Accelerating Stateflow With LLVM

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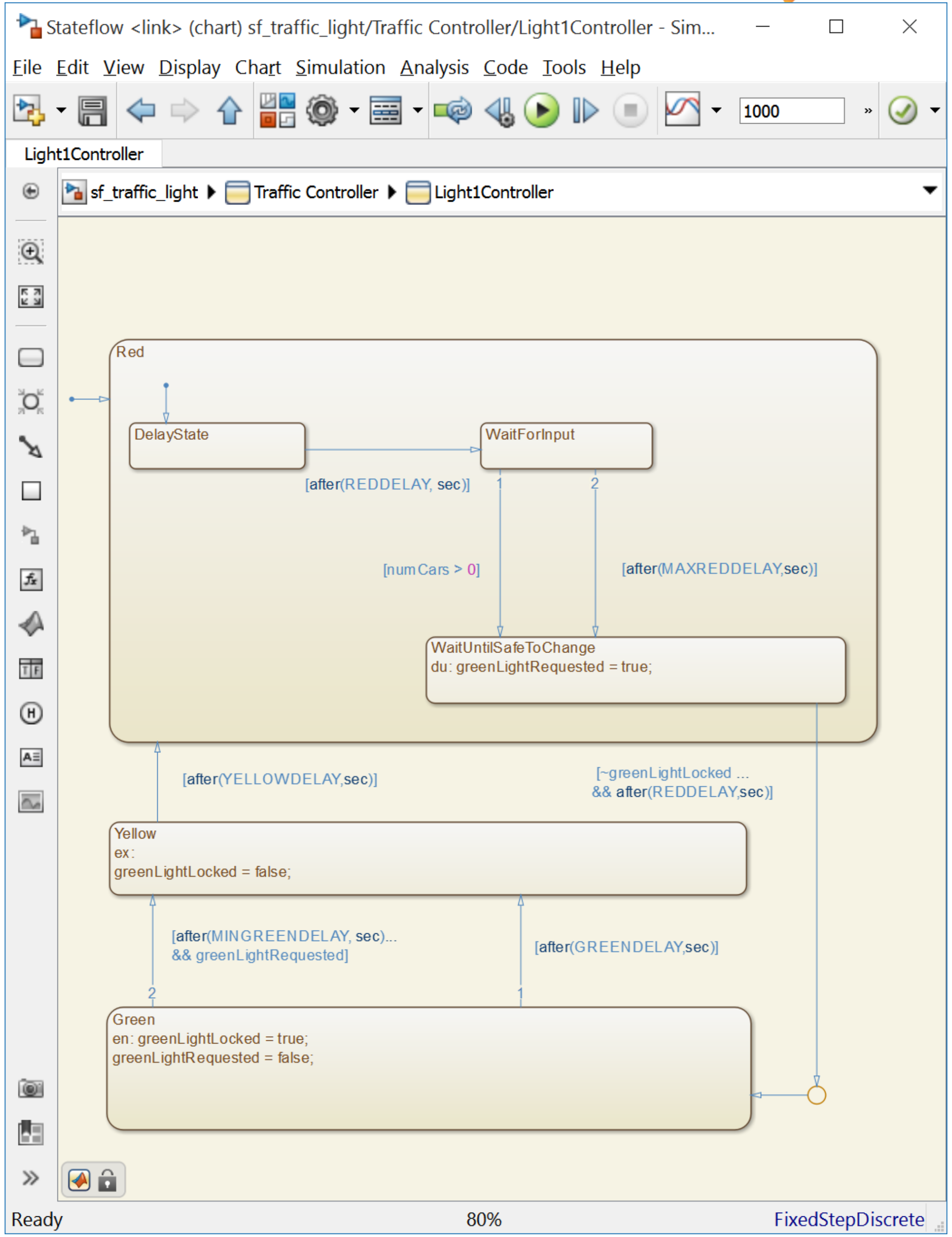

