Application of HPX to Tiled GEMM and QR: A Benchmark

September 25, 2019 | Thomas Miethlinger | Jülich Supercomputing Centre

Part I: Introduction

About me

(Thomas Miethlinger)

- Study: Master Physics
- Johannes Kepler University of Linz
- Institute for Theoretical Physics
  Department Many Particle Systems
- Research:
  - Quantum fluids
  - Complex fluids
  - Non-equilibrium statistical mechanics

About the GSP

- Supervisor: Dr. Edoardo Di Napoli
- Co-Supervisor: Dr. Xinzhe Wu
- SimLab Quantum Materials
- Research:
  - Development and maintenance of numerical libraries
  - Design and implementation of high-performance algorithms
  - Development of new mathematical and computational models within a methodological framework

in the scope of computational materials science and quantum materials.

Part II: Introduction to HPX

Current sitution in high performance computing (HPC)

Currently, speed-up in computing does not stem from higher CPU frequency, but increased parallelism.
However, we already face the following challenges in HPC:

- Ease of programming
- Inability to handle dynamically changing workloads
- Scalability
- Efficient utilization of system resources

$\Longrightarrow$ a need for a new execution model: ParalleX, which is implemented by HPX

ParalleX

ParalleX is a new parallel execution model that offers an alternative to the conventional computation models(e.g. message passing):

- Split-phase transaction model
- Message-driven
- Distributed shared memory
- Multi-threaded
- Futures synchronization
- Local Control Objects (LCOs)
- ...

ParalleX focusses on latency hiding instead of latency avoidance.

About HPX

- High Performance ParalleX (HPX) is the first runtime system implementation of the ParalleX execution model.
- Development: STE||AR group
  Louisiana State University
  LSU Center for Computation and Technology
- Released as open source under the Boost Software License
- Current version: HPX V1.3.0, released on 23.05.2019
- Aims to be a **C++ standards conforming implementation** of the Parallelism and Concurrency proposals for C++ 17/20/23/...
- This means: HPX is a C++ library that supports **dynamic adaptive resource management** and **lightweight task programming and scheduling** within the context of a **global address space**.

On learning HPX

An opinion of a non-CS/HPC student

Learning curve on of HPX is quite steep - in the first days quite some dedication, effort and endurance is needed[1].

- Probably the easiest way in the beginning: watch this nice playlist in 1.25x speed on the youtube channel of cscsch (Swiss National Supercomputing Centre)
- Be aware that the API reference is not complete
- Be aware that there exist at least 5 different “Hello, World!” examples[2]:
  - hpx/examples/hello_world_component/*: 3 files; 28, 30 & 55 lines
  - hpx/examples/quickstart/hello_world_1.cpp; 22 lines
  - hpx/examples/quickstart/hello_world_2.cpp; 24 lines
  - hpx/examples/quickstart/hello_world_distributed.cpp; 156 lines
  - tutorials/examples/01_hello_world/hello_world.cpp; 71 lines

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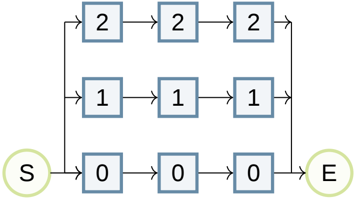
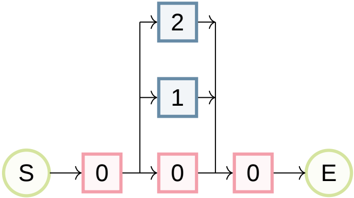
[1] Why is the HPX code repo so big and complicated?

