# An Analysis of Memory Management in HipHopVM

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HHVM Group, Summer Research Scholarship 2013/14

# What is a HipHopVM?

# Background

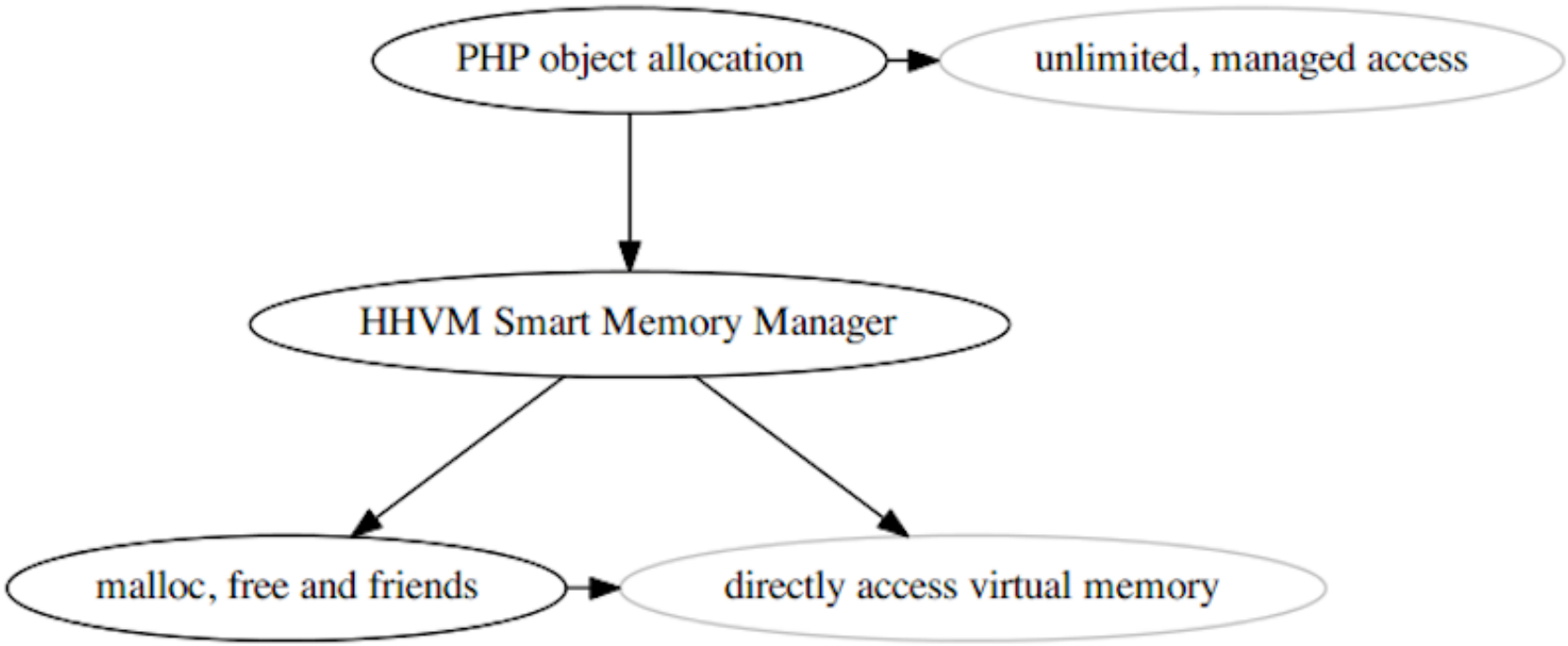
- HipHopVM is an Free and Open Source PHP engine
- Written primarily in C++ with moderate amounts of PHP and x86_64 assembly (1.2 million lines of code total)
- It uses a JIT compiler (though historically it translated PHP to C++ for AOT compilation)
- It is the PHP engine designed by and which hosts Facebook
- Its on GitHub! `https://github.com/facebook/hhvm`

# Our Tasks

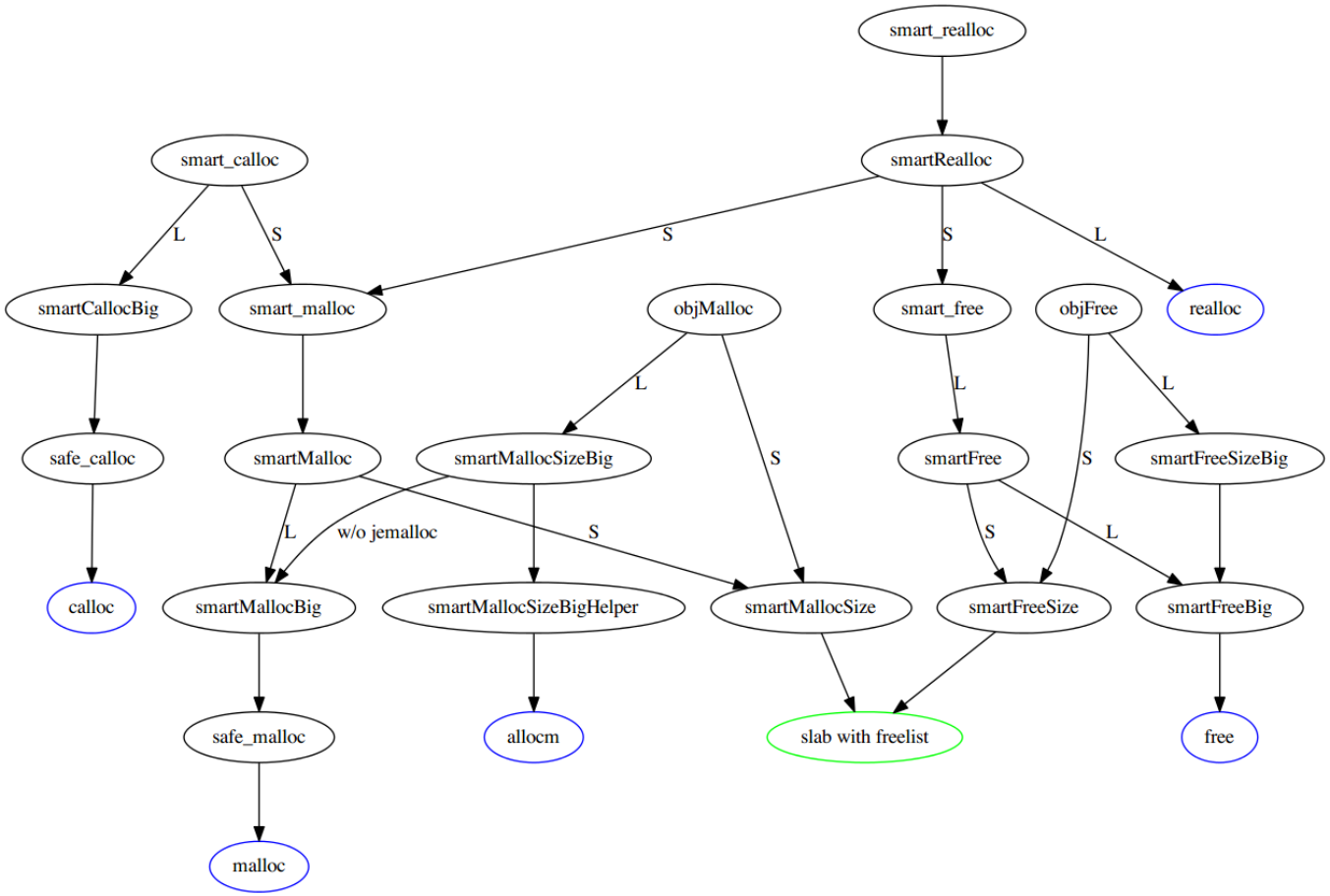
- To isolate the affect of naive reference counting on HHVM's performance
- To observe how memory access maps to actual physical memory access
- To map and analyse the behaviour of HHVM's internal memory management

