Kokkos-HClib: enabling high-performance and resiliency for HPC systems

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Kokkos

- What's Kokkos?
  - Kokkos enables single performance portable codes
    - ✓ CPUs, NVIDIA GPUs, …
  - Kokkos provides data abstractions critical for performance portability not available in OpenMP or OpenACC (Kokkos::View)
  - Essential parallel constructs
    - ✓ Kokkos::parallel_for();
    - ✓ Kokkos::parallel_reduce();
    - ✓ Kokkos::parallel_scan();

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Kokkos Example

```
1  View<int*> x("x", N);                              // Constuct a View (length: N)
2  // Parallel For
3  parallel_for(RangePolicy<>(0, N),                  // 1D Range (0 to N)
4               [=] (int i) {                         // C++11 lambda
5                 x(i) = i;                           // Computational Body
6               });
7
8  int result = 0;
9  // Parallel Reduce
10 parallel_reduce(RangePolicy<>(0, N),               // 1D Range (0 to N)
11                 [=] (int i, int &update) {         // C++11 lambda
12                   update += x(i);                  // Computational Body
13                 }, result);                        // Value to update
14 std::cout << result << std::endl;
```

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Enabling Resiliency in Kokkos

- Motivation
  - Failure probability “significantly” increases as the number of nodes increases [1]
- Observation
  - User-level failure mitigation mechanisms will become more important in the next generation systems
    - ✓ Checkpoint/Restart (C/R)
    - ✓ Task Replay
    - ✓ Task Replication
    - ✓ Algorithm-based Fault Tolerance (ABFT)

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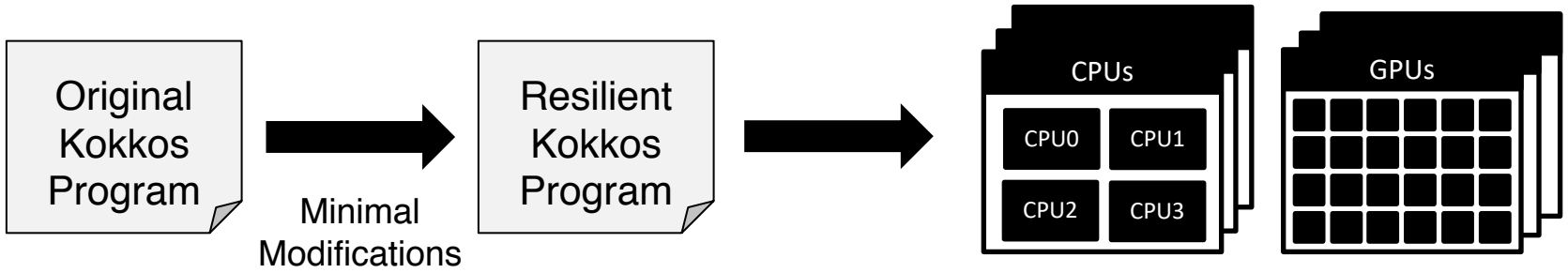
[1] C. D. Martino et al. 2015. Measuring and Understanding Extreme-Scale Application Resilience: A Field Study of 5,000,000 HPC Application Runs. (DSN2015)

Enabling Resiliency in Kokkos

- Research Question
  - When enabling resiliency in Kokkos, what is a desirable point in the performance-portability-productivity (P3) space?
  - What is a desirable user-facing parallel-resilience API that enables good productivity-portability?



