

# Windows, macOS and the Web

## *Lessons from cross-platform development at think-cell*

Sebastian Theophil, think-cell Software, Berlin

[stheophil@think-cell.com](mailto:stheophil@think-cell.com)

# The Problem

# The Problem

- 12 years of development for Windows only
- About 1.000.000 lines of C++
- Pervasive use of Windows platform-specifics through-out code base
- Product is an add-in, dynamically loaded

# The Problem

- 12 years of development for Windows only
- About 1.000.000 lines of C++
- Pervasive use of Windows platform-specifics through-out code base
- Product is an add-in, dynamically loaded
- Not in control of the main application (nor the computer itself!)

# The Problem

- 12 years of development for Windows only
- About 1.000.000 lines of C++
- Pervasive use of Windows platform-specifics through-out code base
- Product is an add-in, dynamically loaded
- Not in control of the main application (nor the computer itself!)
  - Render into application-supplied objects:
    - NSView, CALayer, HWND, DirectX texture
  - Renderer needs to support DirectX and OpenGL/Metal
  - Share the main message loop
  - Support platform-specific features like host application

# The Problem

- 12 years of development for Windows only
- About 1.000.000 lines of C++
- Pervasive use of Windows platform-specifics through-out code base
- Product is an add-in, dynamically loaded
- Not in control of the main application (nor the computer itself!)
  - Render into application-supplied objects:
    - NSView, CALayer, HWND, DirectX texture
  - Renderer needs to support DirectX and OpenGL/Metal
  - Share the main message loop
  - Support platform-specific features like host application
- Need cross-platform toolkit that hides platform specifics and **behaves identically** on different platforms

# Agenda

1. **Levels of Abstraction: Handling Files**
2. Kernel Object Lifetimes: Interprocess Shared Memory
3. Diverging OS Behavior: Handling Mouse Events
4. Common Tooling I: Text Internationalization
5. Common Tooling II: Error Reporting
6. Moving to WebAssembly

# Levels of Abstraction



# Levels of Abstraction

- How many ways to rename a file?

# Levels of Abstraction

- How many ways to rename a file?

```
BOOL MoveFileExW(LPCWSTR lpExistingFileName, LPCWSTR lpNewFileName, DWORD dwFlags)
```

```
int rename(char const* old, char const* new)
```

```
int renamex_np(char const* from, char const* to, unsigned int flags)
```

```
int copyfile(char const* from, char const* to, copyfile_state_t state, copyfile_flags_t flags)
```

```
bool QFile::rename(QString const& newName)
```

```
void boost::filesystem::rename(const path& old_p, const path& new_p)
```

```
- [NSFileManager replaceItemAtURL:withItemAtURL:backupItemName:  
options:resultingItemURL:error:]
```

# Levels of Abstraction

- Hard to get identical semantics on different platforms

# Levels of Abstraction

- Hard to get identical semantics on different platforms
- We don't need a file rename function!
- **This is the wrong level of abstraction!**
- Need functions to

# Levels of Abstraction

- Hard to get identical semantics on different platforms
- We don't need a file rename function!
- **This is the wrong level of abstraction!**
- Need functions to
  - create a user application settings file
  - create a temporary file that is automatically deleted but which can be opened by another application
  - download a file to a cache in thread-safe way
  - create a document in a user-specified folder, open system-specific “Save File” dialog, and create sandbox exception
- Functions with **strong** and **identical** semantics

# Levels of Abstraction

- Create a user application settings file
  - Windows: `%APPDATA%\think-cell [+ integrity level]\`
  - macOS: `~/Library/Application Support/think-cell/` or `~/Library/Group Containers/[Application Group Identifier]/`
  - Exclusive access while writing
  - Inherit ACL from parent folder

# Levels of Abstraction

- Create a temporary file that is automatically deleted but which can be opened by another application

```
CreateFile(  
    "%TEMP%\\...",  
    FILE_GENERIC_READ|FILE_GENERIC_WRITE,  
    FILE_SHARE_READ,  
    // make SECURITY_ATTRIBUTES FILE_ALL_ACCESS&~FILE_EXECUTE  
    // accessible by current user only,  
    CREATE_NEW, // the file should not already exist  
    FILE_ATTRIBUTE_TEMPORARY | FILE_ATTRIBUTE_HIDDEN  
    | FILE_FLAG_DELETE_ON_CLOSE,  
    nullptr  
);  
// synchronize file access
```

# Levels of Abstraction

- Create a temporary file that is automatically deleted but which can be opened by another application

```
open(  
    "~/Library/Group Containers/[Application Group Identifier]/...",  
    O_RDWR | O_CREAT | O_EXCL  
    | O_NOFOLLOW | O_CLOEXEC  
    | O_SHLOCK,  
    S_IRUSR|S_IWUSR  
);  
// synchronize file access  
// handle EINTR  
// manual reference counting in shared memory
```



# Levels of Abstraction

- Cross-platform interfaces need to have well-defined, strong semantics
- Weak semantics lead to subtle errors
  - Warning sign: Having to look at the implementation
- Too high-level: You miss a chance to unify code
- Too low-level:
  - You'll force identical interfaces on very different things
  - Semantics don't match operating system ( `QFile::setPermissions` )
  - or you lose a lot of expressiveness ( `rename` )

# Agenda

1. Levels of Abstraction: Handling Files
2. **Kernel Object Lifetimes: Interprocess Shared Memory**
3. Diverging OS Behavior: Handling Mouse Events
4. Common Tooling I: Text Internationalization
5. Common Tooling II: Error Reporting
6. Moving to WebAssembly

# Kernel Object Lifetimes

- We use shared memory to implement inter-process communication
- Boost.Interprocess (like Qt) offers a common API for shared memory on Windows and Posix



gettyimages<sup>®</sup>  
OAuth 2.0



# Kernel Object Lifetimes

- We use shared memory to implement inter-process communication
- Boost.Interprocess (like Qt) offers a common API for shared memory on Windows and Posix
- named memory objects mappable into different processes
  - `boost::interprocess::managed_shared_memory`
- pointers stored in shared memory
  - `boost::interprocess::offset_ptr`
  - store offset to their own this pointer
  - shared memory can be mapped at different addresses
- named synchronization objects
  - `boost::interprocess::named_mutex`

# Kernel Object Lifetimes

Server process:

```
#include <boost/interprocess/managed_shared_memory.hpp>
...
using namespace boost::interprocess;
using T = std::pair<double, int>;

// Name specific to build version, host, security identifier
char const szName[] = { ... };
managed_shared_memory seg(create_only, szName, /* size */ 65536);
T* p = seg.construct<T>("A") // name of the object
    (10.0, 0); // ctor first argument
```

Child process:

```
// Open managed shared memory
managed_shared_memory seg(open_only, szName);

// Find object
T* p = seg.find<T>("A").first;
assert(p->first == 10.0);
```