# Understanding the 'Smart' Memory Manager (Nathan Yong)

# How do we view memory?



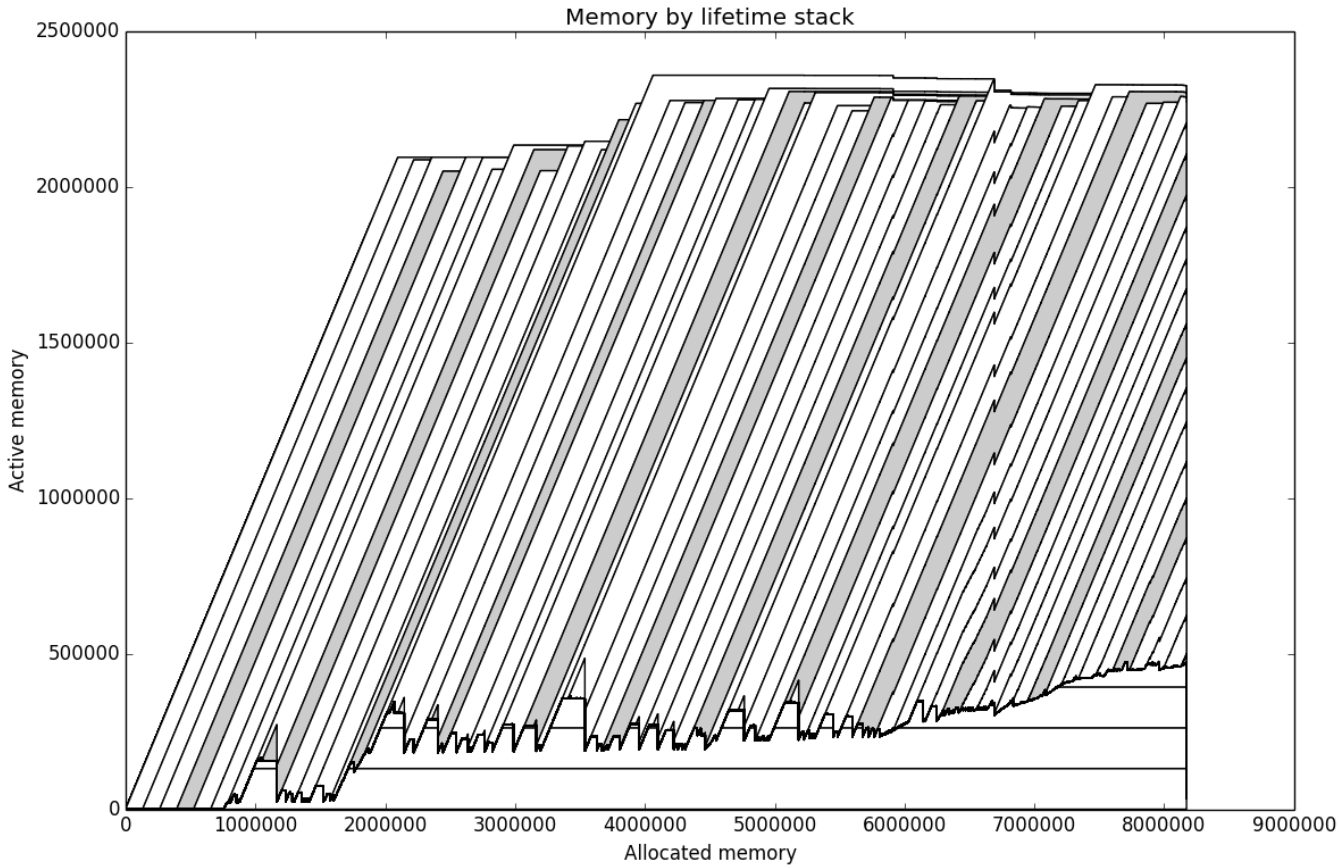
# How HHVM sees memory



# Why is this important?

- Smart memory manager not very well understood
- Usage of own tools very inconsistent

