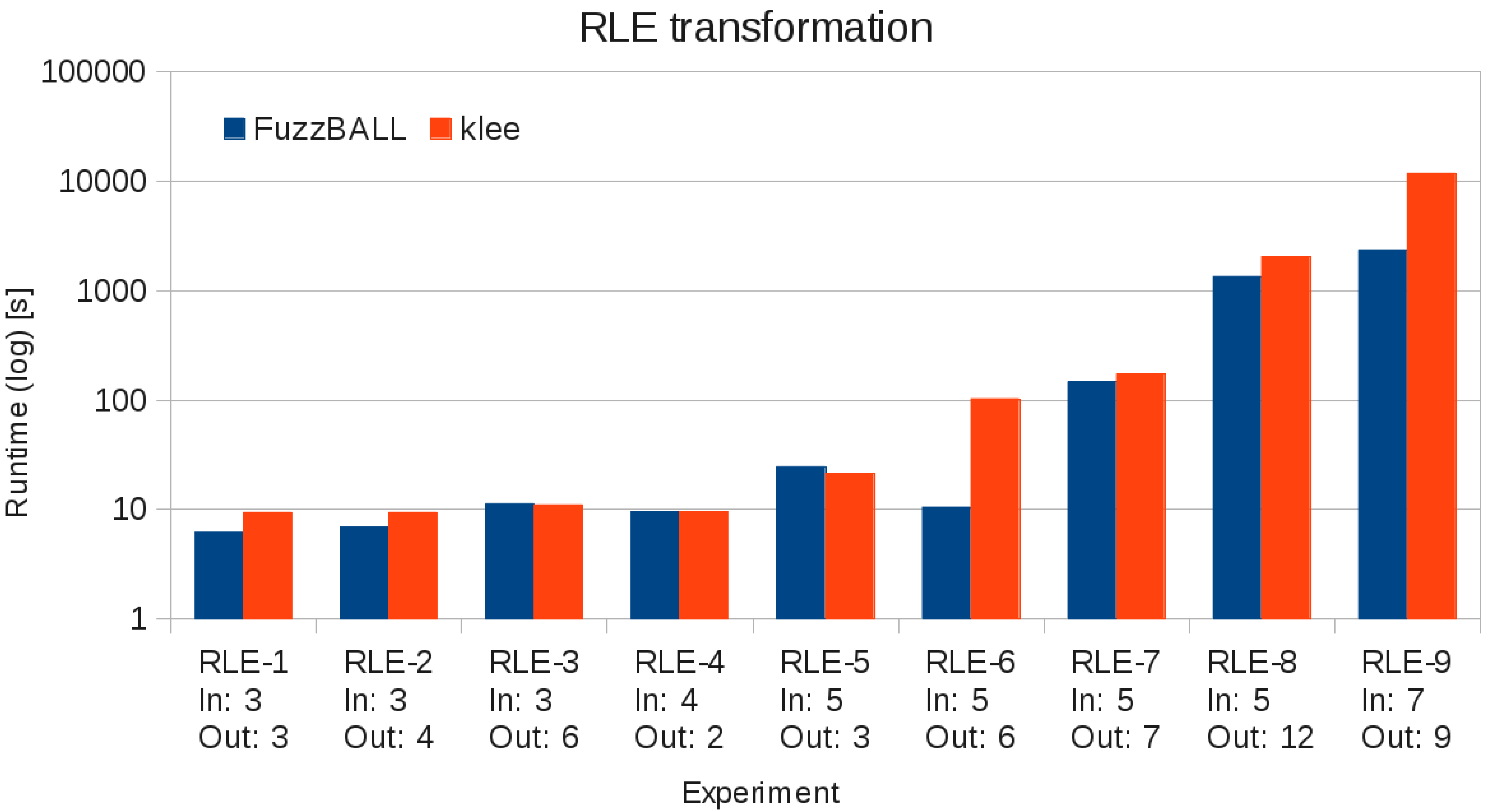
- RLE decoding
- Output as target, SE produces input

