D as a Better C

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https://theartofmachinery.com/

C and C++ are powerful languages
for systems programming

D is not a perfect alternative

(https://wiki.dlang.org/Language_issues)

But D is better for many applications, today

(and getting even better, fast)

Super Short History of C

- Dennis Ritchie, et al, needed a high-level language to rewrite Unix in ~1970
- "The C Programming Language" ("K&R C") published in 1978
- <blink>NOT THE FIRST LANGUAGE AFTER ASSEMBLY</blink>
- Originally only intended for the PDP-11, which heavily influenced design

Super Short History of C++

- Bjarne Stroustrup wanted a fast and convenient language
- Made original "C with Classes" in 1979
- Initial implementation literally just a preprocessor for C
- Language has since diverged (slightly) from C

Super Short History of D

- Walter Bright was the author of Zortech, the first native C++ compiler, and is responsible for several advances in C++ compiler technology since then
- D1 released in 2001
- D2 released in 2007
- First DConf in 2013

Why a new language?
Why a "better C", not "better C++"?

C++'s biggest strength and weakness:

backwards compatibility with C

Why do we need a better C?

```
enum reactor_id
{
    REACTOR_A = 1,
    REACTOR_B = 2,
};

enum reactor_mode
{
    OFF = 0,
    NORMAL = 1,
    EXPERIMENTAL = 2, // TODO: Delete this. Too dangerous. Really bad idea.
};

...

reactor.id = REACTOR_B;
reactor.mode = REACTOR_B;
```

```
0[foo_array]
```

```
if (is_ready);
{
    launchMissile();
}
```

`const` and `volatile`

`volatile` is a broken mess

`const` is not so useful as a compiler hint

In C, pointers to pointers (e.g., arrays of strings) are broken (and unsound)

Lack of low-level systems stuff in standard

Preprocessor includes instead of modules

Generally have to be re-evaluated every time thanks to side effects

Leads to hacks like "inline variables" in C++

(Try `gcc -E` or `clang -E` for fun sometime)

What about C++?

Compilation times

Compiling C++:

Here[not] be
dragon[book]s

```
Result doStuff(Message);
Thing thing(config);

std::map<int, std::pair<int, int>>
val>>2
```

```
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h: In instantiation of 'std::pair<std::_Rb_tree_node_base*,
std::_Rb_tree_node_base*> std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare, _Alloc>::_M_get_insert_unique_pos(const key_type&)
[with _Key = int; _Val = int; _KeyOfValue = std::_Identity<int>; _Compare = int; _Alloc = std::allocator<int>; std::_Rb_tree<_Key, _Val,
_KeyOfValue, _Compare, _Alloc>::key_type = int]':
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h:1498:47:   required from 'std::pair<std::_Rb_tree_iterator<_Val>,
bool> std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare, _Alloc>::_M_insert_unique(_Arg&&) [with _Arg = int; _Key = int; _Val = int;
_KeyOfValue = std::_Identity<int>; _Compare = int; _Alloc = std::allocator<int>]'
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_set.h:511:40:   required from 'std::pair<typename std::_Rb_tree<_Key, _Key,
std::_Identity<_Key>, _Compare, typename ___gnu_cxx::___alloc_traits<_Alloc>::rebind<_Key>::other>::const_iterator, bool> std::set<_Key,
_Compare, _Alloc>::insert(std::set<_Key, _Compare, _Alloc>::value_type&&) [with _Key = int; _Compare = int; _Alloc = std::allocator<int>;
typename std::_Rb_tree<_Key, _Key, std::_Identity<_Key>, _Compare, typename
___gnu_cxx::___alloc_traits<_Alloc>::rebind<_Key>::other>::const_iterator = std::_Rb_tree_const_iterator<int>; std::set<_Key, _Compare,
_Alloc>::value_type = int]'
error.cc:14:18:   required from here
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h:1445:11: error: expression cannot be used as a function
   ___comp = _M_impl._M_key_compare(___k, _S_key(___x));
         ^
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h:1456:7: error: expression cannot be used as a function
      if (_M_impl._M_key_compare(_S_key(___j._M_node), ___k))
      ^
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h: In instantiation of 'std::_Rb_tree<_Key, _Val, _KeyOfValue,
_Compare, _Alloc>::iterator std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare, _Alloc>::_M_insert_(std::_Rb_tree<_Key, _Val,
_KeyOfValue, _Compare, _Alloc>::_Base_ptr, std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare, _Alloc>::_Base_ptr, _Arg&&) [with _Arg =
int; _Key = int; _Val = int; _KeyOfValue = std::_Identity<int>; _Compare = int; _Alloc = std::allocator<int>; std::_Rb_tree<_Key, _Val,
_KeyOfValue, _Compare, _Alloc>::iterator = std::_Rb_tree_iterator<int>; std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare,
_Alloc>::_Base_ptr = std::_Rb_tree_node_base*]':
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h:1502:38:   required from 'std::pair<std::_Rb_tree_iterator<_Val>, bool>
std::_Rb_tree<_Key, _Val, _KeyOfValue, _Compare, _Alloc>::_M_insert_unique(_Arg&&) [with _Arg = int; _Key = int; _Val = int;
_KeyOfValue = std::_Identity<int>; _Compare = int; _Alloc = std::allocator<int>]'
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_set.h:511:40:   required from 'std::pair<typename std::_Rb_tree<_Key, _Key,
std::_Identity<_Key>, _Compare, typename ___gnu_cxx::___alloc_traits<_Alloc>::rebind<_Key>::other>::const_iterator, bool> std::set<_Key,
_Compare, _Alloc>::insert(std::set<_Key, _Compare, _Alloc>::value_type&&) [with _Key = int; _Compare = int; _Alloc = std::allocator<int>;
typename std::_Rb_tree<_Key, _Key, std::_Identity<_Key>, _Compare, typename
___gnu_cxx::___alloc_traits<_Alloc>::rebind<_Key>::other>::const_iterator = std::_Rb_tree_const_iterator<int>; std::set<_Key, _Compare,
_Alloc>::value_type = int]'
error.cc:14:18:   required from here
/usr/lib/gcc/x86_64-pc-linux-gnu/4.9.4/include/g++-v4/bits/stl_tree.h:1140:8: error: expression cannot be used as a function
      || _M_impl._M_key_compare(_KeyOfValue()(___v),
^
```

```
struct Base
{
    void doStuff(double x)
    {
        std::cout << "Got a double: " << x << std::endl;
    }
};

struct Derived : Base
{
    void doStuff(int x)
    {
        std::cout << "Got an int: " << x << std::endl;
    }
};

...

Derived d;
d.doStuff(3.141);
```

