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vecmem: Recent Developments

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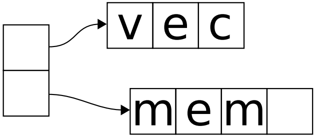
Introduction

- vecmem remains under active development
    - 82 pull requests since our last talk in this meeting (March?!)
- Purpose of this talk is to elucidate ‘recent’ developments in:
    - Compatibility
    - Memory management
    - Testing and continuous integration
    - And more!



Talk schedule

- Since our last talk here, vecmem has been presented in various other places:
  - Heterogeneous Computing and Accelerator Forum (March)
  - KKIO 2021 keynote (September)
  - Parallel Computing Systems group (September)
  - ATLAS Software and Computing HL-LHC Roadmap (October)
- We're hoping to present at the following venues:
  - ACAT 2021 (November)
  - Compute Accelerator Forum (December)

Recap: what is vecmem

- vecmem is a tool to bring the ergonomics of C++ programming to device memory
- Access and modify device memory through standard C++ containers
- Everything you need to create efficient memory allocation schemes

```cpp
int main(void) {
    vecmem::cuda::managed_memory mem;
    std::vector<int> vec(&mem);

    // This vector is accessible on the
    // GPU without any explicit transfer!

    vec.push_back(5);
    vec.push_back(10);
    vec.push_back(2);
}
```

Windows compatibility

- vecmem now supports MSVC, and works on Microsoft Windows!
- Buildable as a static library, or as a DLL
- Explicit symbol visibility can positively impact LTO on Linux
- Several documented instances where MSVC catches additional warnings and errors

MICROSOFT®
WINDOWS™

Testing

- We now have an extensive test suite, with 147 tests
- Based on Google Test
- Rapid stress testing for new resources using ‘data’-driven testing
- These tests have caught more bugs than I am willing to admit...
- Passing the full test suite is a requirement for CI jobs to pass

Arena memory resource

- Gabriel's arena memory resource has been merged (#99)!
  - Fantastic work on incorporating this code into the vecmem model!
- This adds to our toolbox of caching memory allocators to improve performance
- Minor performance problems to hammer out, but available for use right now
- We love to see contributions to the project!

Instrumenting memory resource

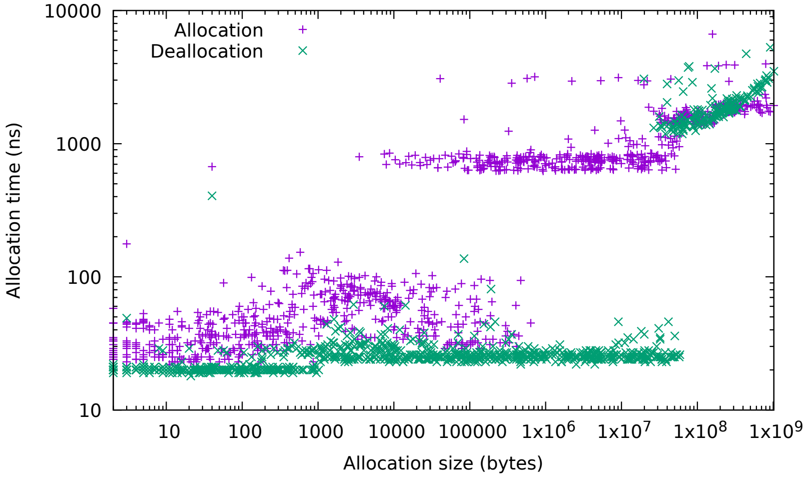
- No longer is vecmem only about managing memory, it is also about monitoring that process
- Instrumenting memory resource works as any downstream resource, but captures useful information:
  - Did an allocation succeed?
  - What were the allocation parameters?
  - How long did the allocation take?
- Support arbitrary higher-order functions, so the sky is the limit
- Useful for benchmarking, profiling, debugging, and testing!

Instrumenting memory resource

```cpp
int main(void) {
    random_device rd;
    mt19937 rng(rd());
    uniform_real_distribution<double> dis(1., 30.);

    host_memory_resource ups;
    instrumenting_memory_resource mem(ups);

    for (size_t i = 0; i < 1000; ++i) {
        size_t b = pow(2, dis(rng));

        void * p = mem.allocate(b);
        mem.deallocate(p, b);
    }

    for (auto & i : mem.get_events()) {
        cout << i.m_size << " " << i.m_time << endl;
    }

    return 0;
}
```

```gnuplot
set terminal pdf
set output "fig.pdf"

set logscale y 10
set logscale x 10

set xlabel "Allocation size (bytes)"
set ylabel "Allocation time (ns)"

set key left top

plot "data.txt" every 2::0 u 2:3 pt 1 ps 0.6 t "Allocation",\
     "data.txt" every 2::1 u 2:3 pt 2 ps 0.6 t "Deallocation
```

Instrumenting memory resource



Debugging memory resource

- After Konrad struggled with a *bug* in one of our downstream resources, we added the debugging resource
- Capable of detecting (at runtime):
  - Overlapping allocations
  - Non-exact deallocations
  - Double deallocations
- Can be composed with any other resource to check its behaviour!
- It's a bit like an in-language valgrind, but with far fewer features

Conditional memory resources

- Is the memory management part of vecmem a library? Or is it a declarative EDSL for memory?
- Vastly increased expressive power and design space by adding control flow to memory management!
- Three new memory resources:
  - Conditional memory resource ($(\mathbb{N} \to \mathbb{N} \to \mathbb{B}) \to M \to M$): allocates only if a predicate function is true, fails otherwise
  - Coalescing memory resource ($\forall n \in \mathbb{N} : M^n \to M$): attempt to allocate using multiple upstreams, and return the first successful one
  - Choice memory resource ($(\mathbb{N} \to \mathbb{N} \to M) \to M$): use a user-provided function to pick the right upstream resource

Minor features

- vecmem now has a strictly enforced style guide. No mess allowed!
- Compatibility with `libc++` has been expanded by providing polyfills for missing functions
- Support has been added for non-container allocations using memory resources
- Support has been added for smart pointers
- We now have a `std::array`-like class for statically sized data on GPUs
- Some additional memory resources which are only there to satisfy my own personal fascination with categories and abstractions

Miscellaneous improvements

- CI has been vastly expanded, supporting a wide range of platforms, and testing extensively on each of them
- Support for jagged vectors, atomics, and other primitives has been improved
- Performance of memory movement code has been greatly increased
- Very robust build system capable of supporting many different models of compilation, and support for recent versions of CMake

Bug fixes

- Of course we have also had to fix many bugs
- Too many too enumerate in this talk...
- Thanks to many of you here for submitting bug reports!

Future developments

- vecmem will continue to be developed to support more heterogeneous platforms, be more robust, and provide a larger feature set
- Currently, working towards improved HIP support, both in code and in the build system
- Also in talks with the LLAMA team to provide mutual compatibility!

Conclusions

- vecmem is under active development and maintenance
- Constantly adding features to support new use cases, improve existing ones, and to push the envelope of memory management
- Very exciting to see vecmem being used by so many different people in different projects!

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