Resilient Execution on different platforms

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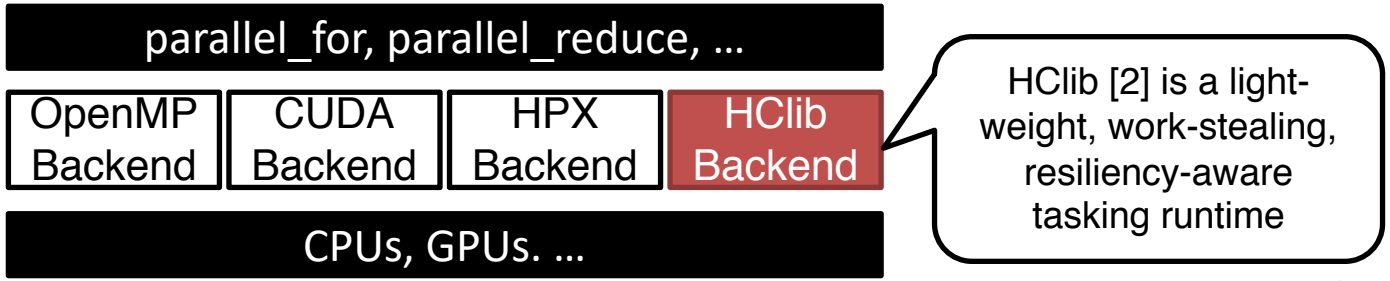
Resilient Kokkos

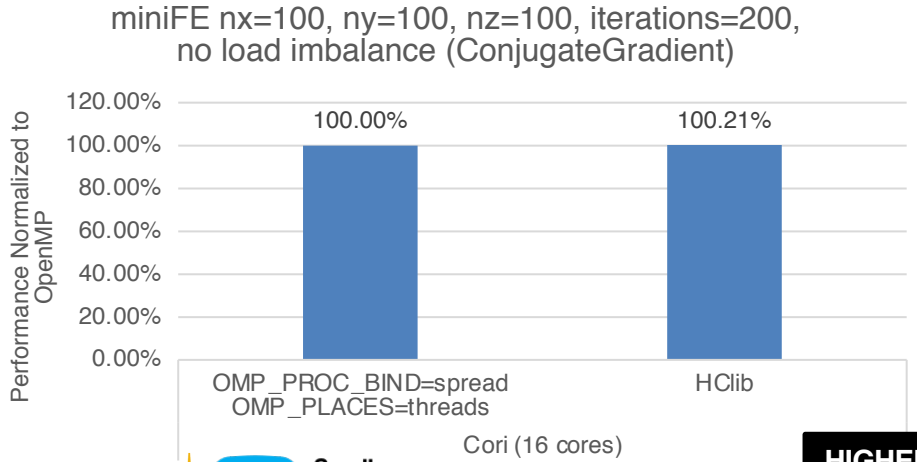
- Overview
  - Provides Kokkos with resilient execution capability
  - Build on top of Resilient HClib [2]
    - ✓ Provides various runtime APIs for task-level resiliency
- Our Current Focus
  - Implementation of Kokkos-HClib Backend
  - Design and implementation of Kokkos Task Replay/Replication API

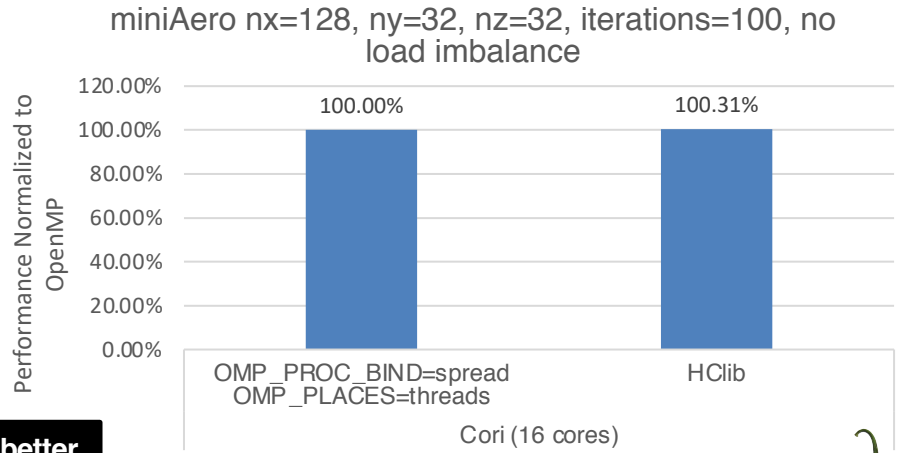


[2] Sri Raj Paul et al. 2019. Enabling Resilience in Asynchronous Many-Task Programming Models. (EuroPar2019)