# What is it doing?



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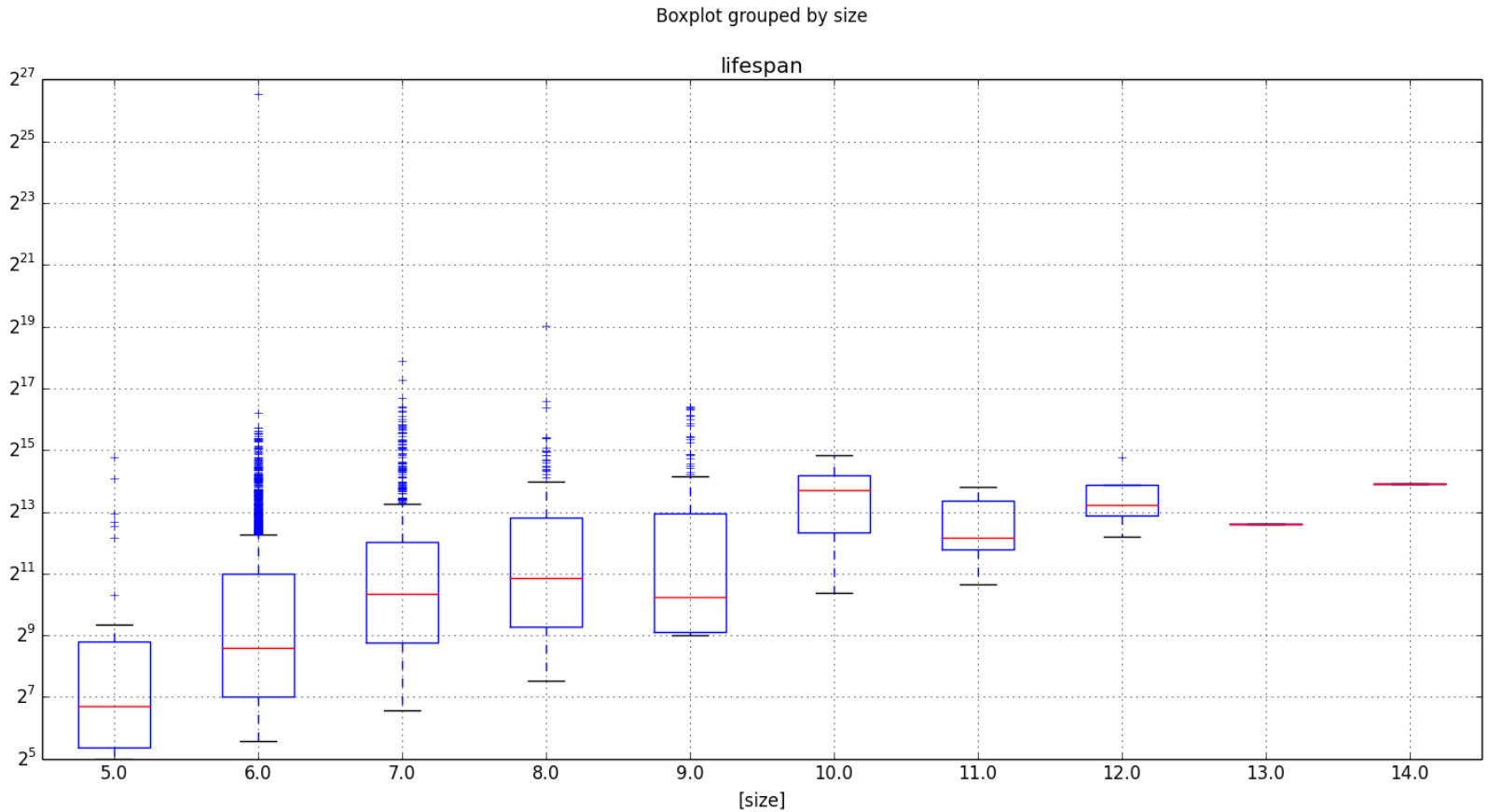

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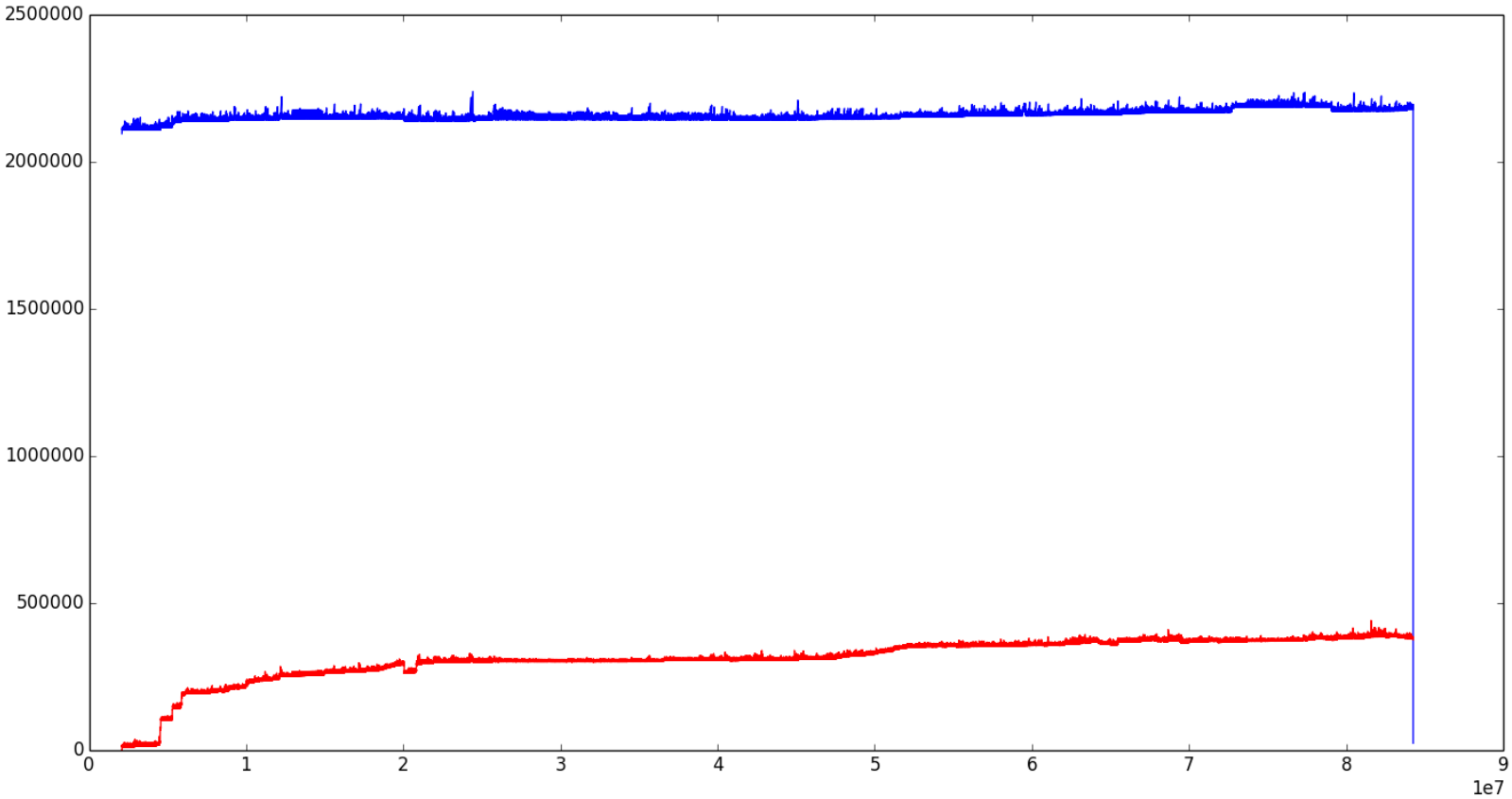