# Kernel Object Lifetimes

Server process:

```
#include <boost/interprocess/managed_shared_memory.hpp>
...
using namespace boost::interprocess;
using T = std::pair<double, int>;

// Name specific to build version, host, security identifier
char const szName[] = { ... };
managed_shared_memory seg(create_only, szName, /* size */ 65536);
T* p = seg.construct<T>("A") // name of the object
    (10.0, 0); // ctor first argument
```

Child process:

```
// Open managed shared memory
managed_shared_memory seg(open_only, szName);

// Find object
T* p = seg.find<T>("A").first;
assert(p->first == 10.0);
```

# Kernel Object Lifetimes

- **But** `managed_shared_memory` does not use native Windows shared memory

```
HANDLE hMapFile = CreateFileMapping(  
    /* use page file */ INVALID_HANDLE_VALUE,  
    /* security attributes */ NULL,  
    PAGE_READWRITE,  
    0,  
    /* size */ 256,  
    /* object name */ szName);
```

- On Windows, if last process accessing the named memory segment dies, memory is freed
- **This is a feature you want**

# Kernel Object Lifetimes

- **But** `managed_shared_memory` does not use native Windows shared memory

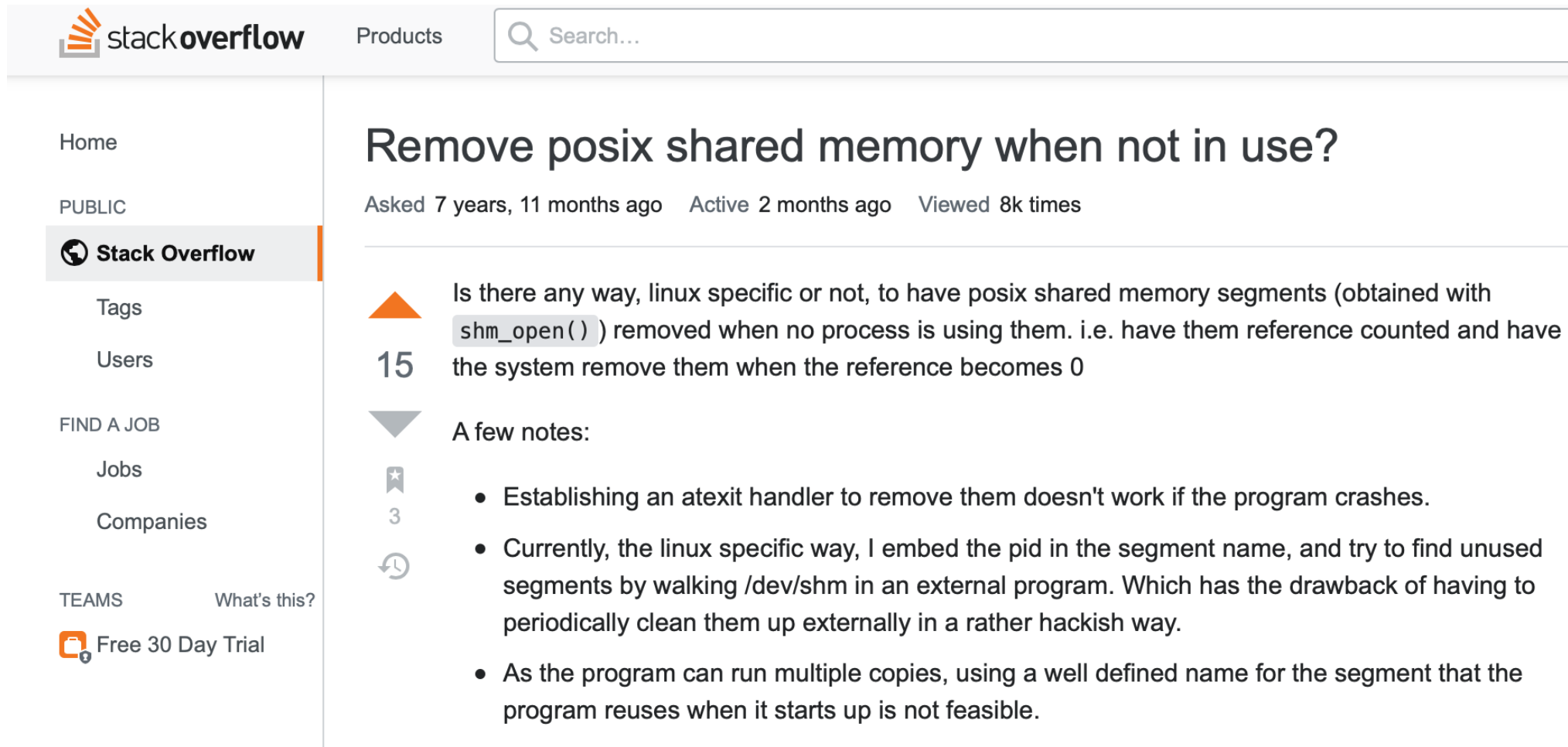
```
HANDLE hMapFile = CreateFileMapping(  
    /* use page file */ INVALID_HANDLE_VALUE,  
    /* security attributes */ NULL,  
    PAGE_READWRITE,  
    0,  
    /* size */ 256,  
    /* object name */ szName);
```

- On Windows, if last process accessing the named memory segment dies, memory is freed
  - **This is a feature you want**
- ... and not supported on Posix



# Kernel Object Lifetimes

- This seems to cause problems occasionally:



The screenshot shows a Stack Overflow page for a question titled "Remove posix shared memory when not in use?". The page includes a navigation sidebar on the left with links for Home, PUBLIC, Stack Overflow, Tags, Users, FIND A JOB, Jobs, Companies, TEAMS, and What's this?. The main content area displays the question title, its metadata (Asked 7 years, 11 months ago, Active 2 months ago, Viewed 8k times), and a single answer with 15 votes. The answer text asks if there is a way to remove posix shared memory segments (obtained with `shm_open()`) when no process is using them. It includes a section titled "A few notes:" with three bullet points: 1) Establishing an `atexit` handler doesn't work if the program crashes. 2) Currently, the linux specific way is to embed the pid in the segment name and find unused segments by walking `/dev/shm` in an external program, which has the drawback of having to periodically clean them up externally in a rather hackish way. 3) As the program can run multiple copies, using a well defined name for the segment that the program reuses when it starts up is not feasible.

