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# WEBASSEMBLY

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April 26, 2020

## ABSTRACT

WebAssembly is neither assembly, nor constrained to only the web. Its main purpose is to provide portability and optimization potential. Its main use today is as a compile target for other languages to be ported to browsers. C/C++/Rust are all common sources to be ported to WebAssembly. The backbone of WebAssembly is the stack machine which allows a simple target for instructions to be executed. The WebAssembly Text Format exists in order to provide a way for humans to write wasm directly. This format is written using S-Expressions and shows how the simplicity of the language. However, although WebAssembly is simple, it can be used to create arbitrarily complex programs, allowing for WebAssembly to pave the way for portability of code.

## 1 Introduction

WebAssembly (Wasm) was created with support from all major browsers. It seeks to provide a means of optimizing javascript in addition to providing a target for other languages to compile to. WebAssemblyl compiles down to bytecode to be fed through a stack machine. The format of the instructions follows this structure. WebAssembly Text Format is the standard for writing Wasm programs directly. The format is simple, allowing for large amounts of optimization. There are only 4 data types and a handful of control structures. There is only basic means of creating Subprograms through modules and functions. Overall, WebAssembly aims to provide smaller files (when compiled) than JavaScript with greater potential for protability and optimization.

## 2 History

The goal of WebAssembly was to be a portable compilation target for higher level languages. Some examples of these languages are C, C++, and Rust. Essentially, the browser is already very portable across platforms, so Wasm aims to provide a way to port programs written in less portable languages (like C) to the "Browser Platform". Wasm was a joint effort from WebAssembly CG members from the four major browsers: Chrome, Edge, WebKit, and Firefox. It was made standard by the W3C.

The WebAssembly Community Group was started in April of 2015. Wasm was made ready to ship to all browsers in March of 2017. Wasm is supported on the four major browsers and is ready for use.

## 3 Control Structures

### 3.1 if-else

The if-else structure in WebAssembly is very similar to other languages. The if statement takes in a condition and if the condition is true, it will execute the body of code given. Below we can see an example of this in action.

( if

```

    (i32.eq (local.get $x) (i32.const 0))
    (then
      CODE FOR TRUE CASE
    )
    (else
      CODE FOR FALSE CASE
    )
  )
)

```

As the WebAssembly text format is written using S-expressions, the format looks closer to function programming languages. We see that the first argument to the if function is a condition. This condition is provided by the .eq method for i32 types and checks if a local var is equal to 0.

### 3.2 br, br\_if, br\_table

The br, br\_if, and br\_table structures are used to branch to various levels of nested blocks/loops. These levels are given by indices, where 0 is the index of the level currently in, and each index higher is an outer-block. Branching to the highest level returns from the function. br is an unconditional branch (branches to given level no matter what).

```
(block ... (br 0) ... )
```

Here, the second ... will not get executed, since branching to a block goes to the end of a block.

br\_if is a conditional branch and accepts an i32 type along with block level index. If the given value is non-zero it branches, otherwise ignored.

```
(block ... (br_if 0 CONDITION) ...)
```

In this case, the second ... will get executed only if CONDITION is false, otherwise the branch will go to the end of the block.

Finally the br\_table instruction acts a bit like a switch statement in C. It is given a list of integers referring to various block depths to branch to, and accepts another integer which is an index for which block depth in the list to branch to. This will make more sense with an example.

```

(block ...
  (block ...
    (block ...
      (BRANCH INDEX)
      (br_table 2 1 0 3)
    )
  )
)

```

If BRANCH INDEX pushed 0, 1, 2 onto the stack, br\_table will branch to the outer-most block, second outer-most, and inner-most block respectively. If some other value was pushed on the stack, br\_table default branches to depth 3 which is whatever structure is above the first block statement (could be another block, or the function, in which case would return).

