JIT Compilation and Dynamically Typed Languages

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Outline

Dynamic Programming Languages

Dynamic Programming Languages - Introduction

Static

"Stuff" happens at/before compile time

Dynamic

"Stuff" happens at runtime

"Stuff" includes:

- Method binding
- Typing
- Program extension
- Modifying objects/classes

Dynamic Typing vs Static Typing

Static typing: types are checked before runtime, for example Java checks while compiling to bytecode
Dynamic typing: types are checked during runtime, Julia/Actionscript

Optional Typing

Dynamic typing but the programmer can force the type of a variable to be something

JIT Compilation

What is JIT compilation?

Just-In-Time (JIT) compilation is compilation to machine code that happens at runtime.

JIT Tradeoffs

Compilation speed vs. generating performant code

Compiler Optimizations

High-Level Optimization

High-Level Optimization

Optimization that requires knowledge about the language semantics and runtime environment

Examples:

- Type inference
- Method inlining
- Type speculation
- Method specialization
- Object unboxing

Low Level Optimization

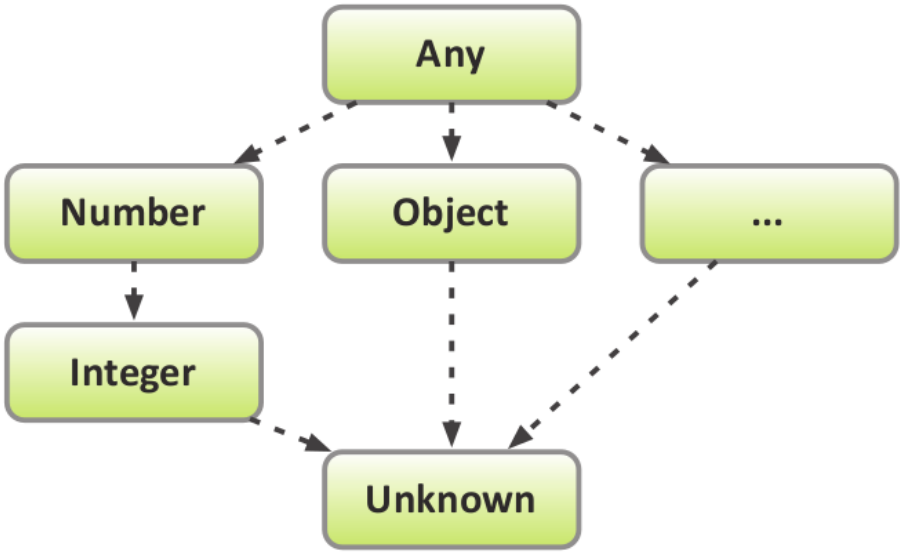
Low-Level Optimization

Optimization that happens in any context, simply by observing the structure of low-level IR

Examples:

- Redundant load/store removal
- Common subexpression elimination
- Dead code elimination
- Register allocation

Type Inference



- Iterative data flow problem
- Start from the most specific type and generalize (contrast with Hindley-Milner)
- *Example in Julia*