Configurations

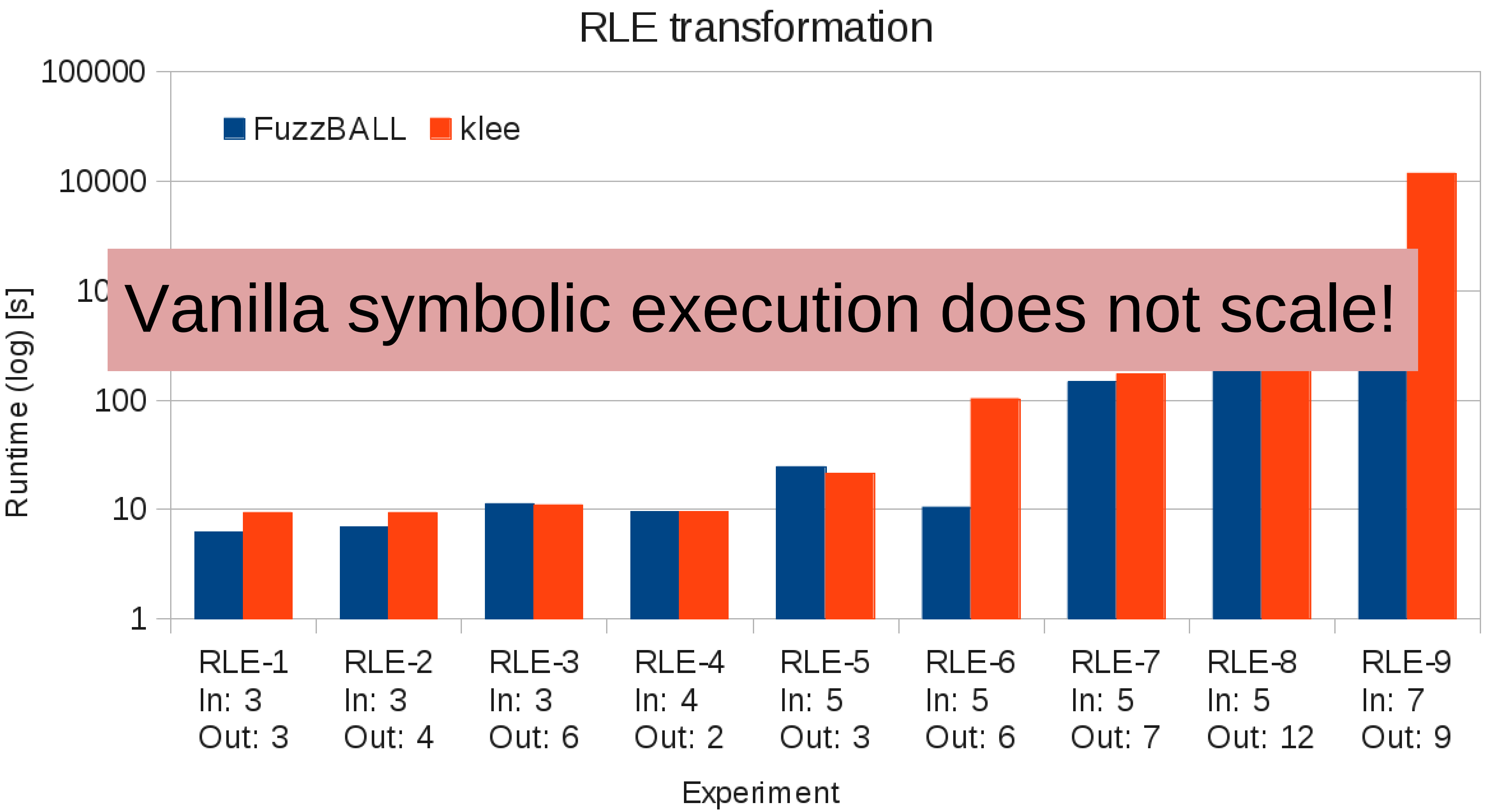
- KLEE
- FuzzBALL

Detailed results from TR Berkeley/EECS-2013-125

Limitations of SE



Limitations of SE



Vanilla symbolic execution does not scale!