# Kernel Object Lifetimes

- This seems to cause problems occasionally:

The screenshot shows a Stack Overflow page for a question titled "Mutex in shared memory when one user crashes?". The page includes a navigation sidebar on the left with links for Home, PUBLIC, Stack Overflow, Tags, Users, FIND A JOB, Jobs, Companies, TEAMS, and What's this?. The main content area displays the question text: "Suppose that a process is creating a mutex in shared memory and locking it and dumps core while the mutex is locked. Now in another process how do I detect that mutex is already locked but not owned by any process?". The question has 15 votes and 6 answers. It is tagged with c++, c, linux, mutex, and shared-memory. The user who edited the question is Zan Lynx, and the user who asked the question is Vivek. The page also shows options to share, edit, follow, close, and flag the question, as well as links to add a comment and start a bounty.

stackoverflow Products Search...

Home

PUBLIC

Stack Overflow

Tags

Users

FIND A JOB

Jobs

Companies

TEAMS What's this?

Free 30 Day Trial

## Mutex in shared memory when one user crashes?

Asked 10 years, 11 months ago Active 8 years, 8 months ago Viewed 10k times

Suppose that a process is creating a mutex in shared memory and locking it and dumps core while the mutex is locked.

15

Now in another process how do I detect that mutex is already locked but not owned by any process?

6

c++ c linux mutex shared-memory

share edit follow close flag

edited Dec 2 '11 at 17:27

Zan Lynx 47.1k 7 73 122

asked Nov 9 '09 at 10:47

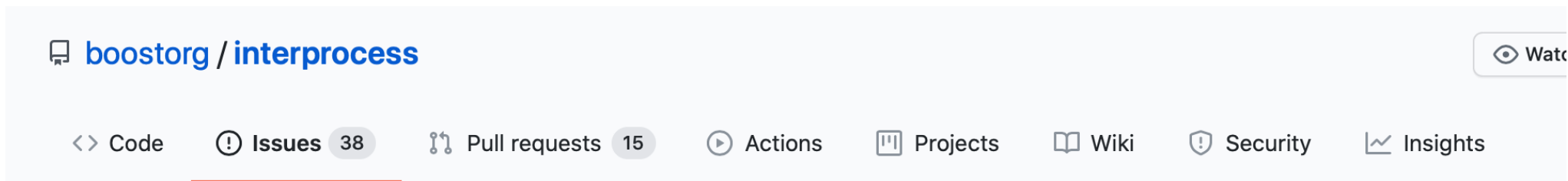
Vivek 423 1 3 10

[add a comment](#)

[start a bounty](#)

# Kernel Object Lifetimes

- This seems to cause problems occasionally:



## robustness of the interprocess mutex #65

Open

reed-lau opened this issue on 26 Oct 2018 · 0 comments



reed-lau commented on 26 Oct 2018



when using interprocess shared memroy, there are about two locks. one is the internal mutex\_family used by boost for managing the sharedmemory in MemoryAlgorithm, one is the user's one for synchronization. both mutex will cause deadlock, when process crash. How do you think about it.

the linux provide pthread\_mutexattr\_setrobust, but the interprocess module do not provide the interface, eg. interprocess:scoped\_lock's lock's return value is void instead of int, which could be compare with EOWNERDEAD.

# Kernel Object Lifetimes

- This seems to cause problems occasionally:

The screenshot shows a Stack Overflow page for a question titled "how to free managed\_shared\_memory after a program crash: what are effective techniques to use during debugging?". The page includes a navigation sidebar on the left with links for Home, PUBLIC, Stack Overflow, Tags, Users, FIND A JOB, Jobs, Companies, TEAMS, What's this?, and Free 30 Day Trial. The main content area shows the question title, a search bar, and a sidebar with 4,613 votes and 20 answers. The question text is as follows:

Asked 4 years, 4 months ago   Active 4 years, 3 months ago   Viewed 460 times

1

Admittedly I am a novice and self-taught programmer, and am finally venturing into the depths and power of C and C++. Some things that come with this self-learning process are not textbook or overtly googleable knowledge, such as tricks to use in difficult circumstances, and debugging strategies.

I am using boost::interprocess to set up shared memory using the managed\_shared\_memory and named objects. Unsurprisingly, my program crashes here and there for a number of reasons during my development. So far, I am rather unfamiliar with debugging tools, especially in linux. As a consequence, many times my shared memory does not get removed properly, as the crashing can result in destructors never being called, etc.

So, after such a program crash, when I attempt to run my application again, when my code tries to allocate a new segment of shared memory I see messages like:

The Overflow E

The Overfl

Featured on M

Respondin  
commitme

What shou  
[\*vcf\*] tag

Hot Meta Posts

36 Rename th

# Kernel Object Lifetimes

- This seems to cause problems occasionally:

[Boost-users] [interprocess] named mutex clean up 90 views



**Chard**

to boost...@lists.boost.org

Does calling `named_mutex::remove()` have consistent cross-platform behaviour?

The reason I ask is that I am trying to use a named mutex for an "I'm the only process" check.

That is, the process takes a shared lock on the named mutex (at start up), then, at points within the program, it attempts to get an exclusive lock in order to perform the check/actions. When finished, the mutex is returned to a shared lock.

# Kernel Object Lifetimes

- On Windows, shared memory and mutexes are reference counted, i.e., when the last user dies or crashes, resource is freed
- On Posix, shared memory is either
  1. File-backed:  
backing file still exists if processes crash, even after reboot
  2. Posix shared memory ( `shm_open` / `shm_unlink` ):  
backing memory persists until reboot
- Posix model assumes server-client model  
& Server owns shared memory object
- If not, there are two solutions to this problem.  
Boost.Interprocess and Qt implement **neither**

# Kernel Object Lifetimes

## 1. Robust mutexes

```
pthread_mutexattr_t attr;
pthread_mutexattr_init(&attr);
// Allow mutex to be placed in shared memory
pthread_mutexattr_setpshared(&attr, PTHREAD_PROCESS_SHARED);
// Mark mutex as robust
pthread_mutexattr_setrobust(&attr, PTHREAD_MUTEX_ROBUST);

pthread_mutex_t mtx;
pthread_mutex_init(&mtx, &attr);

[...]

if(EOWNERDEAD == pthread_mutex_lock(&mtx)) {
    // Owner of lock has died, reinitialize shared memory
}
```

See [Linux man pages](#) and ❤️ this Boost.Interprocess pull request <https://github.com/boostorg/interprocess/pull/67>

# Kernel Object Lifetimes

## 2. File Locking

- macOS does not support robust pthread locks unfortunately
- the only other resource that has process-lifetime are file locks
- **Attention!** File locks are weird on Posix as well:  
"Everything you never wanted to know about file locking" <https://apenwarr.ca/log/20101213>
- Please 👍 our Boost.Interprocess pull request <https://github.com/boostorg/interprocess/pull/132>