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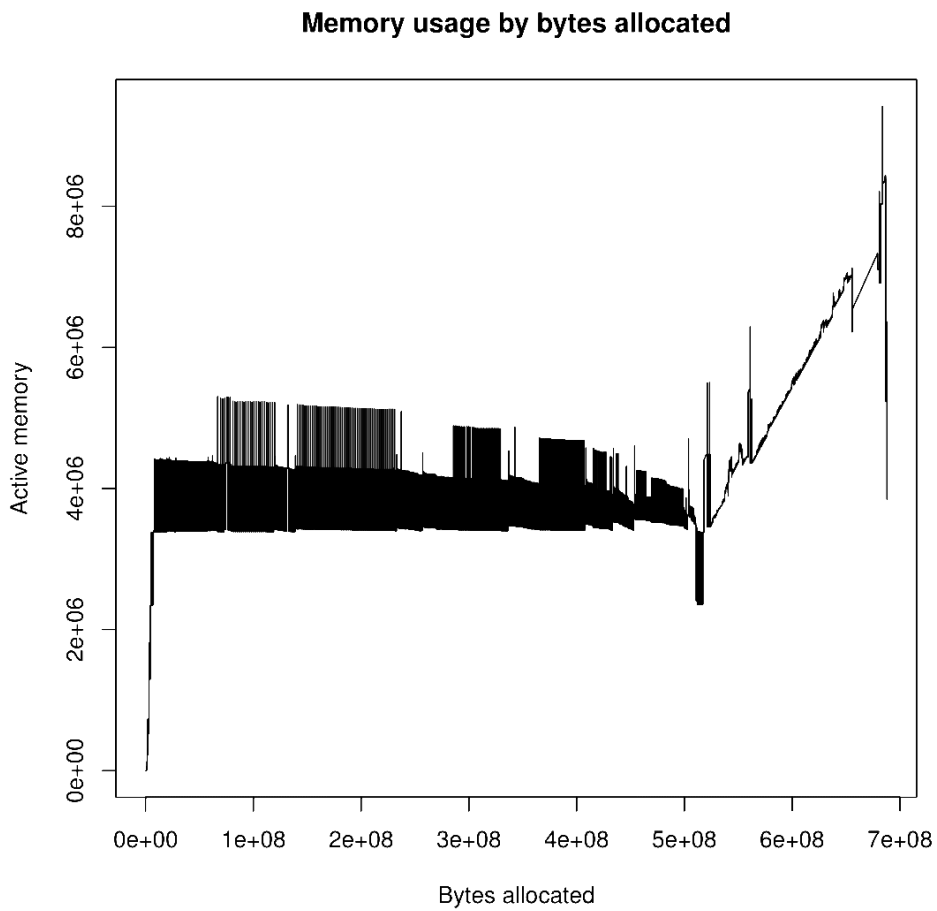

# Where to from here?

- Opportunities for optimisation
- Unified consistent interface
- More efficient allocator design
- Possible use in conjunction with other tools

# HHVM Without Reference Counting (Benjamin Roberts)

# HHVM Without Reference Counting

- Who needs reference counts? (besides the PHP semantics)
- If we are freeing our heap at the end of request, why do we need immediate reclamation?
- Lets try nail down the performance penalty of immediate reference counting.

# Reference Counting in the PHP language

- Based on explicit garbage collection (reference counting)
- Required by language semantics
- PHP is **pass by value**
- Pass by value can be slow due to large amount of copies (especially with large arrays)

- Solution: Copy on Write!
- Problem: Need to know current reference count
- Each mutation requires immediate increment and decrement of reference counts
- Advantage: Immediate garbage reclamation
- **This requirement will cause us major problems shortly**

# Reference Counting in HHVM (C++)

- Reference counted objects have an `int_32t m_count` field and call a macro in countable.h containing various reference counting operations (`incRefCont()`, `hasMultipleRefs()`, `decRefAndRelease()` etc)
- Not consistently used (certain places directly mutate `m_count` or define separate ref-counting methods)
- Difficult to track down all mutations of `m_count`

# Reference Counting in HHVM (JIT)

- `int_32t m_count` at a common offset (12 bytes) in all refcounted objects
- Several opcodes emit reference counting assembly via the JIT
- Intermediate Representation is optimised to remove inc/dec pairs where safe to do so
- Simpler to locate, more difficult to understand

**Both these systems are implemented independent of each other (`m_count` and destructors shared) and the memory manager**

# Lets Modify HHVM

Removed/Disabled 3 forms of reference counting to create hhvmnocount:

- countable.h functions
- JIT emitted reference counting
- Various manual mutations and re-implementations (this took a while)

- Compared to regular HHVM, hhvmnocount was much slower
- Completely different memory usage characteristics
- Hand't yet isolated the effects of reference counting

# Continuous Allocation

In order to isolate the effects of reference counting a modified memory manager was used:

- Memory Manager no longer freed memory, No longer used free lists
- Large objects no longer special case
- Memory not freed at requests end
- Objects still *'sweeped'* due to unreclaimed File and Database objects causing errors.

- Resulted in the hhvmbump and hhvmbumpnocount branches.
- Reference counting was now isolated, time to run some tests.

# Benchmark Setup

- Due to the nature of the changes, it was difficult to find representative PHP packages that ran on all builds
- A modified version of a benchmark included in HHVM (center-of-mass.php) was chosen due to its heavy memory usage
- center-of-mass.php is unlikely to represent the average PHP request but was the only test with sufficient memory usage for benchmarking

The configuration used for benchmarking:

- Linux kernel version: 3.12.6-300.fc20.x86_64
- CPU: Intel(R) Core(TM) i7-3770 CPU @ 3.40GHz
- Memory: 4x4G DDR3 memory at 1600MHz (no swap partiton)
- internal ssd for HHVM builds
- Release configuration
- Apache Benchmark (ab) with various levels of concurrency and test lengths

# Results:

- Results were graphed as surfaces using Matlab
- All results are graphed against total requests and concurrent-requests
- hhvmnocount is omitted from the results due to segmentation faults in Release configuration