Transformation-aware SE

Computations rely on input transformations

Focus on transformations to reduce complexity

- Surjectivity guarantees existing pre-image
- Sequentiality ensures output is never revoked
- Streaming bounds the transformation state

Covered transformations include decryption, decompression, escape sequences, image or sound decoding

Feedback-guided optimization (FGO)

Search pruning

- if target "***unreachable***"

Search prioritization

- look for short inputs that maximize size of output

Symbolic array accesses

- treat choice of index like a branch (baseline)
- combine all possible values into formula

Evaluation setup

Simple transformation

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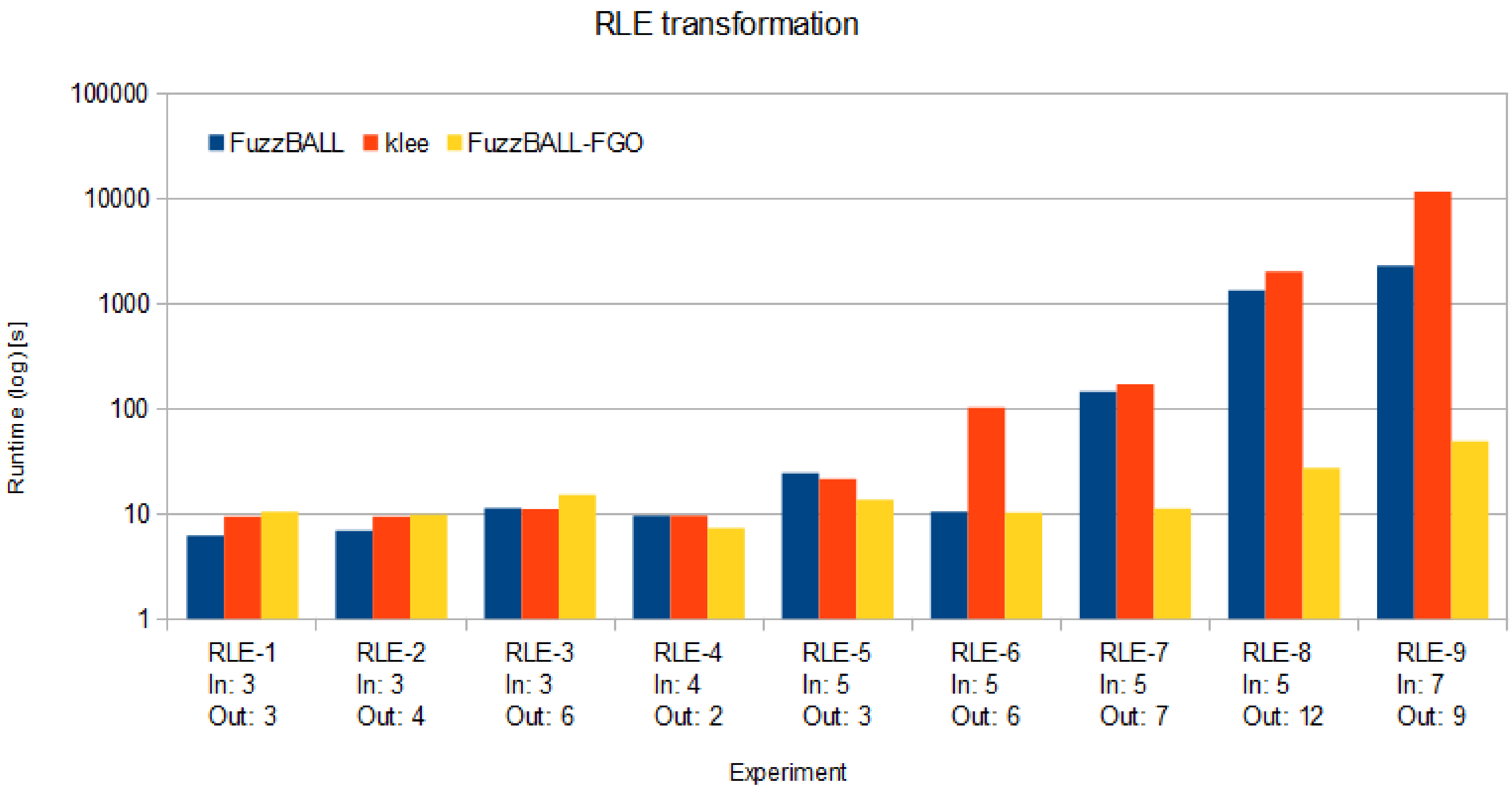
Configurations

