Logisimple

A Simple Hardware Description Language

Yuanxia Lee, Sarah Walker, Kundan Guha, Hannah Pierce-Hoffman

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Team Roles

Yuanxia Lee

- Language Guru

Sarah Walker

- Tester

Kundan Guha

- System Architect

Hannah Pierce-Hoffman

- Manager

Language Overview

- Built off primitives (AND, OR, NOT)
- Allows for easy customization
- Combinational logic

Logisimple Syntax

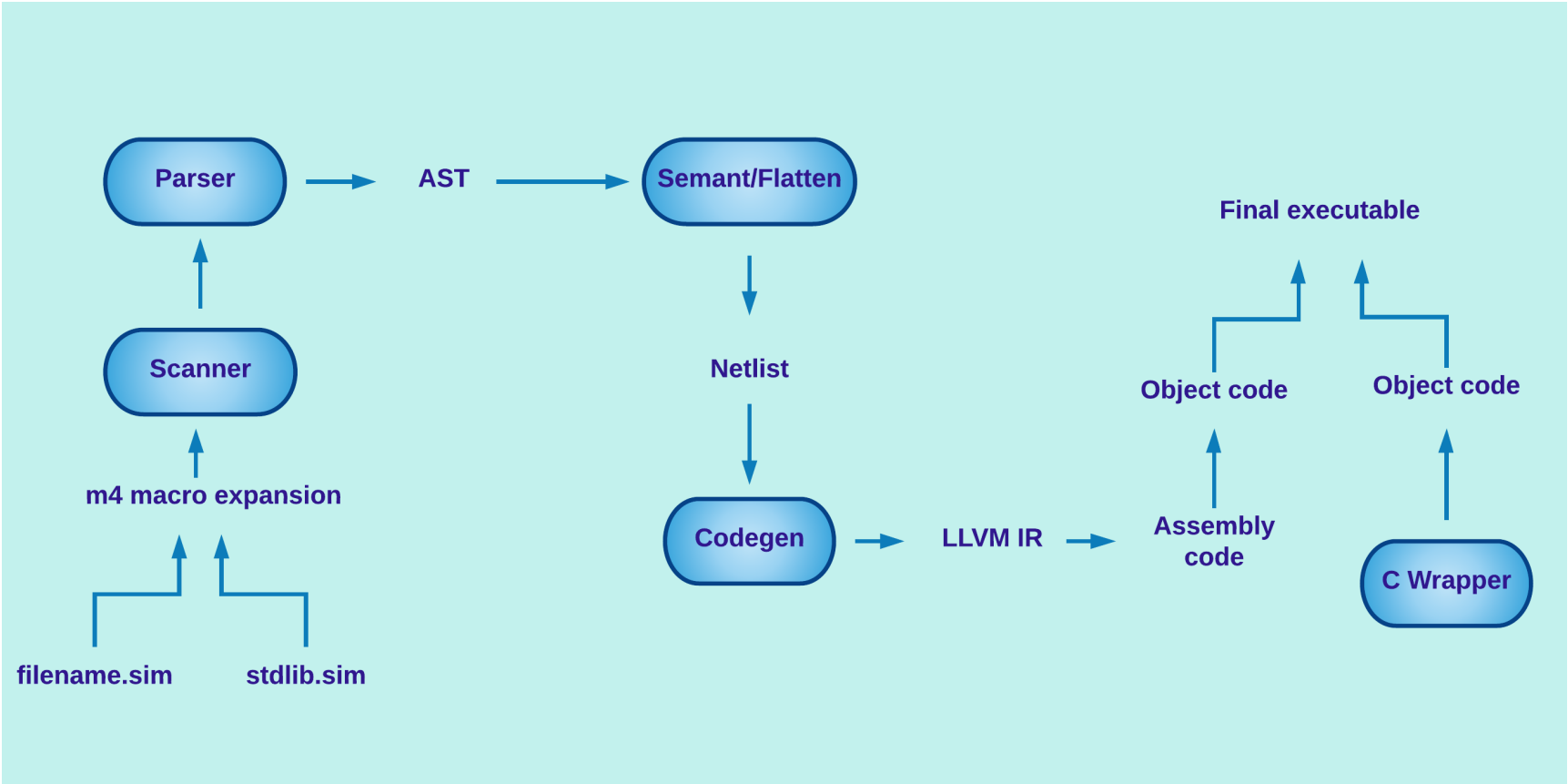
All statements wrapped in a "TICK" gate:

```
TICK(in1, in2){
    AND a(in1, in2);
    out = a;
}
```

Last statement of every gate is the keyword out followed by the output variable.
Example of a user-defined gate:

```
MYGATE{
    OR a(0,0);
    AND b(a,1);
    out = b;
}
```

Pipeline


Parser
AST
Semant/Flatten
Scanner
Netlist
m4 macro expansion
Codegen
LLVM IR
Final executable
Object code
Object code
Assembly code
C Wrapper
filename.sim
stdlib.sim

Hello World: Part 1

Overview:

- An initial Hello World
- Only 2-input AND, OR, and NOT gates
- Multiple primitive statements
- Program represented as `variable list * stmt list`
- No constants
- Biggest challenges:
  - Where to put builder blocks
  - No StringMap for variables
  - No support for constants
  - Needed to bypass AST and feed Netlist directly to Codegen

Hello World: Part 1

What we learned:

- Basic mechanism: allocate space for variable, load variable, perform operation, store result
- Beginning of test suite: single statements, multiple statements. Verify test by manually inspecting LLVM code.