*Batteries not included

Legacy

(E.g., `enum` vs `enum class`)

Low road:

- C strings
- Preprocessor
- C I/O

Integrates easily with C

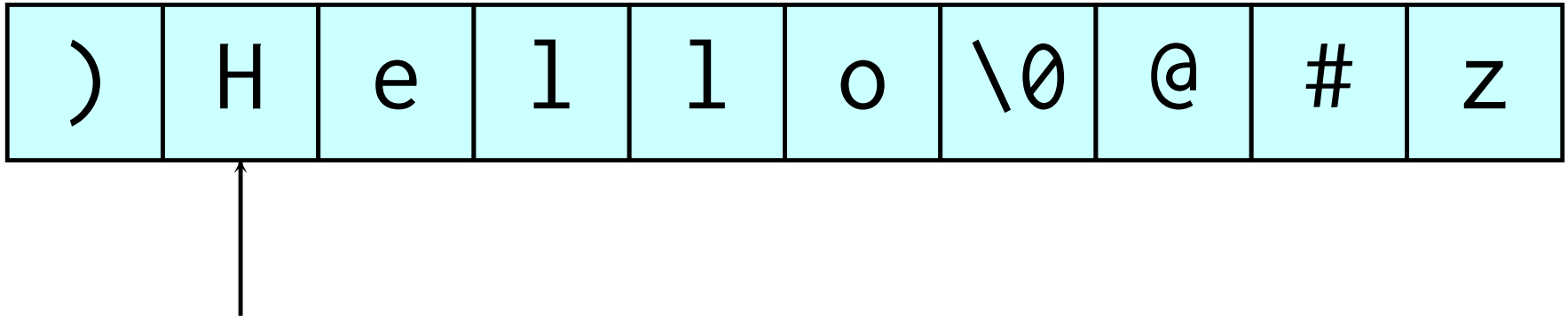
High road:

- C++ strings
- Templates
- C++ I/O

"Impedance mismatch" with C

(This is why the term "C/C++" is kind of silly.)