- KLEE
- FuzzBALL
- FuzzBALL-FGO

FGO: 1 order of magnitude



Transformation-aware SE

Divide-and-conquer strategy for SE

- HI-CFG captures transformations
- Split SE on transformation boundaries

Evaluation setup

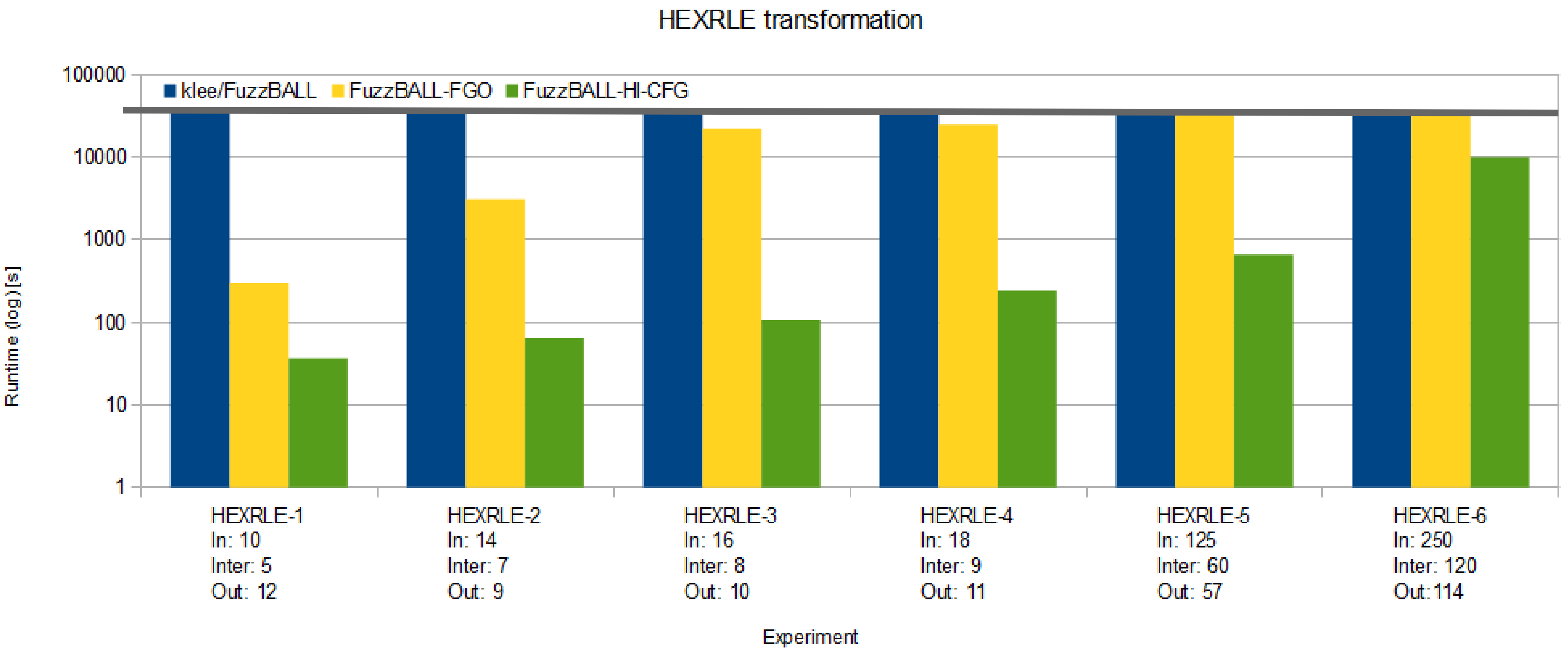
Two transformations

- HEX decoding
- RLE decoding

Different configurations:

- KLEE/FuzzBALL
- FuzzBALL-FGO
- FuzzBALL-HI-CFG (includes FGO)