Traditional Simulation Approach

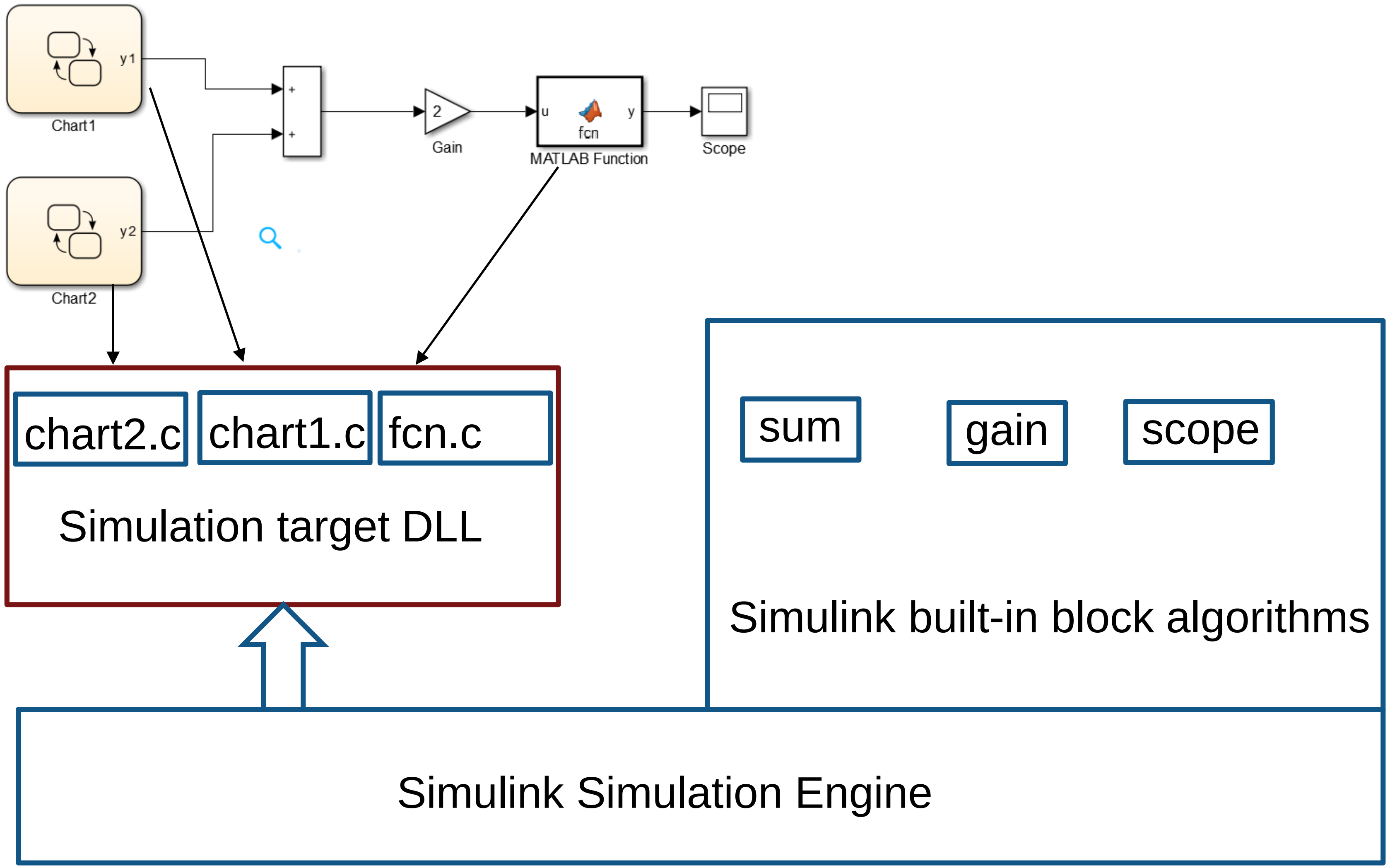

chart2.c chart1.c fcn.c

Simulation target DLL

sum gain scope

Simulink built-in block algorithms

Simulink Simulation Engine

Simulation through Code Generation

- Pros
  - Simulation and production code generation based on same technology => less code, fewer bugs
  - Much faster runtime than “interpreted” implementation
  - Easy to call customer-supplied C/C++ code

- Cons
  - First time overhead due to generating code and invoking a compiler
  - Needs an external C-compiler
    - (Different levels of difficulty to customers on Mac, Linux, and Windows)

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- A new compiler backend – from our internal IR, to LLVM

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- Represents a high level of abstraction – matrix operations, fixed-point and complex math, structures, complex control flow
- Gets progressively lowered into multiple backend languages – C, VHDL, Verilog, PLC Structured Text
- And now LLVM!