C Strings



- Null-terminated arrays
- Memory management totally manual
- Mutable reference types
- Must recalculate string length whenever needed
- Substrings usually need to be copies

C++ Strings

Implementation-defined templated class

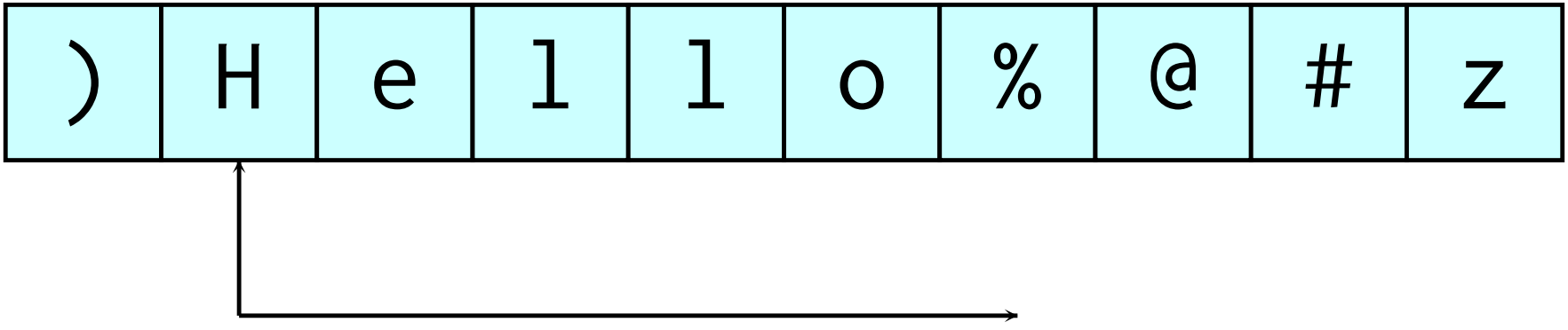
GNU libstdc++ has

- Length
- Capacity
- Reference count
- Data pointer

Generally

- Memory management controlled by string class
- Mutable value types

D Strings



- Slices (pointer + length)
- BYO memory management
- Immutable reference types

Case Study

- Preprocess text file
- Answer queries

Approach #1:

1. Read file one buffer load at a time
2. Construct (copy) strings from buffer to insert into data structure
3. Run query loop

Case Study

- Preprocess text file
- Answer queries

Approach #2:

1. Memory map file (`std.mmfile`)
2. Slice strings without copying
3. Run query loop

Not only was the initialisation much faster, the main query loop was ~10–20% faster thanks to better memory locality.

Could it work with C strings?

- Can fully control the memory layout
- Still need a copy to insert null bytes
- Copied and mutated data isn't implicitly shared with OS or other processes

Could it work with C++ strings?

- Short answer: no
- Longer answer: can partially control memory layout using a custom allocator, but this changes the string type
- Still can't use the memory-mapped file data effectively

What about D's overhead? And who is this D. Runtime, anyway?

```
import io = std.stdio;

class Greeter
{
    void greet()
    {
        io.writeln("Hello");
    }
}

void main()
{
    auto greeter = new Greeter();
    greeter.greet();
}
```

```
import io = std.stdio;

class Greeter
{
    void greet()
    {
        io.writeln("Hello");
    }
}

void main()
{
    auto greeter = new Greeter();
    greeter.greet();
}
```

1. My code

```
import io = std.stdio;

class Greeter
{
    void greet()
    {
        io.writeln("Hello");
    }
}

void main()
{
    auto greeter = new Greeter();
    greeter.greet();
}
```

1. My code
2. Imports

```
import io = std.stdio;

class Greeter
{
    void greet()
    {
        io.writeln("Hello");
    }
}

void main()
{
    auto greeter = new Greeter();
    greeter.greet();
}
```

1. My code
2. Imports
3. Compiler-generated code

```
import io = std.stdio;

class Greeter
{
    void greet()
    {
        io.writeln("Hello");
    }
}

void main()
{
    auto greeter = new Greeter();
    greeter.greet();
}
```

1. My code
2. Imports
3. Compiler-generated code
4. Runtime library

- Garbage collection
- `Object` (Base class of all D classes)
- Initialisation/cleanup of modules and static data
- Associative arrays
- Operations like struct equality and array copying
- Threads and TLS
- Run-time type information (`TypeInfo`)

(Having a runtime isn't just a D thing.)