Transformation-aware SE: another 1 order of magnitude



Poppler Case Study

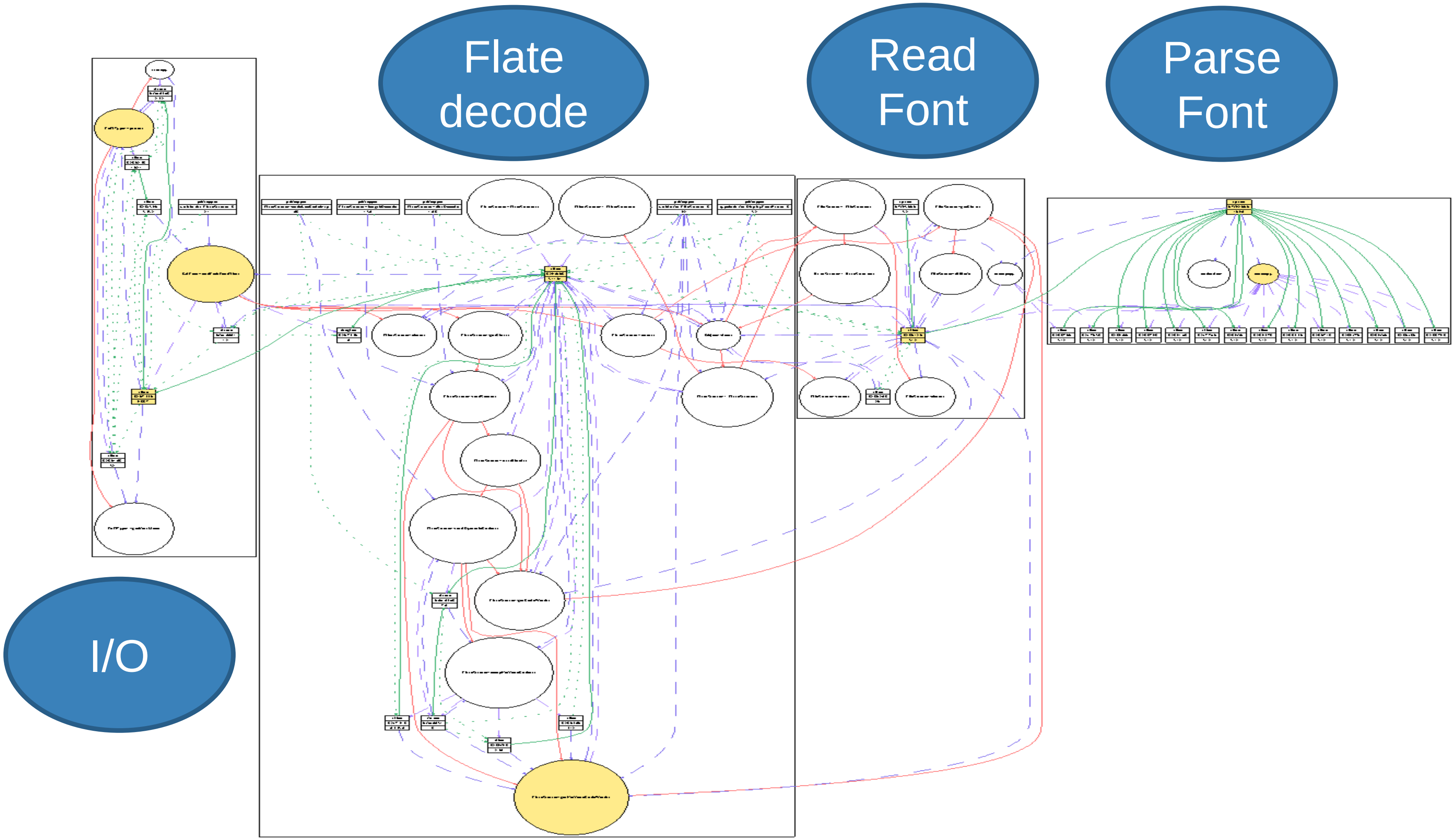
Poppler PDF viewer