# Kernel Object Lifetimes

- Introduces `basic_managed_nonpersistent_shared_memory`
- `nonpersistent_shared_memory_object::priv_open_or_create`:

```
handle = ::open(strFile, O_CREAT | O_EXLOCK | O_NONBLOCK, perm);
if(ipcdetail::invalid_file()==handle) {
    ...
    // We are not the first to open backing file
    // block until we get shared lock instead
    handle = ::open(strFile, O_SHLOCK);
} else {
    ipcdetail::truncate_file(handle, 0);
    // Degrade lock to shared lock when we have truncated file
    // Not actually atomic?
    // What about NFS?
    flock(m_handle, LOCK_SH);
    ...
}
```

Pull request <https://github.com/boostorg/interprocess/pull/132>

# Kernel Object Lifetimes

- Introduces `basic_managed_nonpersistent_shared_memory`
- `nonpersistent_shared_memory_object::priv_open_or_create`:

```
handle = ::open(strFile, O_CREAT | O_EXLOCK | O_NONBLOCK, perm);
if(ipcdetail::invalid_file()==handle) {
    ...
    // We are not the first to open backing file
    // block until we get shared lock instead
    handle = ::open(strFile, O_SHLOCK);
} else {
    ipcdetail::truncate_file(handle, 0);
    // Degrade lock to shared lock when we have truncated file
    // Not actually atomic?
    // What about NFS?
    flock(m_handle, LOCK_SH);
    ...
}
```

Pull request <https://github.com/boostorg/interprocess/pull/132>

# Kernel Object Lifetimes

- Introduces `basic_managed_nonpersistent_shared_memory`
- `nonpersistent_shared_memory_object::priv_open_or_create`:

```
handle = ::open(strFile, O_CREAT | O_EXLOCK | O_NONBLOCK, perm);
if(ipcdetail::invalid_file()==handle) {
    ...
    // We are not the first to open backing file
    // block until we get shared lock instead
    handle = ::open(strFile, O_SHLOCK);
} else {
    ipcdetail::truncate_file(handle, 0);
    // Degrade lock to shared lock when we have truncated file
    // Not actually atomic?
    // What about NFS?
    flock(m_handle, LOCK_SH);
    ...
}
```

Pull request <https://github.com/boostorg/interprocess/pull/132>

# Kernel Object Lifetimes

- Introduces `basic_managed_nonpersistent_shared_memory`
- `nonpersistent_shared_memory_object::priv_open_or_create`:

```
handle = ::open(strFile, O_CREAT | O_EXLOCK | O_NONBLOCK, perm);
if(ipcdetail::invalid_file()==handle) {
    ...
    // We are not the first to open backing file
    // block until we get shared lock instead
    handle = ::open(strFile, O_SHLOCK);
} else {
    ipcdetail::truncate_file(handle, 0);
    // Degrade lock to shared lock when we have truncated file
    // Not actually atomic?
    // What about NFS?
    flock(m_handle, LOCK_SH);
    ...
}
```

Pull request <https://github.com/boostorg/interprocess/pull/132>

# Kernel Object Lifetimes

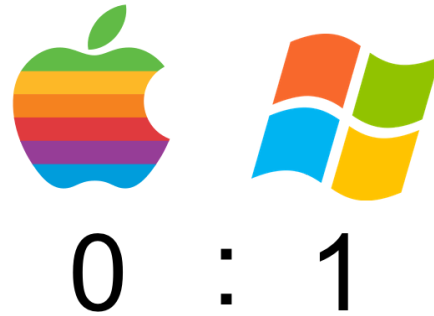
- Introduces `basic_managed_nonpersistent_shared_memory`
- `nonpersistent_shared_memory_object::priv_open_or_create`:

```
handle = ::open(strFile, O_CREAT | O_EXLOCK | O_NONBLOCK, perm);
if(ipcdetail::invalid_file()==handle) {
    ...
    // We are not the first to open backing file
    // block until we get shared lock instead
    handle = ::open(strFile, O_SHLOCK);
} else {
    ipcdetail::truncate_file(handle, 0);
    // Degrade lock to shared lock when we have truncated file
    // Not actually atomic?
    // What about NFS?
    flock(m_handle, LOCK_SH);
    ...
}
```

Pull request <https://github.com/boostorg/interprocess/pull/132>

# Kernel Object Lifetimes

- Aiming for strong and identical semantics
  - ... strong semantics means strong guarantees!
  - ... don't sacrifice operating system guarantees for identical API!
- Implementing strong & identical semantics may be hard
  - ... and is left to the user when cross-platform toolkits fail



# Agenda

1. Levels of Abstraction: Handling Files
2. Kernel Object Lifetimes: Interprocess Shared Memory
3. **Diverging OS Behavior: Handling Mouse Events**
4. Common Tooling I: Text Internationalization
5. Common Tooling II: Error Reporting
6. Moving to WebAssembly

# Mouse Events

- Superficially, Windows and macOS have a similar event handling architecture
- Windows sends messages to windows:

```
struct CMyWindow: ATL::CWindowImpl<CMyWindow>
{
    // window message map
    BEGIN_MSG_MAP(CMyWindow)
        MESSAGE_HANDLER(WM_MOUSEMOVE, OnMouseMove)
        MESSAGE_HANDLER(WM_LBUTTONDOWN, OnButtonDown)
        MESSAGE_HANDLER(WM_LBUTTONDBLCLK, OnDoubleClick)
    END_MSG_MAP()

    ...
    LRESULT OnMouseMove(UINT nMsg, WPARAM wparam, LPARAM lparam,
        BOOL& bHandled);
    LRESULT OnButtonDown(UINT nMsg, WPARAM wparam, LPARAM lparam,
        BOOL& bHandled);
    LRESULT OnDoubleClick(UINT nMsg, WPARAM wparam, LPARAM lparam,
        BOOL& bHandled);
};
```



# Mouse Events

- Superficially, Windows and macOS have a similar event handling architecture
- macOS handles the messages and calls event handlers directly:

```
@interface MyView : NSView {  
    - (void)mouseMoved:(NSEvent*)nsevent;  
    - (void)mouseDragged:(NSEvent*)nsevent;  
    - (void)mouseDown:(NSEvent*)nsevent;  
}
```

# Mouse Events

- Superficially, Windows and macOS have a similar event handling architecture
- macOS handles the messages and calls event handlers directly:

```
@interface MyView : NSView {  
    - (void)mouseMoved:(NSEvent*)nsevent;  
    - (void)mouseDragged:(NSEvent*)nsevent;  
    - (void)mouseDown:(NSEvent*)nsevent;  
}
```

- The semantical differences are large though

# Mouse Events

## Windows

Coordinates relative to client-area of the window/component

Single or double click

`WM_MOUSELEAVE`, `WM_MOUSEENTERED` are opt-in events.

No distinction between `WM_MOUSEMOVE` and drag events.

## macOS

Coordinates relative to top-level window

`-[NSEvent clickCount]`

`-[NSResponder mouseEntered]`

`-[NSResponder mouseExited]`

`-[NSResponder mouseMoved]`

`-[NSResponder mouseDragged]`

# Mouse Events

## Windows

`SetCapture/ReleaseCapture` to receive mouse messages after mouse has exited the window.