It is not running in the background.

```
long factorial(int n)
{
    long f = 1;
    int j;
    for (j = 1; j <= n; j++)
    {
        f *= j;
    }
    return f;
}
```

```
<_D1t9factorialFiZl>:
    push   rbp
    mov    rbp,rsp
    mov    rsi,rdi
    mov    edx,0x1
    mov    rcx,rdx
    cmp    esi,edx
    jl     13893 <_D1t9factorialFiZl+0x23>
    movsxd rax,ecx
    imul   rax,rdx
    mov    rdx,rax
    inc    ecx
    cmp    ecx,esi
    jle    13883 <_D1t9factorialFiZl+0x13>
    mov    rax,rdx
    pop    rbp
    ret
```

In a single-threaded program,
this is *all* that's running.

BTW, this is colloquially known as "Better C"

A subset of D with no D runtime dependencies

(I.e., all C-like code + some other features)

Garbage collection can only happen on GC-based allocation

(or explicit `GC.collect()`)

I.e., normal systems programming idioms like allocating up front will avoid GC pauses

```
import core.memory;

void main()
{
    GC.disable();
    doSomethingLatencySensitive();
    GC.enable();

    // About to do lots of memory-hungry stuff
    // so improve performance by reserving GC memory up front
    GC.reserve(1024 * 1024 * 1024);
    doSomethingMemoryHungry();
    GC.minimize();

    message.sendToSomeServer();
    GC.collect();  // Might as well run GC while waiting
    waitForResponseFromSomeServer();
}
```

D supports

- Static allocation
- Stack allocation
- Plain-old heap allocation
- Garbage-collected heap allocation
- BYO memory with `emplace`

(No, really, it all works.)

"But I'm doing systems programming
so I can't use the runtime."

NB: This concern is **not** just about ricing performance.

"Why should I care? I have a multicore machine with several gigs of RAM and terabytes of storage. Most of the D runtime is in a shared library, anyway."

"I want to write mobile browser code in D. I can't use shared libraries, and every downloaded kilobyte counts."

Different applications have different needs.

More Case Studies

tsv-utils-dlang

https://github.com/eBay/tsv-utils-dlang

The "Keep Calm and Write Sensible Code" approach

- Tools for processing delimited text files (CSV, TSV, etc)
- Made by Jon Degenhardt for data mining at eBay
- Did not worry about avoiding features like GC
- Performance due to common sense like avoiding redundant copying and allocating

https://github.com/eBay/tsv-utils-dlang/blob/master/docs/Performance.md

Benchmark	Tool/Time	Tool/ Time	Tool/ Time	Tool/ Time
Numeric row filter	*tsv-filter*	mawk	GNU awk	Toolkit 1
(4.8 GB, 7M lines)	4.34	11.71	22.02	53.11
Regex row filter	*tsv-filter*	GNU awk	mawk	Toolkit 1
(2.7 GB, 14M lines)	7.11	15.41	16.58	28.59
Column selection	*tsv-select*	mawk	GNU cut	Toolkit 1
(4.8 GB, 7M lines)	4.09	9.38	12.27	19.12
Join two files	*tsv-join*	Toolkit 1	Toolkit 2	Toolkit 3
(4.8 GB, 7M lines)	20.78	104.06	194.80	266.42
Summary statistics	*tsv-summarize*	Toolkit 1	Toolkit 2	Toolkit 3
(4.8 GB, 7M lines)	15.83	40.27	48.10	62.97
CSV-to-TSV	*csv2tsv*	csvtk	xsv	
(2.7 GB, 14M lines)	27.41	36.26	40.40	