# Percentage Response Times (milliseconds, lower is better)

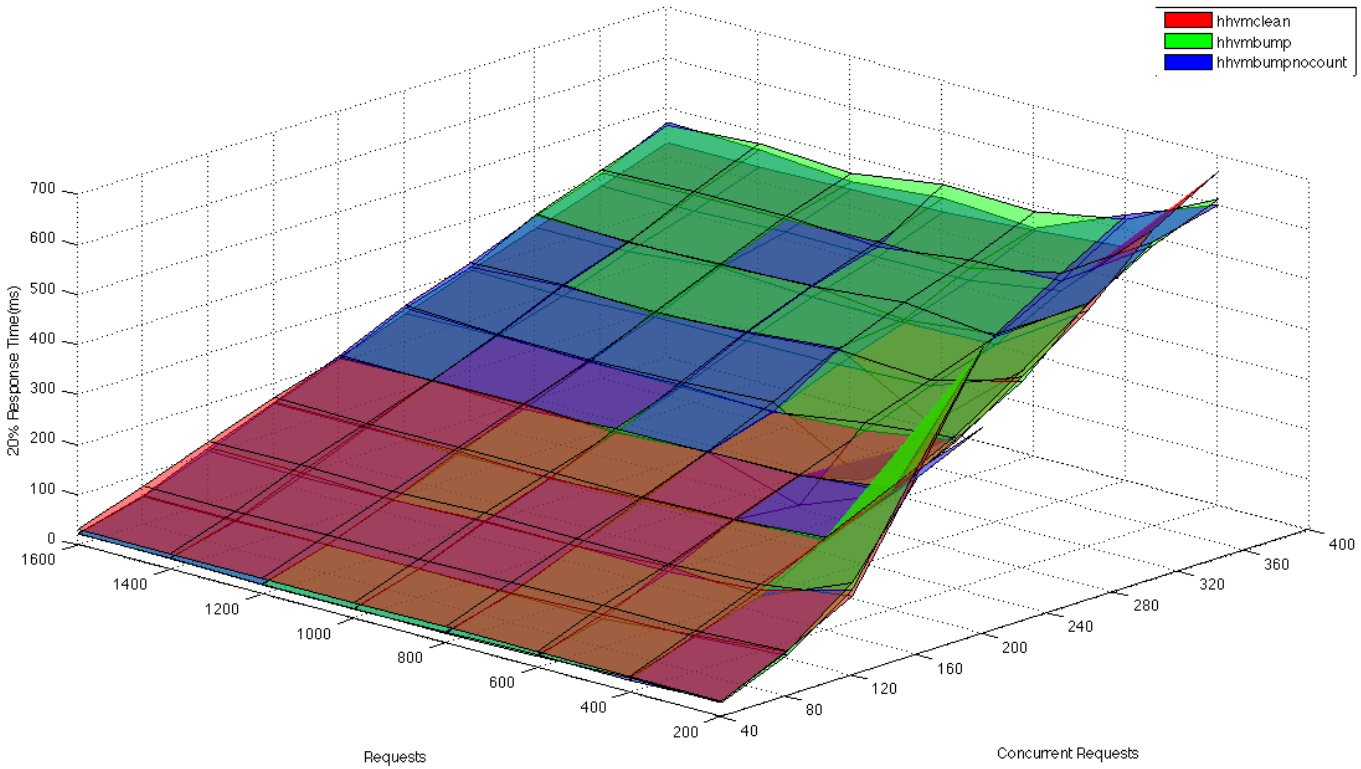


Figure : Time taken for 20% of requests to execute

- The lower 20% of response times are dependant on the build and the number of concurrent requests
- Small sample size, not very representative

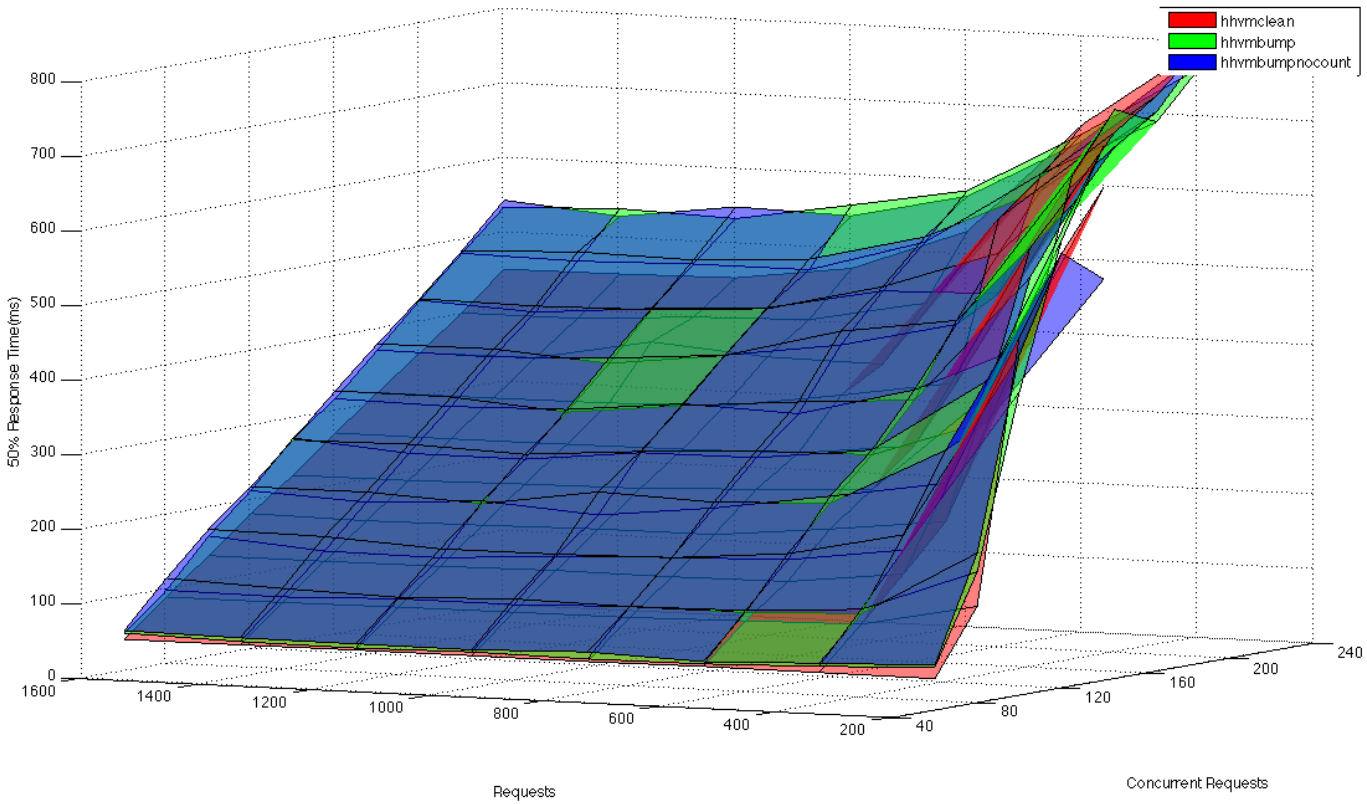


Figure : Time taken for 50% of requests to execute

- Most interesting of the percentage response graphs
- Shows that hhvmbumpnocount performs the worst in majority of runs.
- This is contrary to expectations as it should have performed **less** operations than hhvmbump
- Will be discussed shortly

