D as Better C Compiler

by Walter Bright
dlang.org
C

• Brilliantly conceived language
• Major force for 40 years
• Engine for major critical software
• Well known and understood
• “Man behind the curtain”
All Is Not Roses

- 40 years of advancement in programming languages
- No memory safety
Memory Safety

“being protected from various software bugs and security vulnerabilities when dealing with memory access, such as buffer overflows and dangling pointers.”

– wikipedia
Costs of Memory Unsafty

- millions of dollars
- endless hours of effort to find and correct
- constant threat
- embarrassment
Buffer Overflow

Heartbleed

https://en.wikipedia.org/wiki/Heartbleed
Buffer Overflow

Public Enemy #1
Microsoft's Writing Secure Code 2
Buffer Overflow

Morris Worm

First internet worm relied on buffer overflow C bug
Buffer Overflow

#3 on list of top 25 security vulnerabilities

http://cwe.mitre.org/top25/index.html#CWE-120
Not a Buffer Overflow
Good News!

It's not your fault
• Has persisted for 40 years
• Not a tractable problem
• Not fixable by fixing the programmer
It's a Tooling Problem
int sum(int *array, size_t length) {
    int sum = 0;
    for (size_t i = 0; i <= length; ++i)
        sum += array[i];
    return sum;
}
D Arrays are Phat Pointers

```c
struct Array {
    size_t length;
    int* ptr;
}
```

https://dlang.org/spec/arrays.html#dynamic-arrays
int sum(int[ ] array)
{
    int sum = 0;
    for (size_t i = 0; i < array.length; ++i)
        sum += array[i];
    return sum;
}
Using foreach

```java
int sum(int[] array)
{
    int sum = 0;
    foreach (i; 0 .. array.length)
        sum += array[i];
    return sum;
}
```
More Advanced foreach

```c
int sum(int[ ] array)
{
    int sum = 0;
    foreach (value; array)
        sum += value;
    return sum;
}
```
Same problem with 0 terminated strings

D strings are just arrays of characters
And Much More Safety

- no uninitialized pointers
- no pointers to expired stack frames
- no aliasing pointers with other types
- no implicit narrowing conversions
- pointer lifetime tracking
- etc...
Calling C Code from D

extern (C) void* malloc(size_t);

T[ ] allocArray(T)(size_t numElements) {
    auto p = malloc(T.sizeof * numElements);
    assert(p);
    return p[0 .. numElements];
}
Problem

D code needs to link with the D runtime library. But an existing C project does not link with the D runtime library. Linking it in produces issues with the size of the D runtime library, and how/when it is initialized compared to that of the existing C project.
Solution - BetterC

Create a subset of D that does not require the D runtime library.
Features Altered

- `assert()` failures now go to C standard library
- RAII no longer unwinds exceptions
- No dynamic type info
- No exception handling
- No automatic memory management
What's this going to cost?
```c
#include <stdio.h>

int main(size_t argc, char** argv)
{
  for (size_t i = 0; i < argc; ++i)
    printf("arg[%zd] = %s\n", i, argv[i]);
  return 0;
}
```
import core.std.stdio;

extern (C)
int main(size_t argc, char** argv)
{
    foreach (i, s; argv[0 .. argc])
        printf("arg[%zd] = %s\n", i, s);
    return 0;
}
Some Assembly Required
sub ESP,01Ch
mov 014h[ESP],ESI
mov ESI,020h[ESP]
mov 018h[ESP],EDI
mov EDI,024h[ESP]
mov 010h[ESP],EBX
xor EBX,EBX
test ESI,ESI
je L1

L2: mov ECX,[EBX*4][EDI]
mov 8[ESP],ECX
mov 4[ESP],EBX
mov [ESP],offset _DATA
call _printf
inc EBX
cmp EBX,ESI
jb L2

L1: mov EBX,010h[ESP]
mov ESI,014h[ESP]
mov EDI,018h[ESP]
add ESP,01Ch
xor EAX,EAX
ret

sub ESP,01Ch
mov 014h[ESP],ESI
mov ESI,020h[ESP]
mov 018h[ESP],EDI
mov EDI,024h[ESP]
mov 010h[ESP],EBX
xor EBX,EBX
test ESI,ESI
je L1