- Type 1 font parsing vulnerability CVE-2010-3704

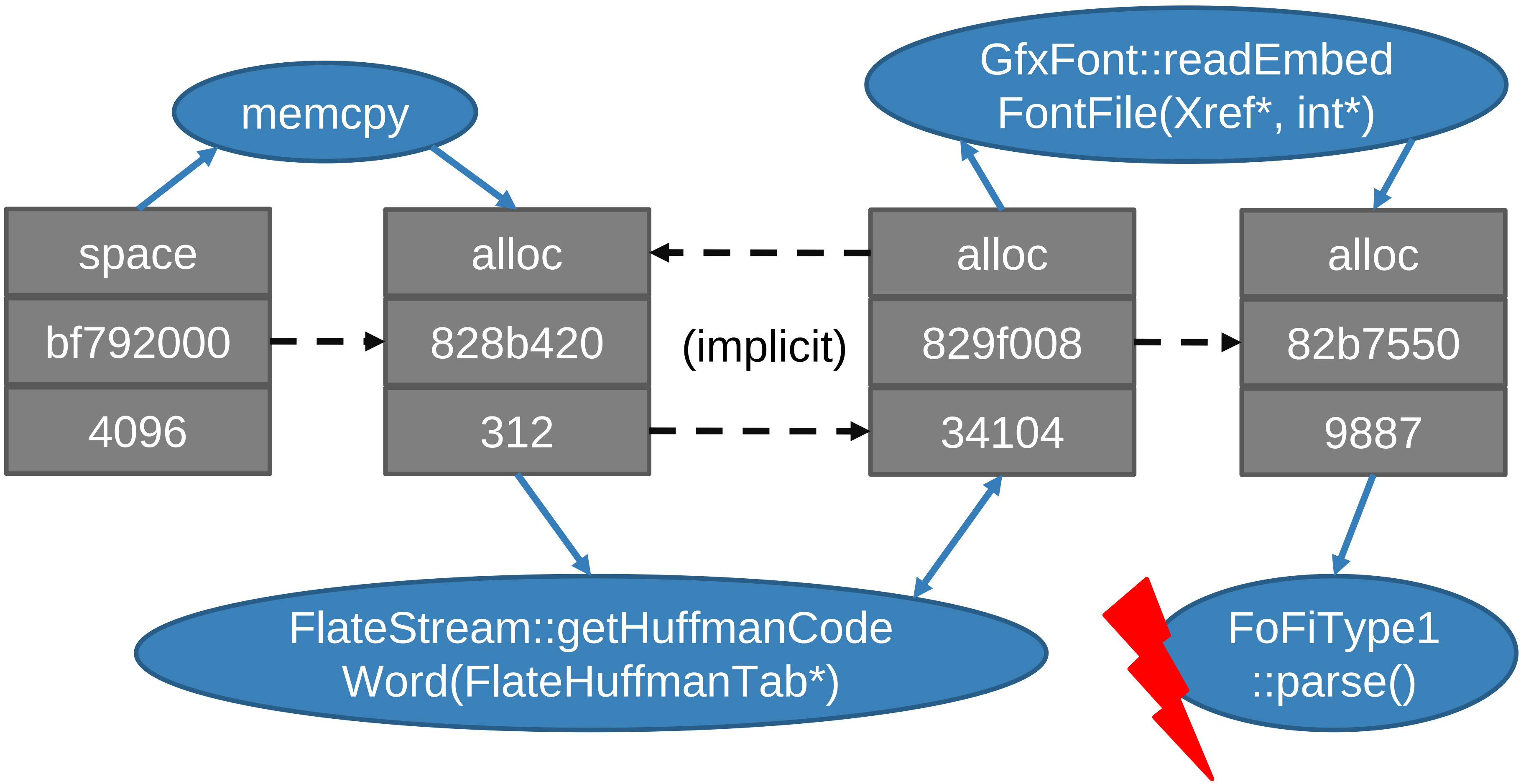
HI-CFG construction using benign document that loads a font