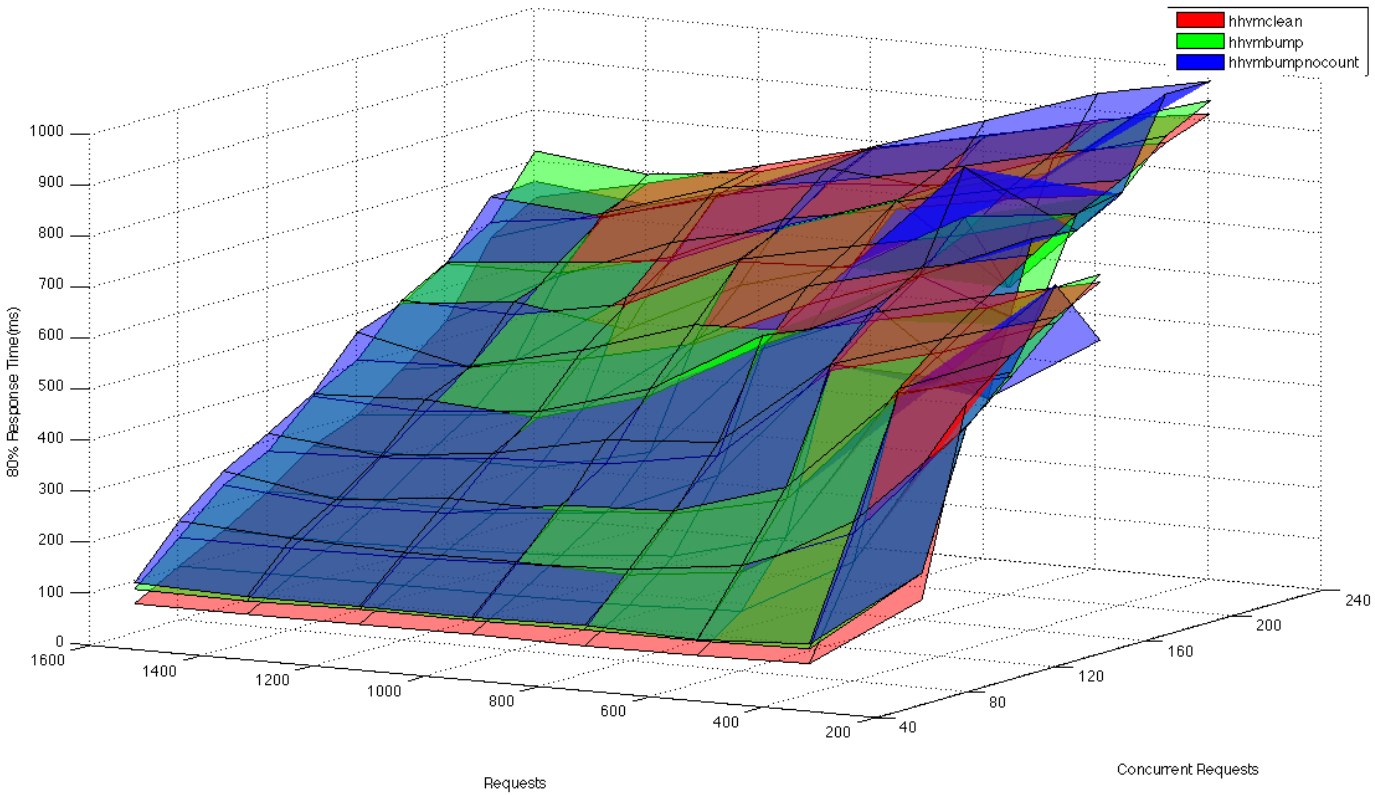


Figure : Time taken for 80% of requests to execute

- Large sample size now starting to include long-response times from warm-up period
- A lot of noise
- Still shows, like the previous graph, that hhvmbumpnocount performs the worst.

# Requests Processed per Second (higher is better)

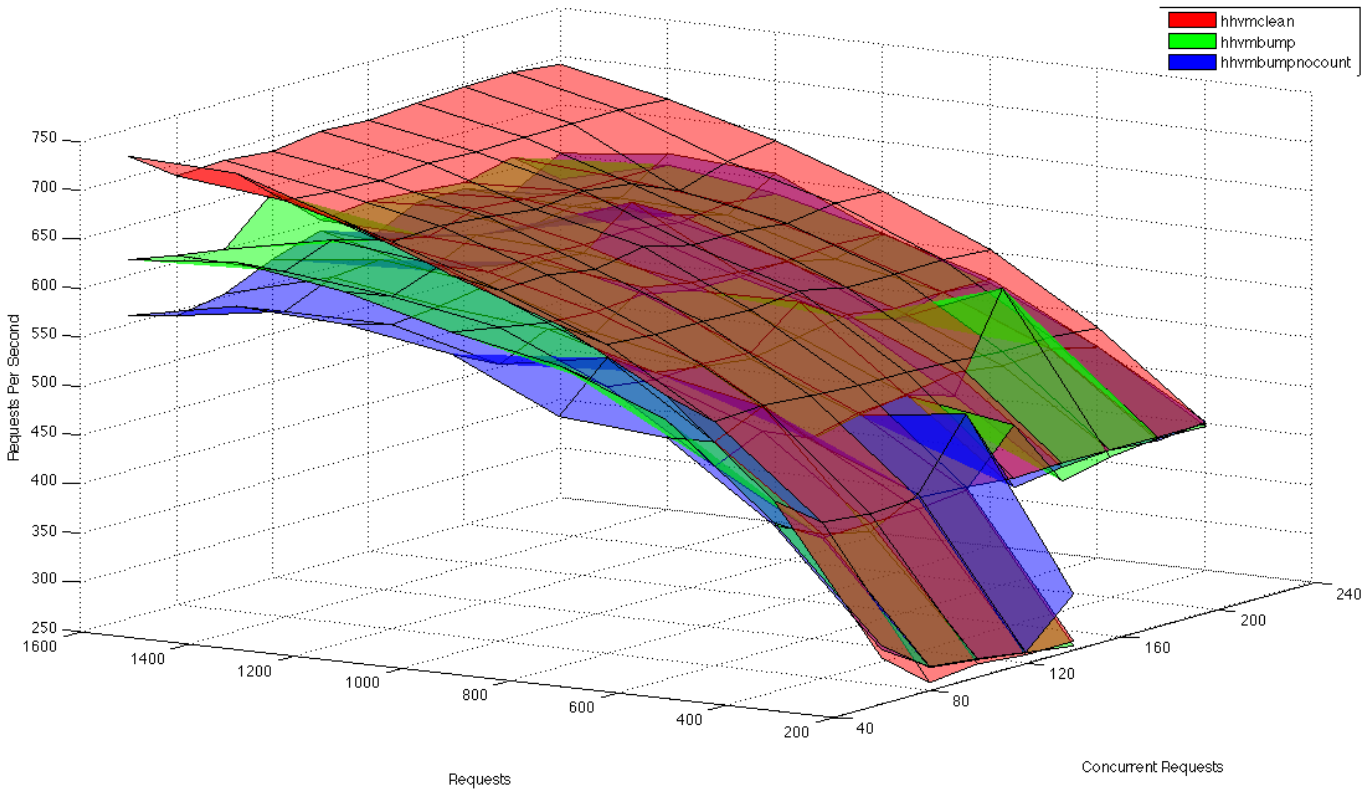


Figure : Average requests per second of benchmark

- This graph shows that the removal of reference counting incurs a notable request processing penalty
- Penalty very noticeable in longer benchmark runs