We compiled `AND mygate(hannah, sarah);` into:

```
Finished, 19 targets (0 cached) in 00:00:00.
; ModuleID = 'Logisimple'

define i32 @main() {
entry:
  %mygate = alloca i32
  %hannah = alloca i32
  %sarah = alloca i32
  %input1 = load i32, i32* %hannah
  %input2 = load i32, i32* %sarah
  %tmp = and i32 %input1, %input2
  store i32 %tmp, i32* %mygate
  %something = load i32, i32* %mygate
  ret i32 %something
```

Moving on from Hello World

Our initial Hello World was nice, but we had a long to-do list:

- Support for constants in Codegen
- StringMaps to hold variables
- AST-to-Netlist
- User-defined gates
- Arrays
- Semantic checking
- Standard library

Codegen

Include boolean LLVM type:

```
16  +    and zero = L.const_int i8_t 0
17  +    and one = L.const_int i8_t 1 in
```

Allocate space for a boolean LLVM type:

```
21  +   let codegen_arg a name builder =
22  +       match a with
23  +         A.Name n -> let arg = L.build_alloca i8_t n builder in
24  +           L.build_load arg (name ^ "inp") builder
25  +       | A.Bool b -> if b then one else zero
26  +   in
27  +      let expr builder (A.Expr (out, gate)) =
```

StringMap to hold variables

```
44          build_inputs 0 inputs StringMap.empty in
    -   let codegen_arg a name builder =
45  +   (*let rec print_keys l = match l with
46  +     [] -> print_endline "contained"
47  +   | (x, y) :: t -> print_bytes (x ^ " "); print_keys t in
48  +   ignore (print_keys (StringMap.bindings vars));*)
49  +   let lookup n vars = try StringMap.find n vars
50  +                       with Not_found -> print_endline ("Key: " ^ n ^ " not found.");
51  +                       raise Not_found in
52  +   let codegen_arg a vars builder =
76  +           StringMap.add out store_output vars
```

AST-to-Netlist

Bridge.ml takes the AST, walks the AST, and calls flatten on the body of the gate definition, and then outputs a Netlist object (name, inputs, list of Netlist statements, outputs).

```
24  let convert_to_nl gdef =
25
26      let prog_body = gdef.A.body in
27
28      let v_starter = [] and vdm_starter = StringMap.empty in
29      let (vl_res, vdm_res) =
30      process_mixed_list prog_body v_starter vdm_starter in
31
32      let gdecl_map = StringMap.empty in
33      let nl_stmts = T.flat vl_res vdm_res gdecl_map in
34
35      let converted_str = special_converter gdef.out in
36
37      let tup = (gdef.name, gdef.inp, nl_stmts, [converted_str]) in
38      tup
39
```

Semant and Flatten

- Semant.ml performs semantic checking (e.g. redefining a gate)
- Flatten produces part of the Netlist

User-defined Gates

Use our primitives to build bigger gates.
Challenges:

- Storing new type names and gate bodies
- Need to "mangle" names to avoid identifier conflicts
- Need to "flatten" AST into a Netlist of primitives that Codegen can translate

Arrays

Arrays hold booleans and boolean variables.
Example of a boolean array "one:"

```
bool a = 1;
bool[2] one = [a,0];
```

```
81  +  | ID LSBRACE num RSBRACE { Index ($1, $3) }
```

```
8   +  | Index of string * int
```

```
62  +      | Deref (s, i) -> ("Deref " ^ s ^ "[" ^ (string_of_int i) ^ "]") in
```

Standard Library linking

- Macro expansion with m4 and `include` keyword in Logisimple source code

```
16  +  Arg.parse speclist (fun filename -> channel := Unix.open_process_in ("m4 " ^ filename)) usage_msg;
```

- Expands standard library files into Logisimple source file
- Example standard library gates:

```
NAND(a,b) {
    AND x(a,b);
    NOT y(x);
    out = y;
}
```

```
NOR(a,b) {
    OR x(a,b);
    NOT y(x);
    out = y;
}
```

```
XOR(a,b) {
    OR o(a,b);
    NAND na(a,b);
    AND a(o,na);
    out = a;
}
```

Test Suite

- tester.c
  - Wrapper to pass inputs and print outputs
- compile_file.sh
  - .sim to .ll to .s to .o to executable

```
9     echo $file $tester "${file}.ll"
10    ./logisimple.native "${file}.sim" > "${file}.ll"
11    llc "${file}.ll"
12    gcc -c -o "${file}.o" "${file}.s"
13    gcc -c -o "${tester}.o" "${tester}.c"
14    gcc -o "${tester}" "${tester}.o" "${file}.o"
```

- Test-to-Pass
  - Testing for syntax and parsing (e.g. one primitive vs. two primitives)
  - Testing for logical operations (i.e. "Does this match its truth table?")
- Test-to-Fail

Lessons Learned

Sarah:

- Learn to love your tools
- Learn from others' success (and failure)
- Communicate your expectations

Hannah:

- Ask for help
- Teamwork

Lessons Learned

Yuanxia:

- Early is never early enough
- Get help, and look at previous work

Kundan:

- Importance of communication
- Don't procrastinate

Demo