[2] Paths are with respect to `https://github.com/STEllAR-GROUP/`

Comparison of HPX and OpenMP

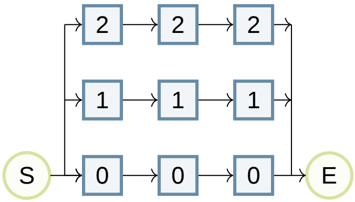
HPX	OpenMP
C++ library Core language: `hpx::C++` Task-based parallelism AGAS (active global address space)	Compiler extension to C and Fortran `#pragma omp` directives Parallel regions (fork-join model) shared memory

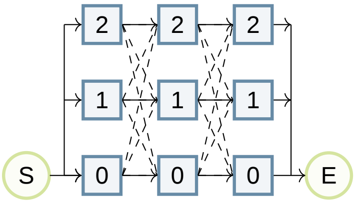




Comparison of HPX and MPI

HPX	MPI
C++ library Core language: `hpx::C++` Task-based parallelism AGAS (active global address space)	Interface specification for C and Fortran Core language: MPI_C, MPI_F08 Single program, multiple data (SPMD) Explicit message passing

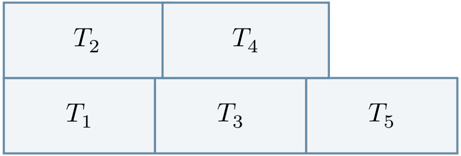




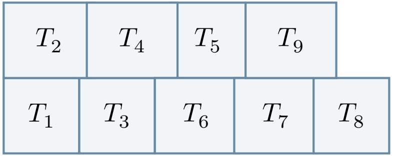
HPX: Tasks and Threads

- HPX: Task-based parallelism
- Split up big problem into smaller tasks
- Tasks are worked off as HPX (lightweight) Threads by the OS Threads
- Task size is crucial: not too small and not too big
- Number of tasks can even be as high as $O(10^8)$

Tasks too large



Right task size



HPX: Example Program

```cpp
double calc_area(hpx::future<double> future_r, hpx::future<double> future_pi)
{
    double r = future_r.get(); // r is returned immediately (make_ready_future)
    double pi = future_pi.get(); // pi is returned once the async computation finishes
    return r * r * pi;
}

int hpx_main(variables_map& vm) // In hpx_main the HPX environment is loaded
{
    hpx::future<double> future_r = hpx::make_ready_future(vm["r"].as<double>());
    hpx::future<double> future_pi = hpx::async([](){ return 4.0 * atan(1.0); });
    hpx::future<double> future_area = hpx::dataflow(&calc_area, future_r, future_pi);
    return hpx::finalize(); // Area can be obtained by: future_area.get()
}

int main(int argc, char * argv[]) // Start program by: ./area --r=...
{
    options_description.add_options()("r", value<double>()->default_value(1.0), "Radius: r");
    return hpx::init(options_description, argc, argv); // hpx::init calls hpx_main
}
```

The HPX API

Selection: Classes

Class	Description
`hpx::thread`	Low level thread of control
`hpx::mutex`	Low level synchronization facility
`hpx::lcos::local::condition_variable`	Signal a condition
`hpx::future`, `hpx::shared_future`	Asynchronous result transport (receiving end)
`hpx::promise`, `hpx::lcos::local::promise`	Asynchronous result transport (producing end)
`hpx::lcos::packaged_task`	Asynchronous result transport (producing end)
`hpx::function`	Type erased function object
`hpx::tuple`	Tuple
...	

The HPX API

Selection: Functions

Functions	Description
`hpx::async`	Spawning tasks (returns a future)
`hpx::make_ready_future`	Spawning tasks (returns a ready future)
`hpx::bind`	Binding Parameters to callables
`hpx::apply`	Signal a condition
`future::{is_ready, valid, has_exception}`	Query state of future
`future::get`	Return computed result of future
`future::then`	Continuations of futures
`hpx::when_all, hpx::when_any`	Waiting on one or more futures (non blocking)
`hpx::wait_all, hpx::wait_any`	Waiting on one or more futures (blocking)
`hpx::dataflow`	Shortcut to hpx::when_all(...).then(...)
`...`	

Part III: Overview of numerical linear algebra and its applications

Part IV: GEMM

Part V: QR

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