`WM_CAPTURECHANGED` `WM_CANCELMODE`

Mouse message order can be "surprising", see

`QWindowsMouseHandler::translateMouseEvent`

## macOS

Capture is automatic

`-[NSResponder mouseMoved]`

`-[NSResponder mouseDown]`

`-[NSResponder mouseDragged]`

`-[NSResponder mouseUp]`

# Mouse Events

## Windows

`SetCapture/ReleaseCapture` to receive mouse messages after mouse has exited the window.

`WM_CAPTURECHANGED` `WM_CANCELMODE`

Mouse message order can be "surprising", see `QWindowsMouseHandler::translateMouseEvent`

The macOS model is much saner, offers strong guarantees.  
Strong guarantees are good!

## macOS

Capture is automatic

`-[NSResponder mouseMoved]`  
`-[NSResponder mouseDown]`  
`-[NSResponder mouseDragged]`  
`-[NSResponder mouseUp]`

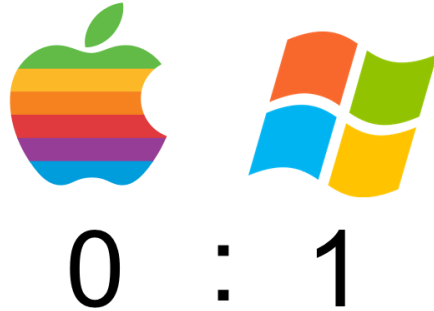
# Mouse Events

## (Simplified) Mouse Message State Machine

1. `WM_MOUSEMOVE`
  - keep track of mouse window
  - `TrackMouseEvent` registers for `WM_MOUSELEAVE`
2. `WM_XBUTTONDOWN`
  - keep track of pressed button
  - ignore all other button presses
  - call `SetCapture` to receive messages
3. `WM_XBUTTONUP`
  - *Pressed* button is released, ignore others
  - call `ReleaseCapture`
3. `WM_CANCELMODE / WM_CAPTURECHANGED`
  - Clear mouse state

# Mouse Events

- Aiming for strong and identical semantics
  - ... strong semantics **implies strong invariants**
  - ... must hold on each operating system
  - ... unify the number of states your app may have



# Agenda

1. Levels of Abstraction: Handling Files
2. Kernel Object Lifetimes: Interprocess Shared Memory
3. Diverging OS Behavior: Handling Mouse Events
4. **Common Tooling I: Text Internationalization**
5. Common Tooling II: Error Reporting
6. Moving to WebAssembly



# Text Internationalization

- Internationalization is more than translation, but focus on that today
- Important translation features:

1. Annotate translatable text in code

```
TRANSLATE("Do not ask for user name/password")
```

2. Translation context

```
TRANSLATECTX("Proxy Authentication",  
"Proxy: http://en.wikipedia.org/wiki/Proxy_server.")
```

3. There are arbitrary number of plural forms

*0 weeks - 0 недель*

*1 week - 1 неделя*

*4 weeks - 4 недели*

*5 weeks - 5 недель*

# Text Internationalization

- What is the general flow for i18n:
  1. Annotation in source code
  2. Extraction of translatable text
  3. Send to translators
  4. Get `xliff` (XML Localization Interchange File Format) file
  5. Import into project as resource
  6. At program runtime, lookup text/language pair
- Supporting native mechanisms would suck
  - You want the same markup in code
  - You want a single text extraction run, preferably platform independent
  - You want a uniform access mechanism for translatable strings, no lifetime issues (`char const*`!)
- `Boost.Locale` would fit the bill

# Text Internationalization

- `Boost.Locale` was added 2018 in boost 1.67:

```
std::cout << translate("Hello World") << std::endl;
```

```
"Привет мир"
```

```
std::cout << translate("File", "open") << std::endl;
```

```
"öffnen"
```

```
std::cout << format(translate("You have {1} file in the directory",  
                             "You have {1} files in the directory",  
                             3)) % 3 << std::endl;
```

```
"У вас есть 3 файла в каталоге"
```

# Text Internationalization

- `Boost.Locale` was added 2018 in boost 1.67:

```
std::cout << translate("Hello World") << std::endl;
```

```
"Привет мир"
```

```
std::cout << translate("File", "open") << std::endl;
```

```
"öffnen"
```

```
std::cout << format(translate("You have {1} file in the directory",  
                             "You have {1} files in the directory",  
                             3)) % 3 << std::endl;
```

```
"У вас есть 3 файла в каталоге"
```

- We don't have to do runtime text lookups like this is 1995
- We have `constexpr` functions!

# Text Internationalization

```
#include <array>

enum ESupportedLanguage {
    elangEN, elangRU, elangCOUNT
};

using STranslatableString = std::array<char const*, elangCOUNT>;

char const* translate(STranslatableString ts) noexcept;

#define TRANSLOOKUP(String, Context) ...
#define TRANSLATECTX(String, Context) \
    translate(TRANSLOOKUP(String, Context))

int main() noexcept {
    std::cout
        << TRANSLATECTX("Cancel", "Cancel: as in Windows dialogs.")
        << std::endl;
}
```

# Text Internationalization

```
#include <array>

enum ESupportedLanguage {
    elangEN, elangRU, elangCOUNT
};

using STranslatableString = std::array<char const*, elangCOUNT>;

char const* translate(STranslatableString ts) noexcept;

#define TRANSLOOKUP(String, Context) ...
#define TRANSLATECTX(String, Context) \
    translate(TRANSLOOKUP(String, Context))

int main() noexcept {
    std::cout
        << TRANSLATECTX("Cancel", "Cancel: as in Windows dialogs.")
        << std::endl;
}
```

# Text Internationalization

```
#include <array>

enum ESupportedLanguage {
    elangEN, elangRU, elangCOUNT
};

using STranslatableString = std::array<char const*, elangCOUNT>;

char const* translate(STranslatableString ts) noexcept;

#define TRANSLOOKUP(String, Context) ...
#define TRANSLATECTX(String, Context) \
    translate(TRANSLOOKUP(String, Context))

int main() noexcept {
    std::cout
        << TRANSLATECTX("Cancel", "Cancel: as in Windows dialogs.")
        << std::endl;
}
```

# Text Internationalization

```
using STranslatableString = std::array<char const*, eLangCOUNT>;

template<std::uint64_t, std::uint64_t, std::uint64_t, std::uint64_t>
struct STranslatableStringMap {
    static STranslatableString const m_apsz;
};

#define TRANSLOOKUP(String, Context) \
    (STranslatableStringMap< \
        StaticMurmurHash::Hash(u8 ## String).first, \
        StaticMurmurHash::Hash(u8 ## String).second, \
        StaticMurmurHash::Hash(u8 ## Context).first, \
        StaticMurmurHash::Hash(u8 ## Context).second \
    >::m_apsz)
```