Building Kokkos-HClib backend

- Non-resilient Execution of miniFE and miniAero of the Mantevo benchmark on Cori@NERSC
- The HClib backend is comparable to the OpenMP backend





HIGHER is better

CPU: 16-core 2.3 GHz Intel Xeon Processor E5-2698 v3 (Haswell), Compiler: gcc 8.3

Resilient Kokkos API Design

- Key Idea: Provide resilient execution spaces

Original parallel_for

```
parallel_for(RangePolicy<ExecutionSpace>(0, N), lambda);
```

- Task Replication
  - Semantics: Replicate a task, and check for the equality of output variables

Replicate parallel_for

```
parallel_for(RangePolicy<ReplicateSpace>(0, N), lambda);
```

- Task Replay
  - Semantics: Execute a task, then invoke a user-provided error checking function, and replay the task if the error checking is failed

Replay parallel_for

```
parallel_for(RangePolicy<ReplaySpace>(0, N), lambda, lambda_check);
```

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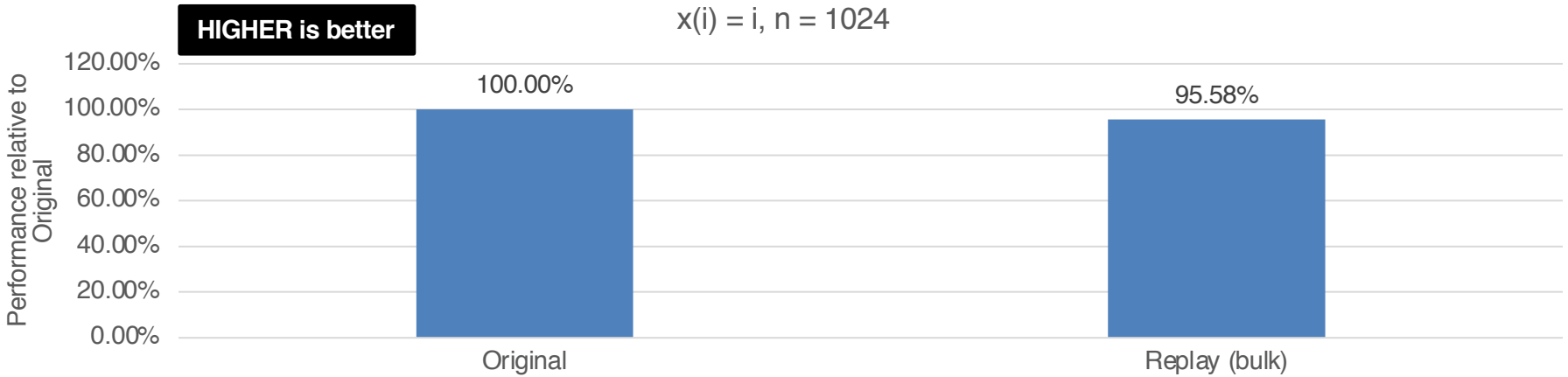
Preliminary Performance Evaluation (Overhead of Error Checking)



- Variants
  - Original: parallel_for only
  - Replay (bulk): parallel_for w/ a single error checking (no replay)

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CPU: 4-core 3.5 GHz Intel(R) Core(TM) i5-7600 CPU, Compiler: gcc 7.5

Summary & Future Work

- Summary
  - The Kokkos Resilient API enables resiliency in Kokkos in a portable and productive manner
    - ✓ Essentially, the user is only supposed to 1) replace an execution policy with a resilient version and 2) provides an error checking function if necessary
  - The developed Kokkos-HClib backend is comparable to existing OpenMP backend for non-resilient execution
    - ✓ Verified with two of the Mantevo benchmark (miniFE/miniAero)
- Future Work
  - Continue the implementation and discuss the performance impact of the Resilient API using different applications
  - Support the all the Kokkos constructs in the Kokkos-HClib backend

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