# Total Execution Time

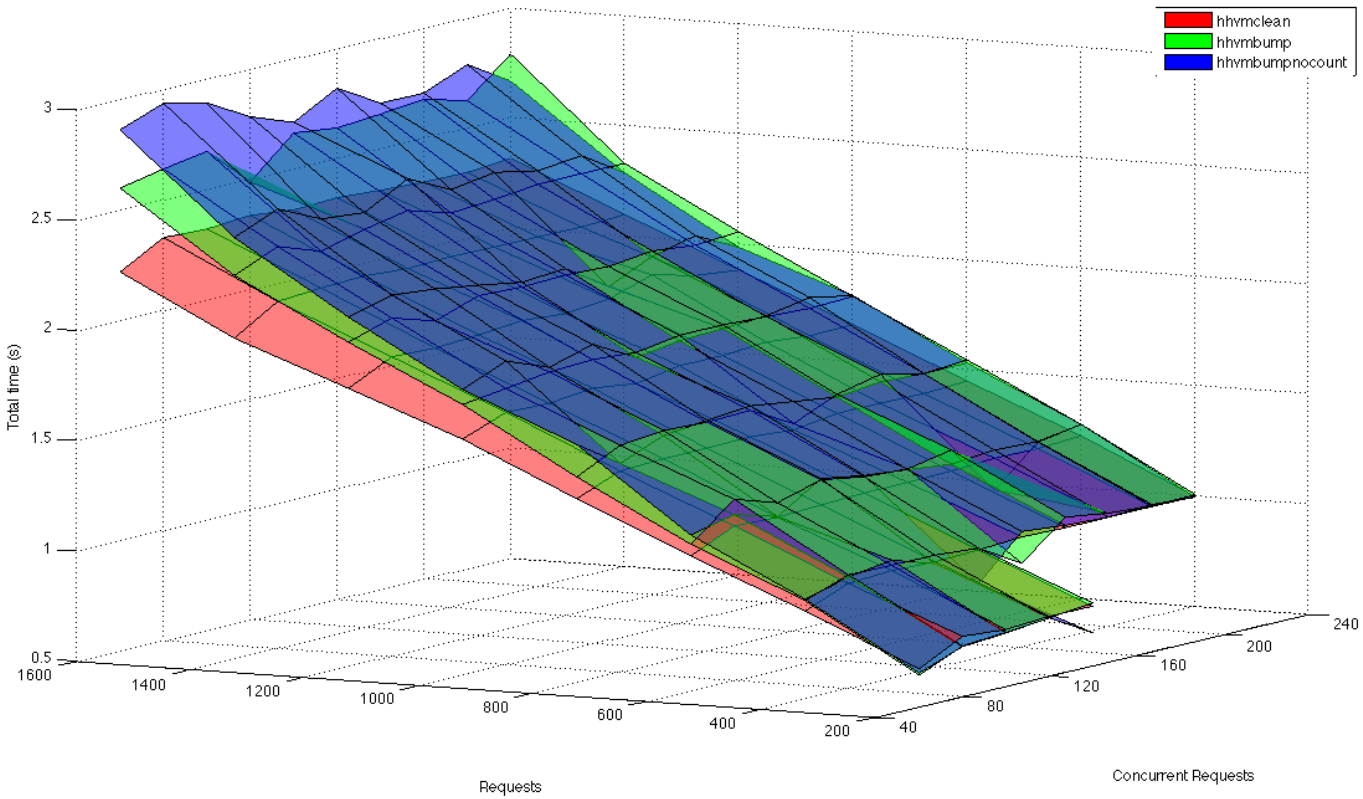


Figure : Total execution time of benchmark

- Again shows that the removal of reference counting results in longer execution times

# Why Did This Happen?

- Remains uncertain
- Benchmark chosen not representative of real PHP workload?
- Copy on Write behaviour?

# Copy on Write

- As previously mentioned, copy on write requires exact reference counts
- ArrayData and StringData mutation behaviour based on the `hasMultipleRefs()` call (which is inaccurate in hhvmbumpnocount build)
- Over zealous copying may have occurred on mutation, resulting in performance penalty
- Could be confirmed by profiling and comparing memory usage of hhvmbump and hhvmbumpnocount

# Further Work

Due to time constraints, several questions and problems remain unsolved:

- Identify source of negative result
- Re-run benchmark with Copy on Assignment semantics (potential method for previous point)
- Benchmark true request based GC (This was attempted early on before focus shifted to reference counting)
- Analyse the relationship between memory usage and response time (these modifications begin make memory a player in processing bottlenecks)
- Preserve copy-on-write behaviour without reference counting

# Physical Memory Profile (Jan Zimmer)

# Memory Utilisation

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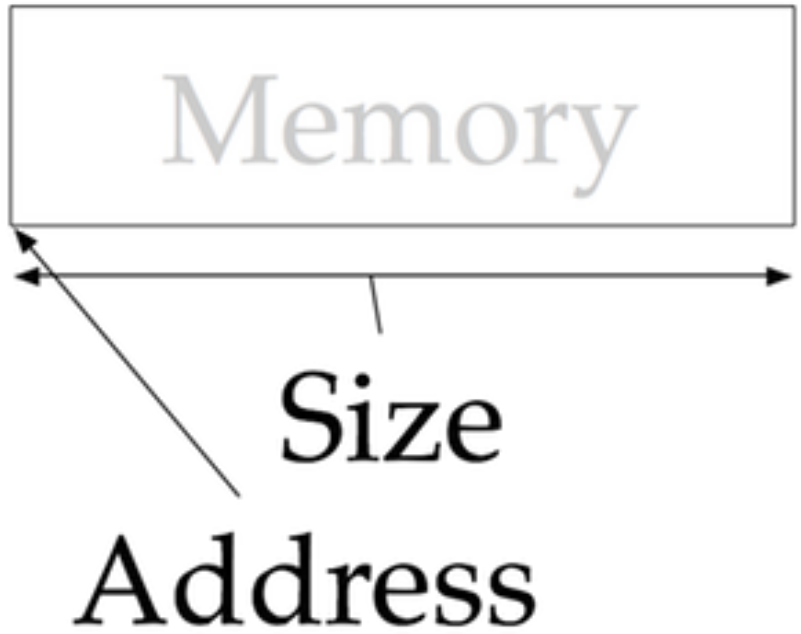
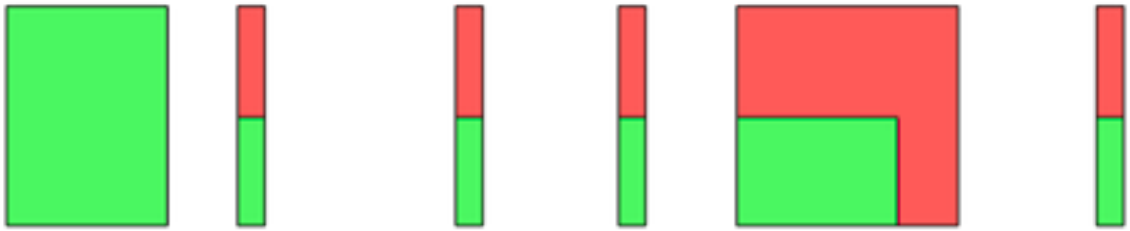
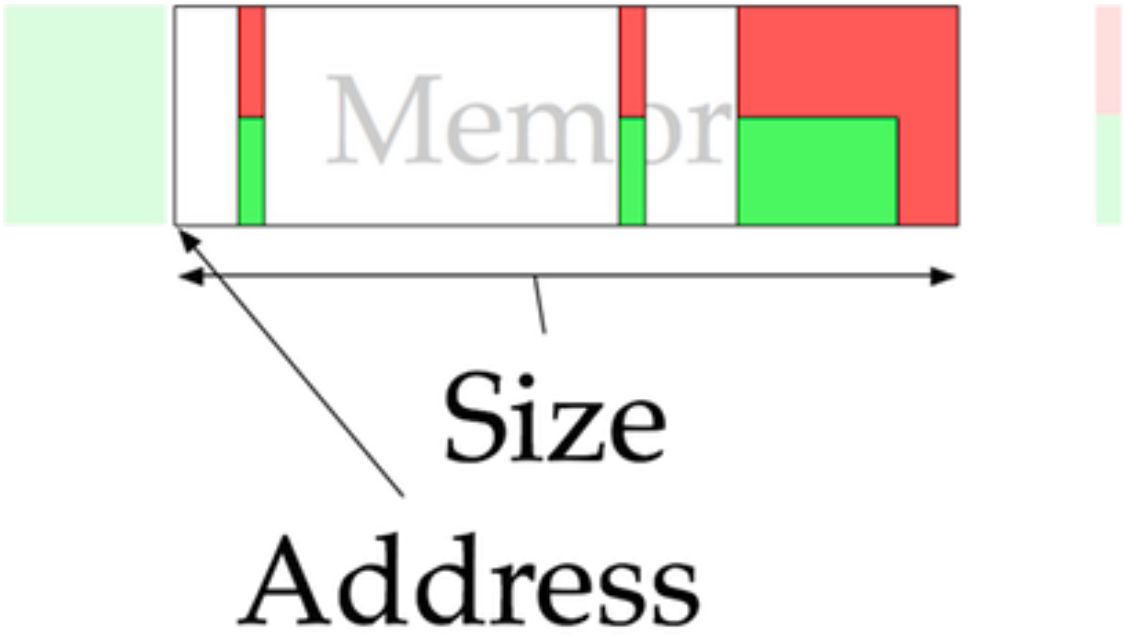
# What HHVM can give us