# Text Internationalization

```
using STranslatableString = std::array<char const*, elangCOUNT>;

template<std::uint64_t, std::uint64_t, std::uint64_t, std::uint64_t>
struct STranslatableStringMap {
    static STranslatableString const m_apsz;
};

template<> constexpr std::array<char const*, elangCOUNT>
STranslatableStringMap<0x17aa19f18a894459, 0xab6ff21156e8a341,
    0x691fc12842a48f3c, 0x4720a1a3af148ae1
>::m_apsz{
    "Cancel", "Отменить"
};

#define TRANSLOOKUP(String, Context) \
    (STranslatableStringMap< \
        StaticMurmurHash::Hash(u8 ## String).first, \
        StaticMurmurHash::Hash(u8 ## String).second, \
        StaticMurmurHash::Hash(u8 ## Context).first, \
        StaticMurmurHash::Hash(u8 ## Context).second \
    >::m_apsz)
```

# Text Internationalization

- Reminder constexpr functions:
  - implicitly inline.
  - must accept and return only literal types.
    - i.e. scalars, references,
    - aggregate types `T t = { ... };`, e.g., `std::array`
    - type with `constexpr` ctor and dtor, all data members and base classes are literal types, e.g., `std::pair`
    - arrays of such types
  - can't be virtual, cannot contain `goto` or `try/catch`
  - may contain `if`, `switch`, all loop statements
  - local variable declarations if variable is initialized and literal type
  - ctor cannot be `constexpr` if class has virtual base classes

# Text Internationalization

```
namespace StaticMurmurHash {
    using uint128_t = std::pair<std::uint64_t, std::uint64_t>;

    template<int N>
    constexpr uint128_t Hash(
        char const (&at)[N],
        std::uint32_t seed=0) noexcept
    {
        return MurmurHash3_x64_128(&at[0], N, seed);
    }
}
```

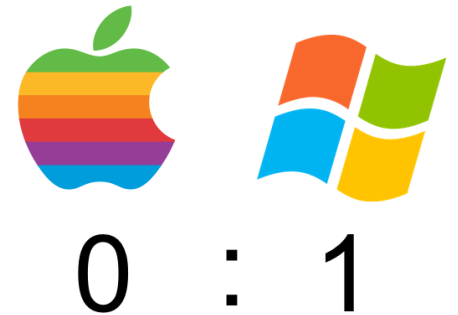
See <https://github.com/aappleby/smhasher> for MurmurHash sources

# Text Internationalization

```
namespace StaticMurmurHash {  
    using uint128_t = std::pair<std::uint64_t, std::uint64_t>;  
  
    template<int N>  
    constexpr uint128_t Hash(  
        char const (&at)[N],  
        std::uint32_t seed=0) noexcept  
    {  
        return MurmurHash3_x64_128(&at[0], N, seed);  
    }  
}
```

See <https://github.com/aappleby/smhasher> for MurmurHash sources

- Aiming for strong and identical semantics  
... that includes external tools in your build process!



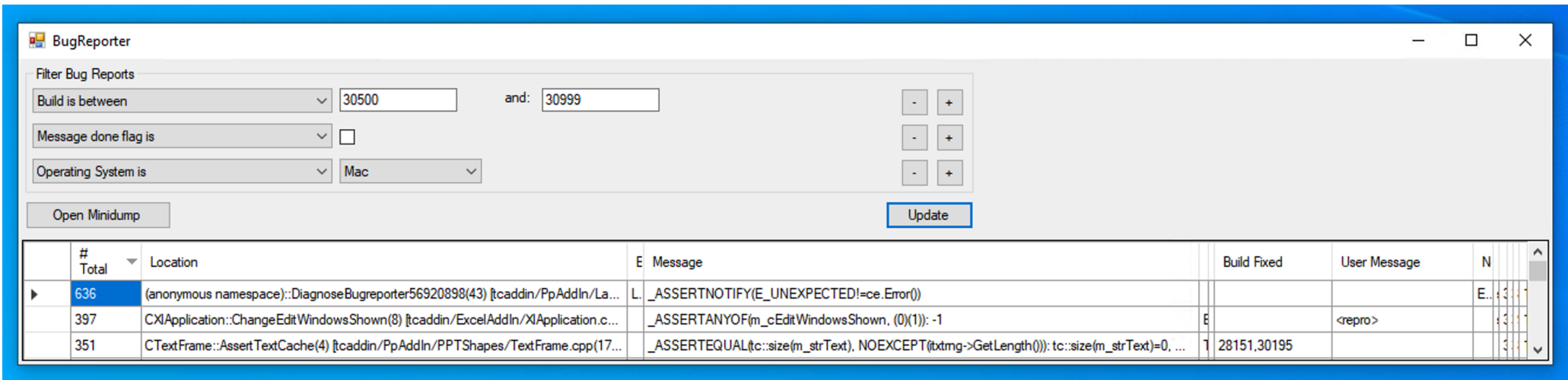
# Agenda

1. Levels of Abstraction: Handling Files
2. Kernel Object Lifetimes: Interprocess Shared Memory
3. Diverging OS Behavior: Handling Mouse Events
4. Common Tooling I: Text Internationalization
5. **Common Tooling II: Error Reporting**
6. Moving to WebAssembly

# Error Reporting

- think-cell has a powerful error reporting architecture
- We use a lot of ASSERTs to check invariants
- Check all system API error codes, distinguish expected and unexpected errors
- Once we encounter unexpected behavior
  1. Decide to show user message
  2. Send an error report home
    - Our backend analyzes error report
    - Checks if we have already fixed bug or if we would like more info from user
    - Reports back
    - May silently download & install update

# Error Reporting



The screenshot shows the BugReporter application window. At the top, there are filter controls for Bug Reports. The filters include: 'Build is between' (30500 and 30999), 'Message done flag is' (checkbox), and 'Operating System is' (Mac). There are 'Open Minidump' and 'Update' buttons. Below the filters is a table of bug reports.