An observation: we’re really good at working with our own IR

- Many good debugging tools
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- Many good debugging tools
- Many experts in the building
- Let’s map our semantics onto LLVM in our own IR

What does that mean exactly?

- Like our “normal” compiler flows, we do “lowerings” to go from high-level abstractions to lower level abstractions
  - Lower matrix operations into loops
  - Fixed-point math into integer math, etc

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- Like our “normal” compiler flows, we do “lowerings” to go from high-level abstractions to lower level abstractions
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  - Fixed-point math into integer math, etc.
- In addition, we go further
  - Booleans become int1 or int8 depending on context (control flow vs. data)
  - Unions get mapped into Structures with one field; accesses get turned into cast operations
  - Many more examples

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- That maps one-to-one onto LLVM IR
- This makes the translation really simple

R2015a: Just-in-Time (JIT) Compilation

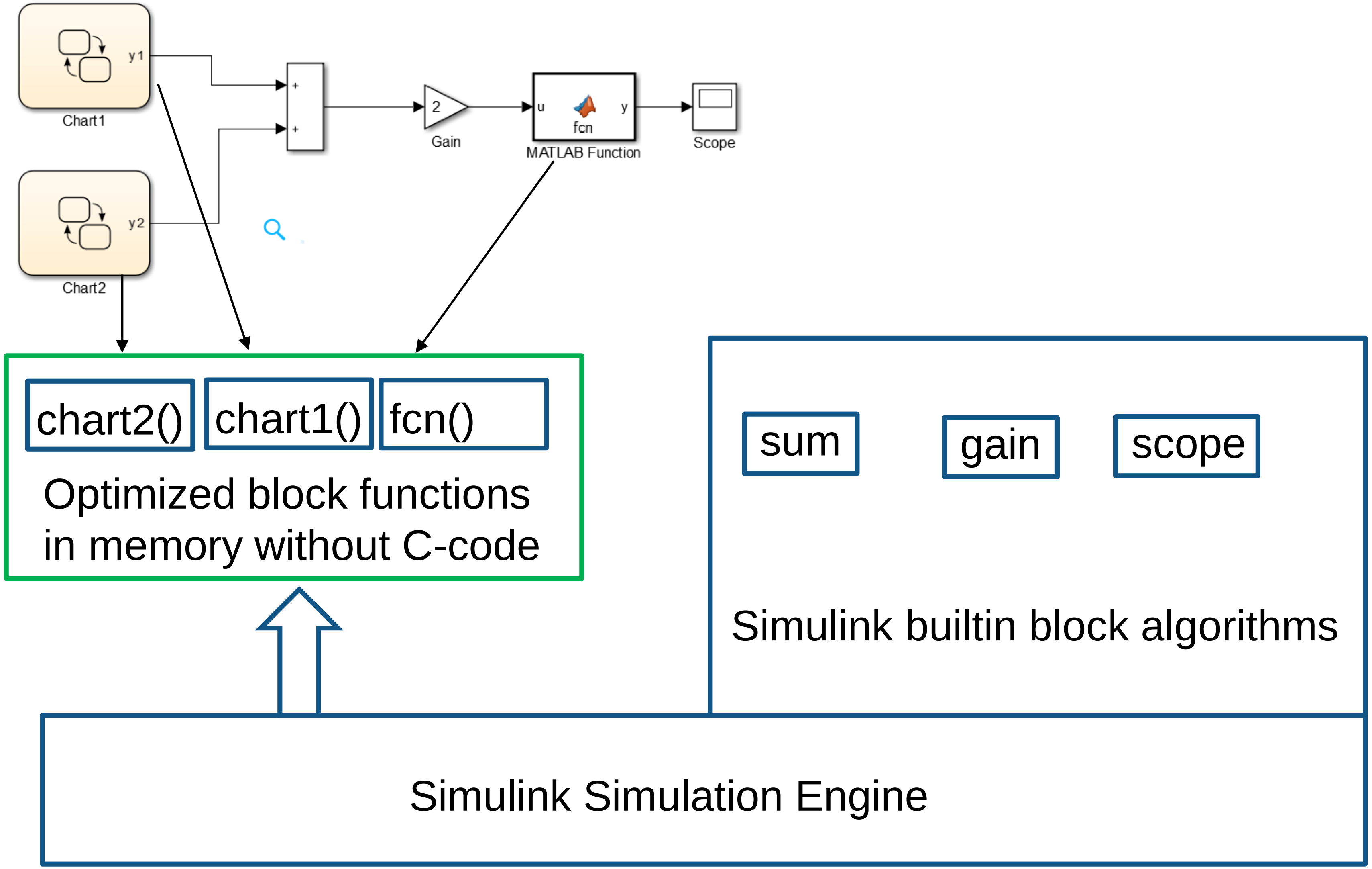


chart2() chart1() fcn()

Optimized block functions
in memory without C-code

sum gain scope

Simulink builtin block algorithms

Simulink Simulation Engine

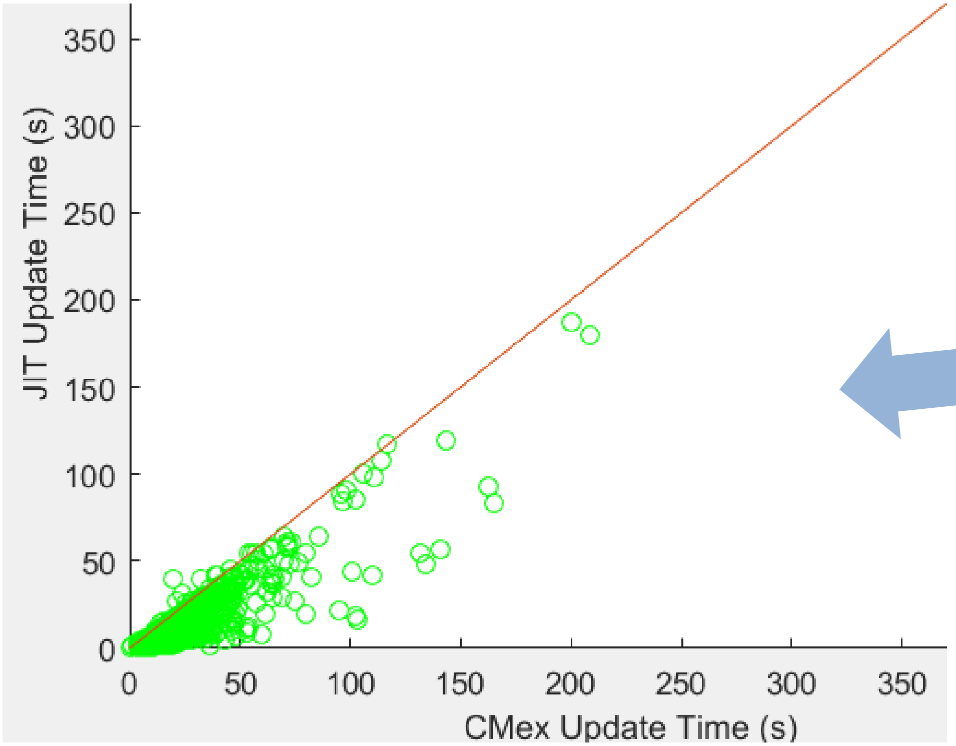
JIT-based Simulation in R2015a

- **No need for a C compiler ☺**
- **Fast startup ☺☺**

- Transparent to the user
  - No knobs or buttons or options
  - Model compilation speeds up through JIT when it can

- Automatically fall back to codegen modes as needed
  - e.g., Custom code, and step-by-step debugging use code generation

JIT Model Compile Time Improvement



Points below the line indicate speedup

Data from >5000 internal test models

- 99% of the models are 20-50% faster

Challenges

- Supporting Linux, Mac, and Win64
- Our runtime can throw exceptions
  - On win64, LLVM can’t handle exceptions passing through
  - Wrote a pass (in our IR) to wrap every runtime call with error checks/early returns

Challenges

- Discovered the hard way that MC-JIT does not really work on Windows with LLVM 3.5 or 3.6 ☹
- Due to release schedule, stuck at 3.5 and legacy JIT for now

Questions?

- Come find me or email Dale.Martin@mathworks.com