# What Valgrind can give us



# What Valgrind and HHVM can give us



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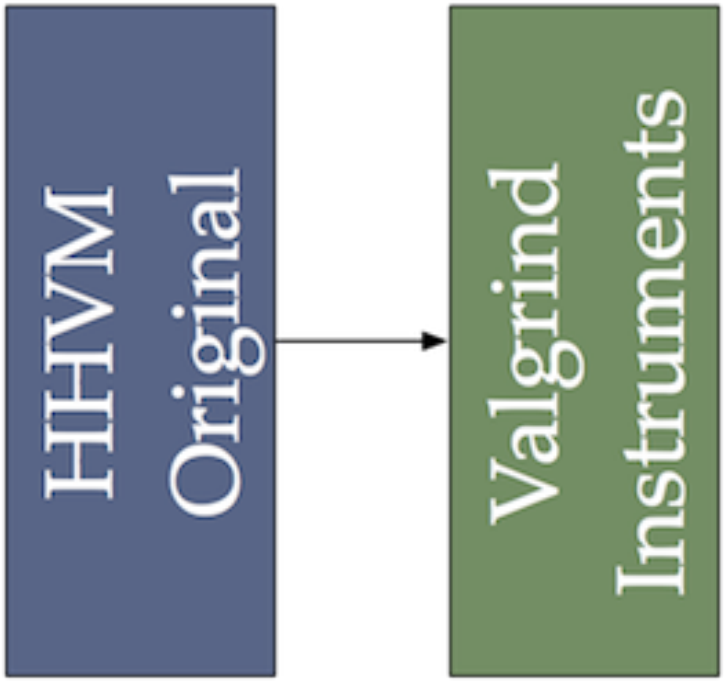

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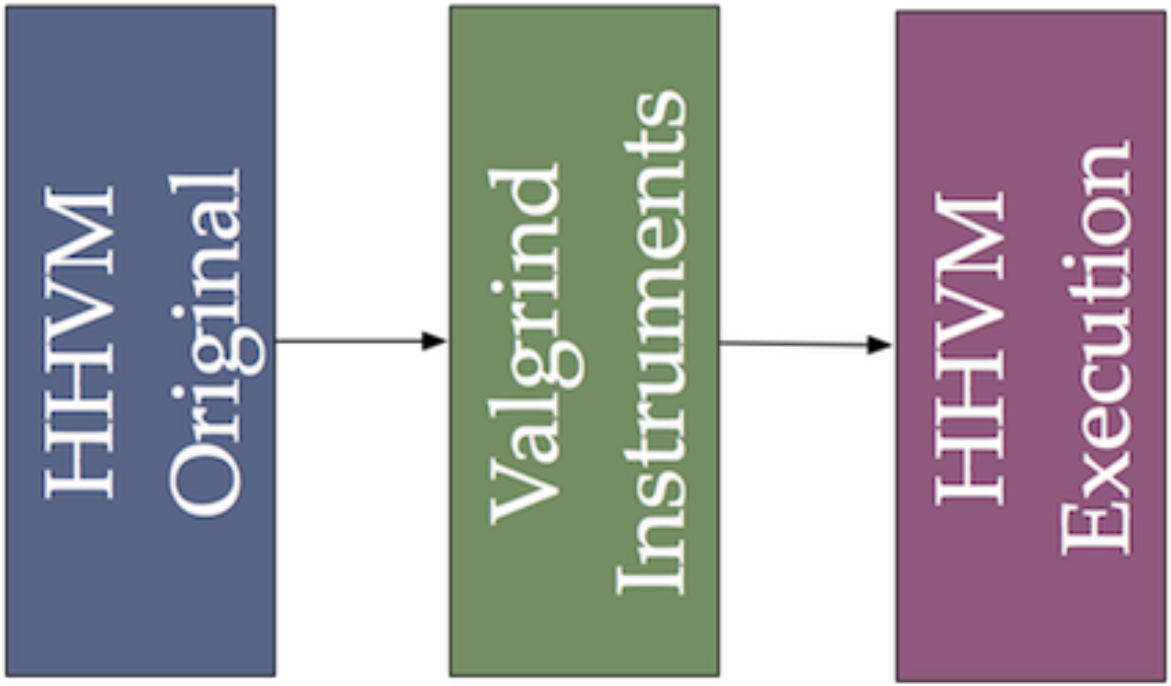

# An example of the result

# Physical Memory Profile

- Tool: Valgrind
- Get Memory Sectors from HHVM
- Monitor memory loads and stores from valgrind
- Valgrind alternates with HHVM in execution