# Total	Location	E Message	Build Fixed	User Message	N
636	(anonymous namespace)::DiagnoseBugreporter56920898(43) [tcaddin/PpAddIn/La...	L _ASSERTNOTIFY(E_UNEXPECTED!=ce.Error())			E..
397	CXlApplication::ChangeEditWindowsShown(8) [tcaddin/ExcelAddIn/XlApplication.c...	_ASSERTANYOF(m_cEditWindowsShown, (0)(1)): -1	E	<repro>	
351	CTextFrame::AssertTextCache(4) [tcaddin/PpAddIn/PPTShapes/TextFrame.cpp(17...	_ASSERTEQUAL(tc::size(m_strText), NOEXCEPT(txtmg->GetLength())): tc::size(m_strText)=0, ...	1 28151,30195		

- Developers check and analyze most frequent bug reports regularly
  - Annotate in which version bug is fixed
- Backend pre-analyzes bug reports:
  - Walk stack back to relevant frame (skip smart pointers, error reporting code)
  - Group errors based on method offset (not source line, nor error message)
- **Finds a lot of bugs that depend on user's setup**

# Error Reporting

The core of this functionality on Windows:

```
BOOL MiniDumpWriteDump(
    HANDLE                hProcess,
    DWORD                 ProcessId,
    HANDLE                 hFile,
    MINIDUMP_TYPE          DumpType,
    PMINIDUMP_EXCEPTION_INFORMATION ExceptionParam,
    PMINIDUMP_USER_STREAM_INFORMATION UserStreamParam,
    PMINIDUMP_CALLBACK_INFORMATION CallbackParam
)
```

- Writes dump including the full stack and registers
- Microsoft provides symbol servers for system libraries
- Let you symbolicate the dump and analyze it
- A lot of information in ~ 100kb
- **Nothing similar existed on macOS**



# Error Reporting

- There is Google Breakpad/Crashpad of course:
  - Writes Windows minidumps on all systems
  - Need custom tools to analyze for Posix crashes (instead of lldb)
  - Now planning to let lldb support windows pdb format
- A lot of code (that you need to support if you include it!)
- not very powerful solution

# Error Reporting

- There is Google Breakpad/Crashpad of course:
  - Writes Windows minidumps on all systems
  - Need custom tools to analyze for Posix crashes (instead of lldb)
  - Now planning to let lldb support windows pdb format
- A lot of code (that you need to support if you include it!)
- not very powerful solution
- Mach-o file format is well documented, google "Mach-O File Format Reference"
- This includes the core file format
  - there are docs for ELF as well, but ELF core file is not standardized (Check what gdb does)
- "all" we have to do is write mach-o core file only with stack memory

# Error Reporting

## Out-of-process crash handling: Send task access rights

```
mach_port_t portBootstrap;
task_get_bootstrap_port(mach_task_self(), &portBootstrap);

// Lookup port opened by handler process
mach_port_t portChild;
bootstrap_look_up(portBootstrap, "port name", &portChild);

STcDumpMsg msg = {
    { MACH_MSGH_BITS_REMOTE(MACH_MSG_TYPE_COPY_SEND)
      | MACH_MSGH_BITS_COMPLEX, sizeof(msg), portChild },
    { 1 },
    // Message copying access rights to mach_task_self()
    { mach_task_self(), 0, 0, MACH_MSG_TYPE_COPY_SEND,
      MACH_MSG_PORT_DESCRIPTOR }
};
mach_msg(std::addressof(msg.header), MACH_SEND_MSG, sizeof(msg), 0,
        MACH_PORT_NULL, MACH_MSG_TIMEOUT_NONE, MACH_PORT_NULL);
```

# Error Reporting

## Out-of-process crash handling: Send task access rights

```
mach_port_t portBootstrap;
task_get_bootstrap_port(mach_task_self(), &portBootstrap);

// Lookup port opened by handler process
mach_port_t portChild;
bootstrap_look_up(portBootstrap, "port name", &portChild);

STcDumpMsg msg = {
    { MACH_MSGH_BITS_REMOTE(MACH_MSG_TYPE_COPY_SEND)
      | MACH_MSGH_BITS_COMPLEX, sizeof(msg), portChild },
    { 1 },
    // Message copying access rights to mach_task_self()
    { mach_task_self(), 0, 0, MACH_MSG_TYPE_COPY_SEND,
      MACH_MSG_PORT_DESCRIPTOR }
};
mach_msg(std::addressof(msg.header), MACH_SEND_MSG, sizeof(msg), 0,
        MACH_PORT_NULL, MACH_MSG_TIMEOUT_NONE, MACH_PORT_NULL);
```

# Error Reporting

## Out-of-process crash handling: Send task access rights

```
mach_port_t portBootstrap;
task_get_bootstrap_port(mach_task_self(), &portBootstrap);

// Lookup port opened by handler process
mach_port_t portChild;
bootstrap_look_up(portBootstrap, "port name", &portChild);

STcDumpMsg msg = {
    { MACH_MSGH_BITS_REMOTE(MACH_MSG_TYPE_COPY_SEND)
      | MACH_MSGH_BITS_COMPLEX, sizeof(msg), portChild },
    { 1 },
    // Message copying access rights to mach_task_self()
    { mach_task_self(), 0, 0, MACH_MSG_TYPE_COPY_SEND,
      MACH_MSG_PORT_DESCRIPTOR }
};
mach_msg(std::addressof(msg.header), MACH_SEND_MSG, sizeof(msg), 0,
        MACH_PORT_NULL, MACH_MSG_TIMEOUT_NONE, MACH_PORT_NULL);
```

# Error Reporting

## Out-of-process crash handling: Read thread state

```
mach_msg_type_number_t cThreads;
thread_array_t athread;

task_threads(task, &athread, &cThreads);

struct SThreadCommand {
    thread_command m_header;
    x86_thread_state m_threadstate;
    x86_float_state m_floatstate;
    x86_exception_state m_exceptionstate;
};
std::vector<SThreadCommand> vecthreadcmd;
// call thread_get_state for each thread/state pair
```

# Error Reporting

## Out-of-process crash handling: Read thread state

```
mach_msg_type_number_t cThreads;  
thread_array_t athread;  
  
task_threads(task, &athread, &cThreads);  
  
struct SThreadCommand {  
    thread_command m_header;  
    x86_thread_state m_threadstate;  
    x86_float_state m_floatstate;  
    x86_exception_state m_exceptionstate;  
};  
std::vector<SThreadCommand> vecthreadcmd;  
// call thread_get_state for each thread/state pair
```

# Error Reporting

## Out-of-process crash handling: Read stack memory

```
mach_vm_address_t pvBegin = 0;
mach_vm_size_t cb = 0;
vm_region_submap_info_64 vmregioninfo;
natural_t nDepth = 0;
mach_msg_type_number_t cbVMRegionInfo =
    VM_REGION_SUBMAP_INFO_COUNT_64;

std::vector<segment_command_64> vecsegment;
while(KERN_SUCCESS == mach_vm_region_recurse(
    task, &pvBegin, &cb, &nDepth, &vmregioninfo, &cbVMRegionInfo
)) {
    if(VM_MEMORY_STACK==vmregioninfo.user_tag) { // stack memory
        vecsegment.emplace_back(
            segment_command_64{LC_SEGMENT_64, ...}
        );
    }
    pvBegin += cb;
}
```