- PDF generated by pdftex using a small tex file

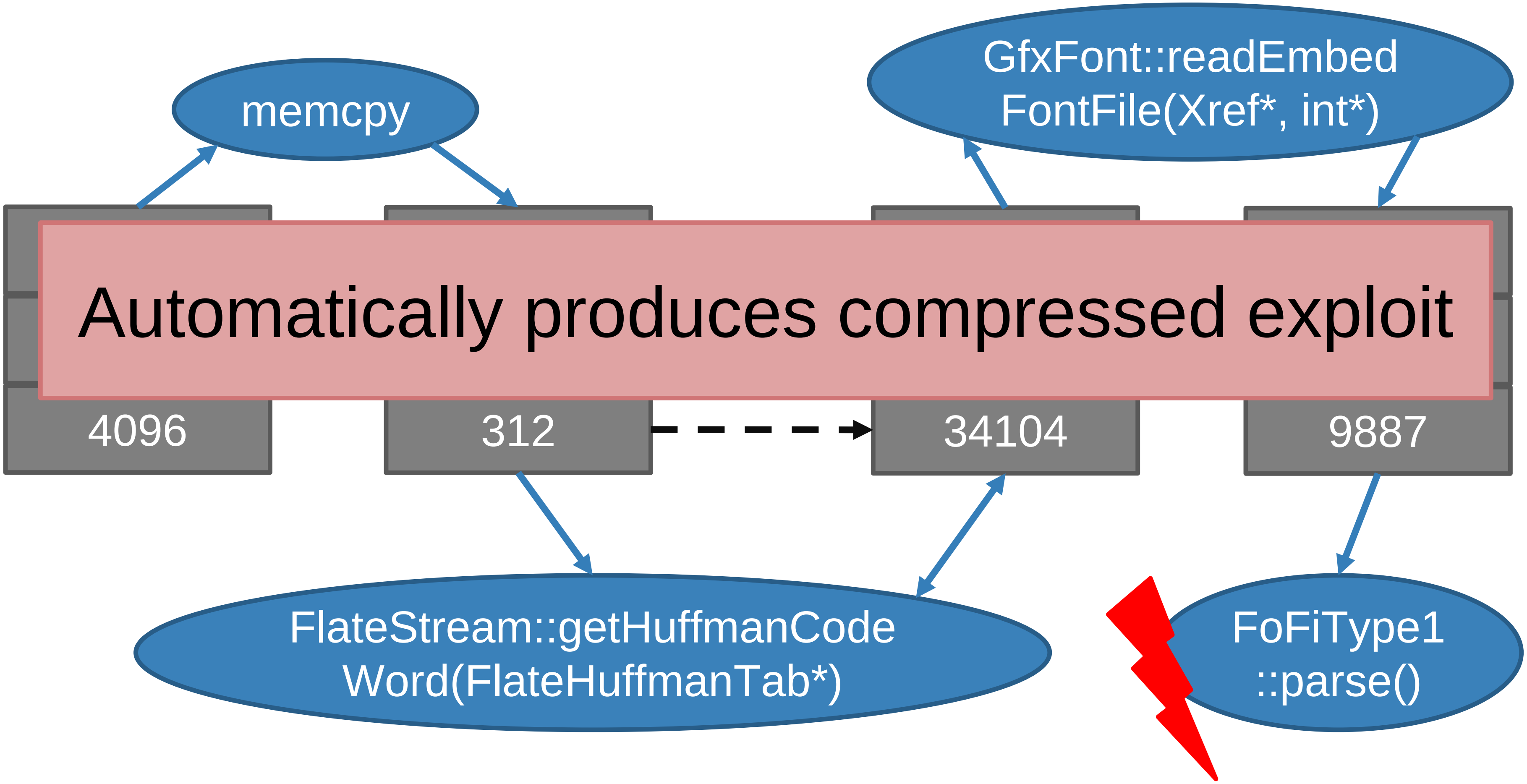
Poppler Phases



Poppler Buffers



Poppler Buffers



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Related Work

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Related Work

HOWARD (Slowinska et al., NDSS’11, ATC12):
Type and data structure inference from binaries

- HI-CFG looks at code & relationships between code and data (not just data structures)

AEG (Avgerinos et al., NDSS’11) and
MAYHEM (Cha et al., Oakland’12):
SE-based attack input generation

- HI-CFG enables focus on iterative and scalable SE (not focus on coverage)

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Presented HI-CFG as new data-structure

- Construction from binary execution traces

HI-CFG enables

- Deep program analysis
- Recover components from binaries
- Guide SE along probable paths

FuzzBALL symbolic execution engine:

- http://github.com/bitblaze-fuzzball/fuzzball