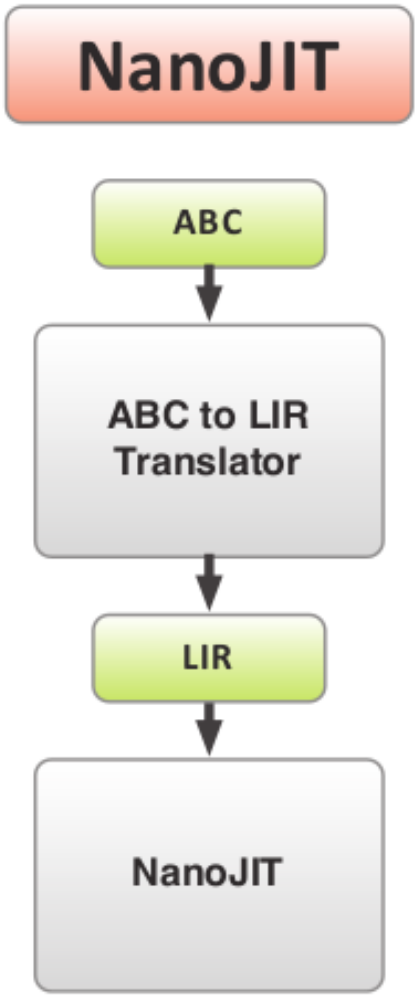
Examples

ActionScript

- Dynamic programming language
- Optionally typed
  - Programmer can specify type of variable or it has `Any` type
- Tamarin VM
  - NanoJIT
  - Type Enriched Static Single Assignment (TESSA)

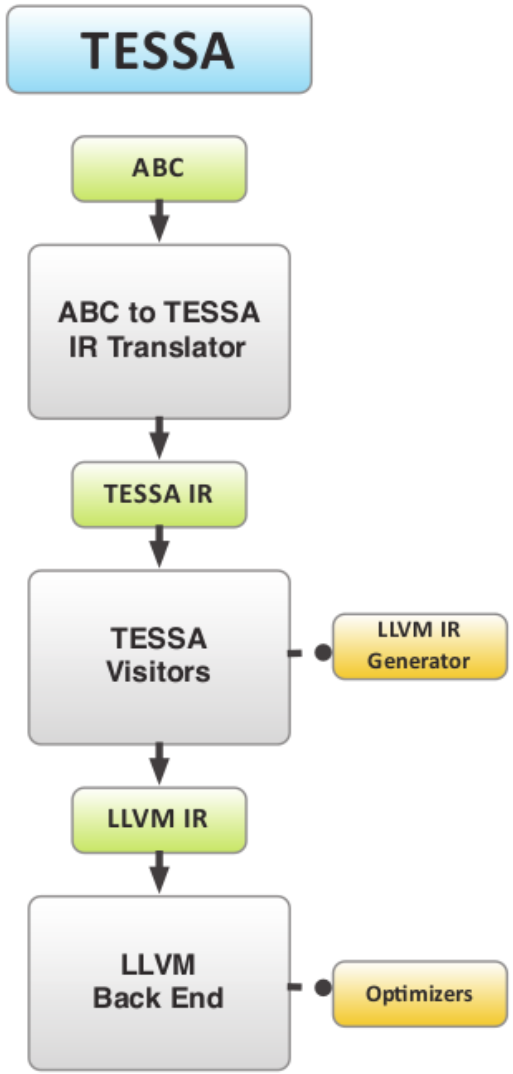
NanoJIT

- Designed for fast compilation
- ActionScript Bytecode (ABC)
- Few optimizations
  - Common subexpression elimination
  - Redundant load/store removal
- Untyped variables given the `Any` Type
  - requires C++ conversion code to be inlined



TESSA

- Designed to produce faster code
- Performs heavier optimizations
  - Type inference
  - Method inlining
  - LLVM low-level optimizations

