Emscripten: An LLVM to JavaScript Compiler

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What? Why?

Compiling to JavaScript

- The web is everywhere
  - PCs to iPads
  - No plugins, no installation required
  - Built on standards
- The web runs JavaScript

Existing Compilers to JavaScript

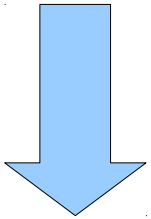
- Google Web Toolkit: Java (Gmail, etc.)
- CoffeeScript
- Pyjamas: Python
- SCM2JS: Scheme
- JSIL: .NET bytecode
- (and many more)

- But C and C++ are missing!

Emscripten

- Enables compiling C and C++ into JavaScript
- Written in JavaScript
- Open source

http://emscripten.org



https://github.com/kripken/emscripten

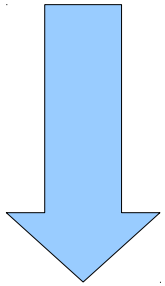
Demos!

- Bullet
- SQLite
- Python, Ruby, Lua

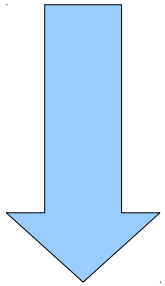
- Real-world code
  - Large, complex codebases
- Manual ports exist
  - Typically partial and not up to date

The Big Picture

C or C++



LLVM Bitcode



JavaScript

Low Level Virtual Machine (LLVM)

- A compiler project (cf. GCC)
- Intermediate Representation: LLVM bitcode
  - Very well documented
  - Great tools
- Much easier to compile LLVM bitcode than compile C or C++ directly!

How?

Code Comparison

```
#include <stdio.h>

int main() {
  printf(“hello, world!\n”);
  return 0;
}
```

Code Comparison

```
@.str = private unnamed_addr constant [15 x i8]
                c"hello, world!\0A\00", align 1

define i32 @main() {
entry:
  %retval = alloca i32, align 4
  call i32 (i8*, ...)* @printf(i8* getelementptr
        inbounds ([15 x i8]* @.str, i32 0, i32 0))
  store i32 0, i32* %retval
  ret i32 %retval
}
```

Code Comparison

```
define i32 @main() {

entry:

  %retval = alloca i32,
            align 4

  call i32 (i8*, ...)*
       @printf (..)

  store i32 0, i32*
        %retval

  ret i32 %retval

}
```

```
function _main() {


  var _retval;


  _printf (..);


  _retval = 0;


  return _retval;

}
```

Code Generation Principles

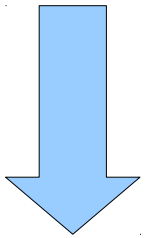
- 1-to-1 translation as much as possible
- LLVM function calls become native JavaScript function calls
- LLVM variables become native JavaScript variables

Memory

- A single JavaScript array represents the entire memory space
  - `HEAP[ptr] = 0;`
  - `var x = HEAP[ptr];`
  - Pointers are simple integers
- This includes the stack
  - However, variables on the stack are optimized to native JavaScript variables when possible

Control Flow: Relooper

```
while (1) {
  switch (__label__) {
    case 1:
      var _x = 0;
      __label__ = 2;
      break;
    case 2:
      _x++;
      if (x > 10)
        __label__ = 3;
      else
        __label__ = 2;
      break;
    case 3:
      printf("done.\n");
      return 0;
  }
}
```



```
var _x = 0;
while (_x <= 10)
  _x++;
printf("done.\n");
return 0;
```

Types / Semantics

- 5/2 in C/C++ gives 2
  - But we get 2.5 in JS
- -1 == 255 if they are 8-bit integers in C/C++
  - But we get false in JS
- x = 255; x++; gives 0 if x is uint8 in C/C++
  - But we get 256 in JS

Types / Semantics

- C/C++, and LLVM bitcode, have types, JavaScript does not
- Emscripten by default generates code that corrects all of this
- But in practice, most code doesn't need it
  - Profile-Guided Optimization (PGO) helps

Performance

Benchmark	V8	V8 TA*	SM	SM TA
dlmalloc	8.57	3.19	4.00	**1.80**
fannkuch	78.17	**2.92**	6.10	4.95
fasta	18.22	**1.56**	3.65	2.67
memops	239.28	**4.22**	6.96	6.06
primes	4.64	**2.16**	2.59	2.48
raytrace	90.40	29.28	**6.03**	6.80

numbers are times slower than gcc 4.6.1, **lower numbers are better**

V8 = V8 (Chrome) **SM** = SpiderMonkey (Firefox) **TA** = Typed Arrays

* V8 TA Benchmarks were patched to work around V8's lack of .subarray

Performance

- Modern JavaScript engines can in many cases be just 2-3X slower than native code
  - Close to portable, memory-safe languages like Java and C#, which are statically typed
- However, JavaScript engines do not always reach that speed
  - Bugs
  - Differences between JS engines
  - Various things JS engines are not good at yet

Advanced Optimizations

- `struct X_t { char a; int b; };`

  `X_t x = { 20, 500 };`
  - In C, x is [20, 0, 0, 0, 244, 1, 0, 0]

- Emscripten has various memory layouts:
  - Default: [20, 0, 0, 0, **500**, **0**, 0, 0]
  - Typed arrays, dual buffers: As default, plus [0, …] in the floating-point buffer
  - Typed arrays, shared buffer: Identical to C
  - Memory compression: [20, 500]

Conclusion

- C and C++ code can be compiled in an effective way into JavaScript, and run on the web
- Performance is good and improving, casting doubt on the various “JavaScript replacements”
- The future: Compile everything into JavaScript!

http://emscripten.org

Thank you.