### 3.3 loop

The loop structure allows for repeated iteration over some instructions. The above branching instructions are used with loop as well as with block, the only difference being, when branching to a loop, it branches to the start of the loop, versus the end of a block. Here's an example:

```
(loop ... (br 0))
```

This would execute the instructions in ... repeatedly forever...

```
(loop ... (br_if 1 CONDITION) ... (br 0))
```

This behaves like a while loop which breaks when CONDITION is true.

### 3.4 other

There are a few small control structure tools that work with the big forms mentioned above. First there is the nop instruction. This is exactly what the name implies, it does nothing. Next, there is the block. This allows for organization of a sequence of instructions with a label at the end of the block. Additionally, there is an end instruction. This marks the end of a block, loop, or function. Finally, there is a return instruction which allows for early exits in functions.

## 4 Data Types

WebAssembly only has 4 data types: i32, i64, f32, f64. This might seem limiting at first, but like assembly languages, these types can represent both values and addresses. This allows the programmer/compiler to build data structures as complex as they need to be, so it is more powerful than what it seems.

### 4.1 i32, i64

i32 can hold 32-bit signed integers while i64 can hold 64-bit signed integers. However, the operation on the value is what actually determines if the number is signed or not. In essence, these types are just numbers, with the complexity coming from the operations which can be performed on them. Here are some examples on i-operations:

```
i32 . const 35
i32 . const 28
i32 . add
```

### 4.2 f32, f64

f32 can hold 32-bit floating point values while f64 can hold 64-bit floating point values. Another way of looking at it is f32 are single precision floating point numbers and f64 are double precision floating point numbers. Here are some examples on f-operations:

```
(f32 . add (f32 . const 4.2) (f32 . const 6.9))
(f32 . sub (f32 . const 1.2345) (f32 . const 0.2345))
(f32 . div (f32 . const 99.9) (f32 . const 3.0))
```

## 5 Subprograms

WebAssembly has basic means of creating subprograms. There are two layers: modules and functions. Modules are the base of all wasm files. Every function a programmer writes must be contained within a module. These modules are then loaded into javascript objects. So, you can not have a function without a module but you can have a module without any functions (though, this has only limited use). There is a sense of private and public functions. All functions can be considered private until they are explicitly exported using the export keyword. Once this is done, they can be called from javascript or other wasm modules. To use external functions in your module, you must import them. You can see in the program below, it needs to import a simple print function from javascript and then exports its own function back to javascript. All of this contained in a wasm module.

```
(module
  (import "terminal" "sprint" (func $sprint (param i32) (param i32))) ;;can import JS

  (import "terminal" "mem" (memory 1))
  (data (i32 . const 0) "Each module contains functions which are exported to be called by
  (data (i32 . const 76) "\n\00")

  (func $line ;;local functions can be called by other functions in the module
    (call $sprint (i32 . const 76) (i32 . const 2))
  )

  (func (export "p4_func") ;;export functions to be called by JS
    (call $sprint (i32 . const 0) (i32 . const 75))
    call $line
```

)  
)

## 6 Summary

The WebAssembly Text Format (Wast) is the standard way of writing directly to webassembly as the stack machine would interpret it. It is written using S-Expressions. The language is simple compared to most programming languages. There are only 4 types (i32, i64, f32, f64) and a few control structures. However, the combination of these allows for arbitrarily complex code, similar to assembly languages. This was important because Wasm is meant to be a target for compilers, rather than a language to be written in directly. These simple instructions are fed to a stack machine. Because of this, the S-Expressions can be read like pushing and popping off values from a stack. Understanding this is key in understanding Wast.

WebAssembly is a very promising addition to not only the web, but to the future of portability in programming. Wasm is not going to be a popular language to program in directly, but rather as a target for compilers which seek to port to platforms like the web. With webassembly, it is now possible to take many C/C++ programs and port them to a module to be used with JavaScript. WebAssembly builds the next step in the "write once, run anywhere" idea started back with Java.

## References

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