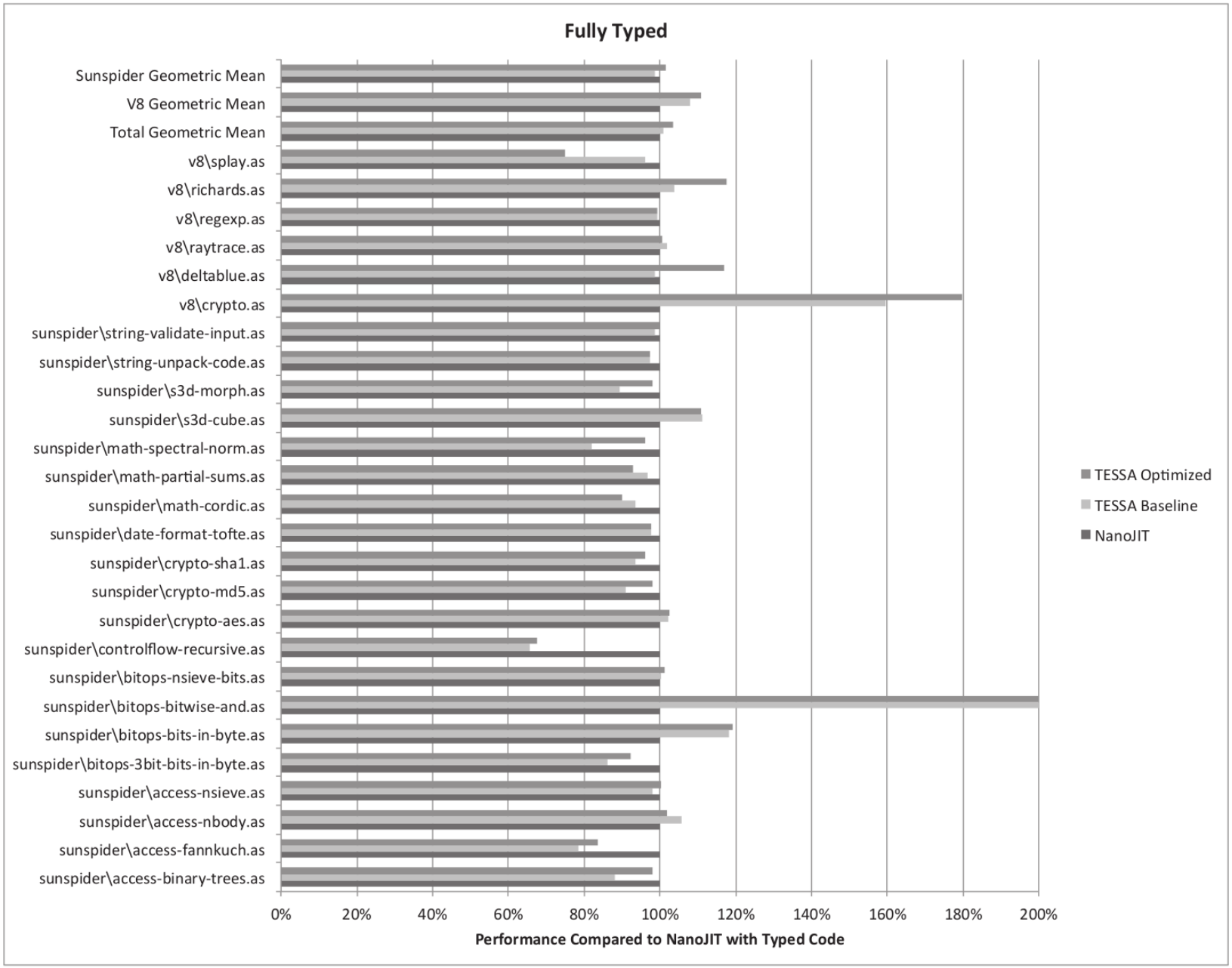


Evaluation

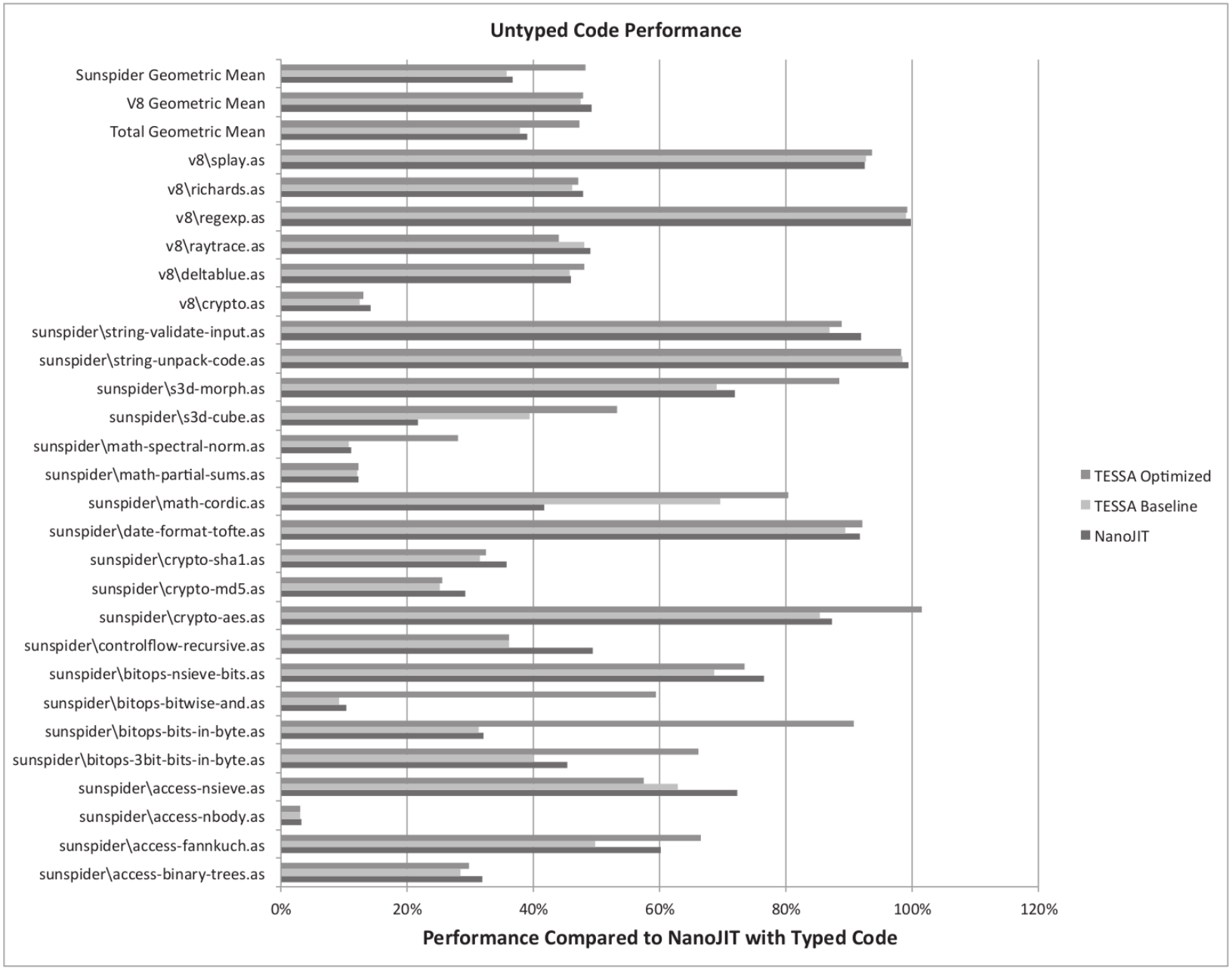
Comparing:

- Generated code performance
  - Differing amounts of type information
  - Different backend optimization levels
- JIT compilation time