# Error Reporting

## Out-of-process crash handling: Read stack memory

```
mach_vm_address_t pvBegin = 0;
mach_vm_size_t cb = 0;
vm_region_submap_info_64 vmregioninfo;
natural_t nDepth = 0;
mach_msg_type_number_t cbVMRegionInfo =
    VM_REGION_SUBMAP_INFO_COUNT_64;

std::vector<segment_command_64> vecsegment;
while(KERN_SUCCESS == mach_vm_region_recurse(
    task, &pvBegin, &cb, &nDepth, &vmregioninfo, &cbVMRegionInfo
)) {
    if(VM_MEMORY_STACK==vmregioninfo.user_tag) { // stack memory
        vecsegment.emplace_back(
            segment_command_64{LC_SEGMENT_64, ...}
        );
    }
    pvBegin += cb;
}
```

# Error Reporting

## Out-of-process crash handling: Read stack memory

```
mach_vm_address_t pvBegin = 0;
mach_vm_size_t cb = 0;
vm_region_submap_info_64 vmregioninfo;
natural_t nDepth = 0;
mach_msg_type_number_t cbVMRegionInfo =
    VM_REGION_SUBMAP_INFO_COUNT_64;

std::vector<segment_command_64> vecsegment;
while(KERN_SUCCESS == mach_vm_region_recurse(
    task, &pvBegin, &cb, &nDepth, &vmregioninfo, &cbVMRegionInfo
)) {
    if(VM_MEMORY_STACK==vmregioninfo.user_tag) { // stack memory
        vecsegment.emplace_back(
            segment_command_64{LC_SEGMENT_64, ...}
        );
    }
    pvBegin += cb;
}
```

# Error Reporting

## Out-of-process crash handling: Write to File

```
struct mach_header_64
+ std::vector<SThreadCommand>
+ std::vector<segment_command_64>
+ actual memory segments
```

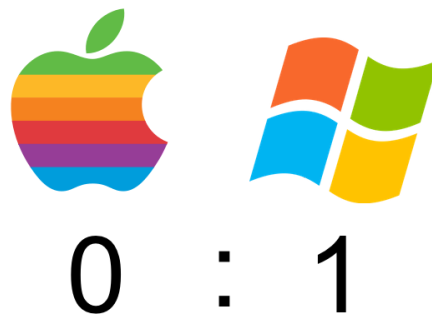
- Resulting file can be loaded in lldb as core file
- As zip file ~100-200 Kb
- Need some additional meta data

```
<m_nThread val="0"/>
<m_vecmodule length="538">
  <elem>
    <m_pvStartAddress val="140735072636928"/>
    <m_strPath>/usr/lib/libz.1.dylib</m_strPath>
    <m_modver val="66059"/>
    <m_uuid val="db120508-3bed-37a8-b439-5235eab4618a"/>
  </elem>
```

# Error Reporting

## Out-of-process crash handling: Backend

- Needs debug symbols for your builds
- Cached system binaries for macOS
- Symbol lookup: <https://lldb.llvm.org/use/symbols.html>
- Backend wraps lldb <https://lldb.llvm.org/design/sbapi.html>
  - load core file
  - lookup binaries/symbols and add them as modules
- Check out <https://github.com/think-cell/minidump>



# Agenda

1. Levels of Abstraction: Handling Files
2. Kernel Object Lifetimes: Interprocess Shared Memory
3. Diverging OS Behavior: Handling Mouse Events
4. Common Tooling I: Text Internationalization
5. Common Tooling II: Error Reporting
6. **Moving to WebAssembly**

# WebAssembly

- think-cell ships with Google Chrome extension and web app
- What language to use?

# WebAssembly

- think-cell ships with Google Chrome extension and web app
- What language to use?
  1. JavaScript was a hard no
  2. TypeScript looked much better
    - somewhat type-safe, type definition libraries <https://github.com/DefinitelyTyped/DefinitelyTyped>
    - **but** sharing code with C++ was impossible
  3. Emscripten looked interesting
    - Interfacing with JavaScript loses type-safety again

```
auto xhr = emscripten::val::global("XMLHttpRequest").new_();  
xhr["open"]("GET", "http://google.com");
```

# WebAssembly

- think-cell ships with Google Chrome extension and web app
- What language to use?
  1. JavaScript was a hard no
  2. TypeScript looked much better
    - somewhat type-safe, type definition libraries <https://github.com/DefinitelyTyped/DefinitelyTyped>
    - **but** sharing code with C++ was impossible
  3. Emscripten looked interesting
    - Interfacing with JavaScript loses type-safety again

```
auto xhr = emscripten::val::global("XMLHttpRequest").new_();  
xhr["open"]("GET", "http://google.com");
```

... so we build our own compiler



# WebAssembly

Type definition libraries

```
interface HTMLElement extends Element, GlobalEventHandlers, ... {  
  hidden: boolean;  
  innerText: string;  
  readonly offsetParent: Element | null;  
  
  click(): void;  
  
  ...  
}
```

# WebAssembly

+ Typescript compiler API

```
function transform(file: string) : void {
  let program = ts.createProgram([file]);
  const sourceFile = program.getSourceFile(file);

  ts.forEachChild(sourceFile, node => {
    if (ts.isFunctionDeclaration(node)) {
      // do something
    } else if (ts.isVariableStatement(node)) {
      // do something else
    }
  });
}
```

## **tcjs** — <https://github.com/think-cell/tcjs>

- Compiles typescript interface declarations to C++ interfaces
- **i.e. type-safe calls to JavaScript libraries via emscripten**
- Almost self-hosting, i.e., compiling typescript compiler interface
- Still missing typescript language features, but already usable
- Originally master thesis of Egor Suvorov at think-cell
- Check it out!

# WebAssembly

Type-safe calls to JavaScript/TypeScript libraries via emscripten

```
void transform(js::string const& file) {
    js::Array<js::string> arr(jst::create_js_object);
    arr->push(file);

    auto const program = js::ts::createProgram(arr, ...);
    auto const sourceFile = program->getSourceFile(file);

    js::ts::forEachChild(sourceFile,
        js::js::lambda(
            [](js::ts::Node jnodeChild) noexcept -> js::unknown {
                if(js::ts::isFunctionDeclaration(jnodeChild)) {
                }
            }
        )
    );
}
```

Check out <https://github.com/think-cell/tcjs>

Lots of interesting work to do!

# Conclusion

**No premature unification in code**

**Unify object lifetimes across Operating Systems**

**Maintain cross-platform invariants with state machines**

**Make your build tools and backends cross-platform**

# Conclusion

**No premature unification in code**

**Unify object lifetimes across Operating Systems**

**Maintain cross-platform invariants with state machines**

**Make your build tools and backends cross-platform**

**Always use C++ 🤘**

# Thank you!

## Now to your questions!

Sebastian Theophil, think-cell Software, Berlin

[stheophil@think-cell.com](mailto:stheophil@think-cell.com)