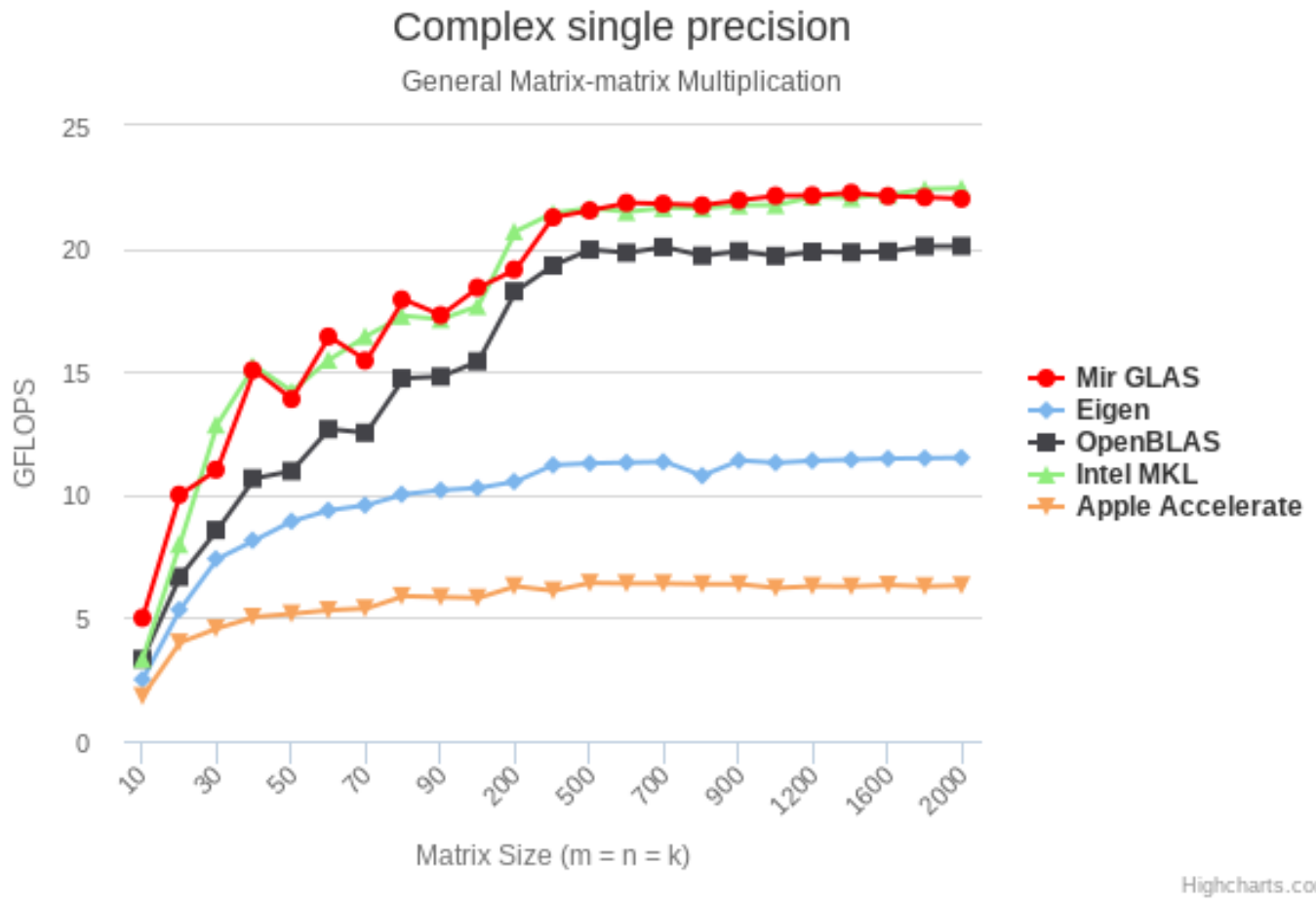
Mir numerical library

https://github.com/libmir/mir

The "D as a Better C" approach

- Collection of numerical libraries in D (think BLAS, NumPy) by Ilya Yaroshenko
- Uses `-betterC` flag and avoids D runtime features
- Mir GLAS can be linked to plain C code as BLAS implementation
- High performance through solid engineering and effective use of CPU features like SIMD

http://blog.mir.dlang.io/glas/benchmark/openblas/2016/09/23/glas-gemm-benchmark.html



Auburn Sounds

https://www.auburnsounds.com/index.html

The `@nogc` approach

- Commercial audio plugins in D
- Mostly relies on `@nogc` for latency-sensitive code

Alternative: put audio handling in thread detached from GC (see `core.thread`)

PowerNex

https://github.com/Vild/PowerNex

https://dlang.org/blog/2016/06/24/project-highlight-the-powernex-kernel/

The stub runtime approach

- An x64 OS project in D started by Dan Printzell
- Ports a minimal subset of the D runtime to bare metal (based on package by Adam Ruppe)
- Intended to eventually support a complete D development environment

Xanthe

https://gitlab.com/sarneaud/xanthe

https://theartofmachinery.com/2017/02/28/bare_metal_d.html

The horrible hacks approach

- Short vertical-scrolling shooter game demo that boots on bare metal x86
- Freestanding D
  - No D runtime
  - No C runtime
  - No OS

Even more case studies:

Weka.IO

Distributed data storage system

https://www.youtube.com/watch?v=q7wyQHF6SXY

Vibe.d

Event-loop-based web (and network) application framework

https://dlang.org/blog/2017/03/01/project-highlight-vibe-d/

Questions?

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