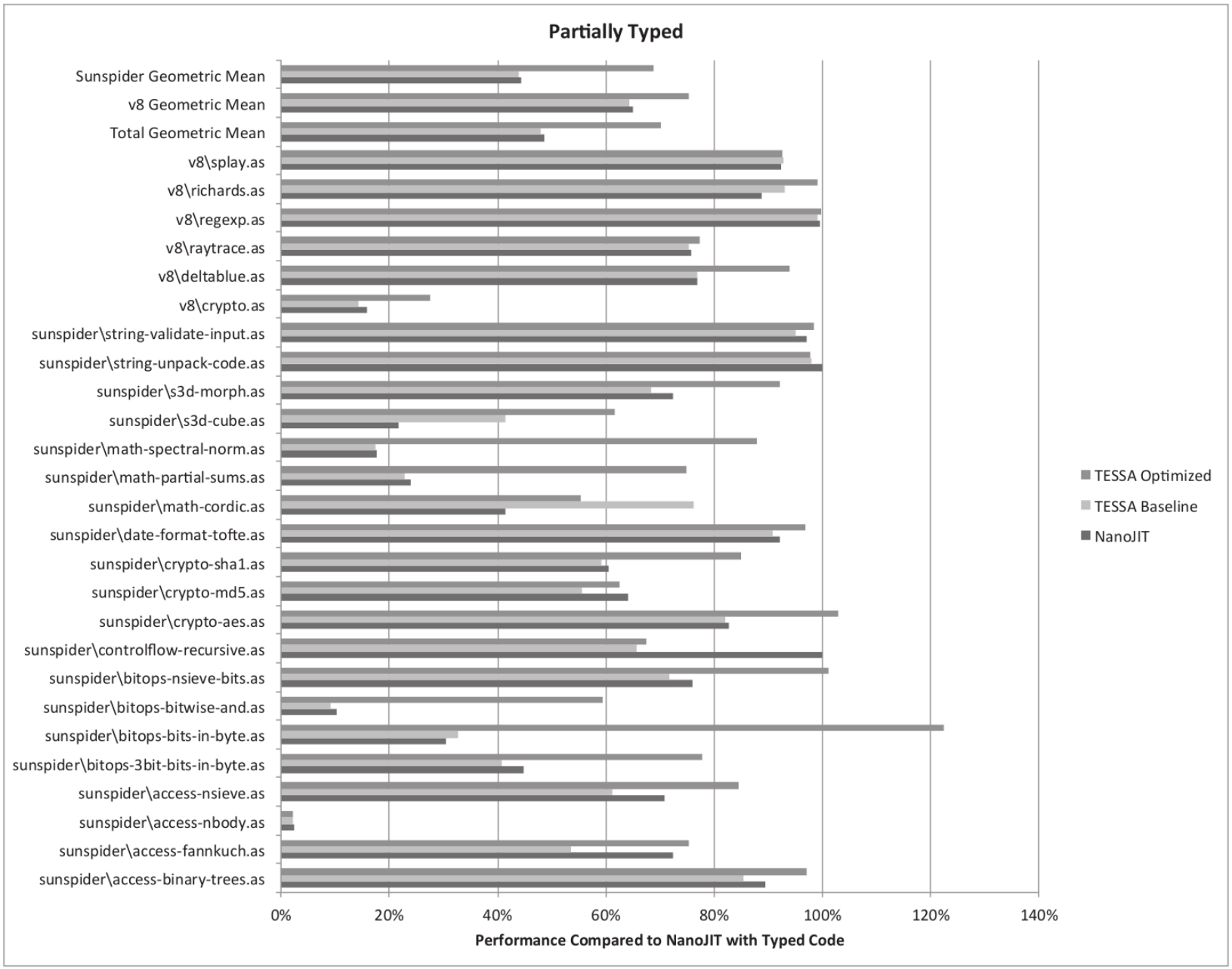
Typed Code


Fully Typed
Sunspider Geometric Mean
V8 Geometric Mean
Total Geometric Mean
v8\splay.as
v8\richards.as
v8\regexp.as
v8\raytrace.as
v8\deltablue.as
v8\crypto.as
sunspider\string-validate-input.as
sunspider\string-unpack-code.as
sunspider\s3d-morph.as
sunspider\s3d-cube.as
sunspider\math-spectral-norm.as
sunspider\math-partial-sums.as
sunspider\math-cordic.as
sunspider\date-format-tofte.as
sunspider\crypto-sha1.as
sunspider\crypto-md5.as
sunspider\crypto-aes.as
sunspider\controlflow-recursive.as
sunspider\bitops-nsieve-bits.as
sunspider\bitops-bitwise-and.as
sunspider\bitops-bits-in-byte.as
sunspider\bitops-3bit-bits-in-byte.as
sunspider\access-nsieve.as
sunspider\access-nbody.as
sunspider\access-fannkuch.as
sunspider\access-binary-trees.as
0%
20%
40%
60%
80%
100%
120%
140%
160%
180%
200%
Performance Compared to NanoJIT with Typed Code
TESSA Optimized
TESSA Baseline
NanoJIT