L2: mov ECX,[EBX*4][EDI]
mov 8[ESP],ECX
mov 4[ESP],EBX
mov [ESP],offset CONST
call _printf
inc EBX
cmp EBX,ESI
jb L2

L1: mov EBX,010h[ESP]
mov ESI,014h[ESP]
mov EDI,018h[ESP]
add ESP,01Ch
xor EAX,EAX
ret
No Compromise

The same code is generated!
How to compile and link in a BetterC function into a C project...
#include <stdio.h>

int sum(int *array, size_t length) {
    int sum = 0;
    for (size_t i = 0; i < length; ++i)
        sum += array[i];
    return sum;
}

int main(size_t argc, char** argv) {
    int array[3] = { 1, 37, 28 };
    int s = sum(array,sizeof(array)/sizeof(array[0]));
    printf("sum = %d\n", s);
    return 0;
}
#include <stdio.h>

int sum(int *array, size_t length);

int main(size_t argc, char** argv) {
  int array[3] = { 1, 37, 28 };
  int s = sum(array,sizeof(array)/sizeof(array[0]));
  printf("sum = %d\n", s);
  return 0;
}
extern ( C )
int sum(int *array, size_t length) {
    return sum(array[0 .. length]);
}

@saf e int sum(int[ ] array) {
    int sum = 0;
    foreach (value; array)
        sum += value;
    return sum;
}
Compiling

dmd -c sum.d
dmc main.c sum.obj
Converting a C file to D

- Remove preprocessor metaprogramming
  - (should get rid of it anyway)
- Copy the code to a .d file
- Translate one function at a time
  - run the test suite after each
Don't Refactor/Improve/Fix

- Wait until it is all translated
  - and passes all tests!
  - resist overwhelming temptation
    - or you'll be sorry!
- Just rote translate it
Proof That This Works

The Digital Mars C/C++ Compiler Front End

Now That It's Working in D

• What can be done to benefit?
  – (Besides using proper arrays!)
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>

bool see(void* buf, int maybe);

bool isPossible(int maybe) {
  void *buf = malloc(100);
  if (see(buf, maybe)) {
    free(buf);
    return true;
  }
  free(buf);
  return false;
}
import core.stdio.stdlib;  // modules!

bool see(void* buf, int maybe);

bool isPossible(int maybe) {
    void *buf = malloc(100);
    scope(exit) free(buf);  // scope guard
    if (see(buf, maybe))
        return true;
    return false;
}
RAII

```c
import core.stdc.stdlib;

bool see(void* buf, int maybe);

struct S { void* buf; ~this() { free(buf); } }

bool isPossible(int maybe) {
    S s;
    s.buf = malloc(100);
    if (see(s.buf, maybe))
        return true;
    return false;
}
```
int compute(int x, int y) {
    if (x == y)
        return -1; // error
    if (x == 5)
        return 2;
    if (x == y + 3)
        return 7;
    return -1; // error
}

int compute(int x, int y) {
    const bool log = true;
    if (x == y)
        { if (log) printf("fail\n"); return -1; }
    if (x == 5)
        { if (log) printf("success 2\n"); return 2; }
    if (x == y + 3)
        { if (log) printf("success 7\n"); return 7; }
    if (log) printf("fail\n");
    return -1;
}
Nested Functions

int compute(int x, int y) {
    enum log = true;
    int fail() {
        if (log) printf("fail\n"); return -1;
    }
    int success(int i) {
        if (log) printf("success %d\n", i); return i;
    }

    if (x == y)
        return fail();
    if (x == 5)
        return success(2);
    if (x == y + 3)
        return success(7);
    return fail();
}
Some Things D Can't Do
#define BEGIN {
#define END}

int sum(int *array, size_t length)
BEGIN
  int sum = 0;
  size_t i;
  for (i = 0; i < length; ++i)
    BEGIN
      sum += array[i];
    END
  return sum;
END
Get Started Today!

- Incrementally use D functions in large C project
- Stop buffer overflows and other safety bugs
- Use D to improve code

dlang.org