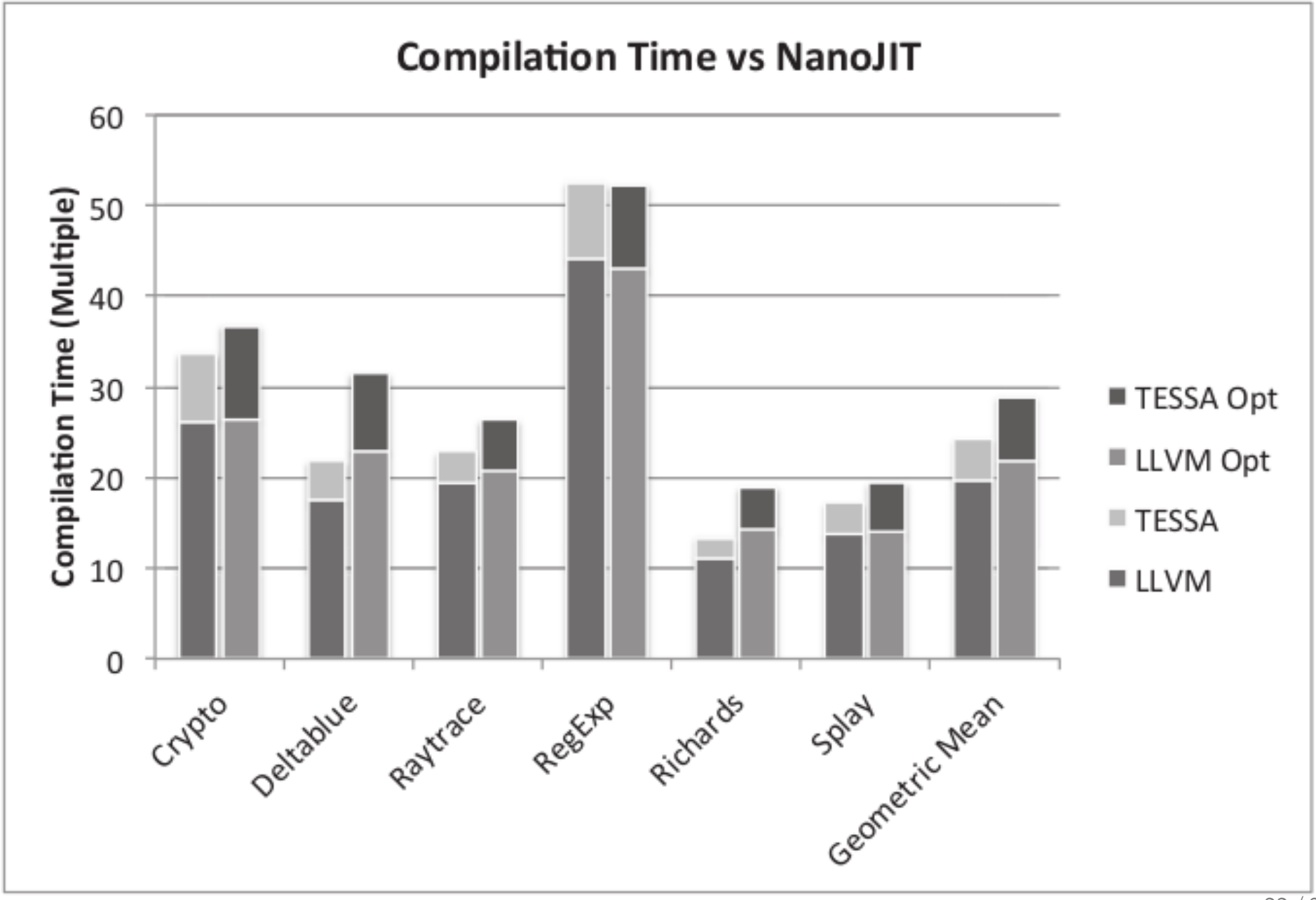
Untyped Code



Partially Typed Code



Compilation Time



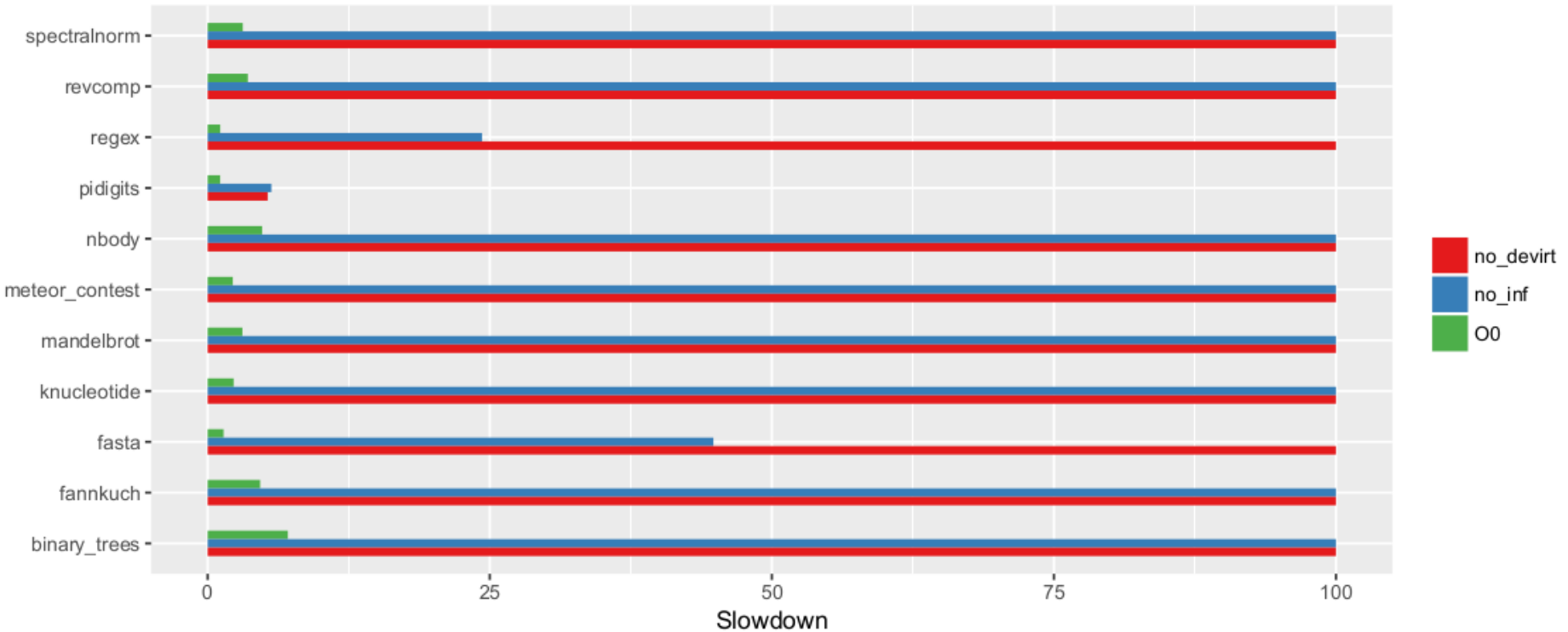
Julia

- Dynamic programming language
- Optionally typed
- Multiple dispatch
- Designed for fast development that can be later sped up
- Can control memory layout of datatypes

Julia's Optimizations

- Method specialization
- Type inference
- Method inlining (In Julia methods are function implementations that are ad hoc polymorphic)
- Object unboxing

Evaluation


spectralnorm
revcomp
regex
pidigits
nbody
meteor_contest
mandelbrot
knucleotide
fasta
fannkuch
binary_trees
0
25
50
75
100
Slowdown
no_devirt
no_inf
O0

Conclusions

Conclusions:

- High-level optimizations are key to performance gains
- Large amounts of low-level optimization often takes too long to justify the speedup

References

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Questions?