Cpp-Taskflow

"The cleanest tasking API ever," user remark

Fast Parallel Programming using Modern C++

Tsung-Wei Huang

Research Assistant Professor, CSL & ECE

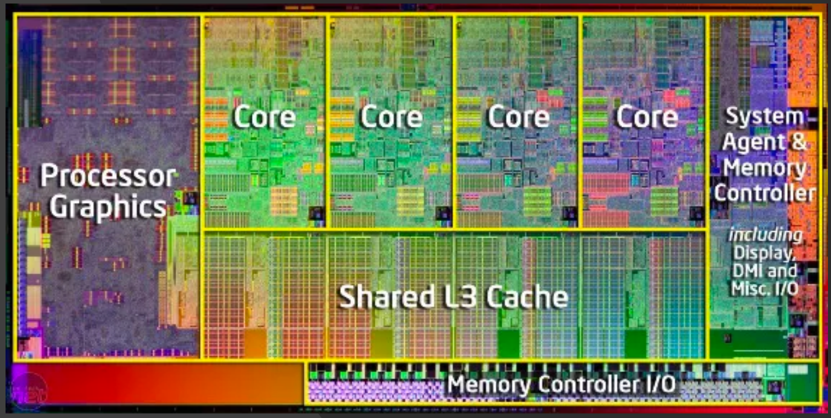
This is a 15-minute Lightning Talk

- ❑ **Identify your need of parallel programming**
- ❑ **Parallelize your workload using the right tools**
- ❑ **Boost your performance in writing parallel code**

Identify Your Need of Parallel Programming

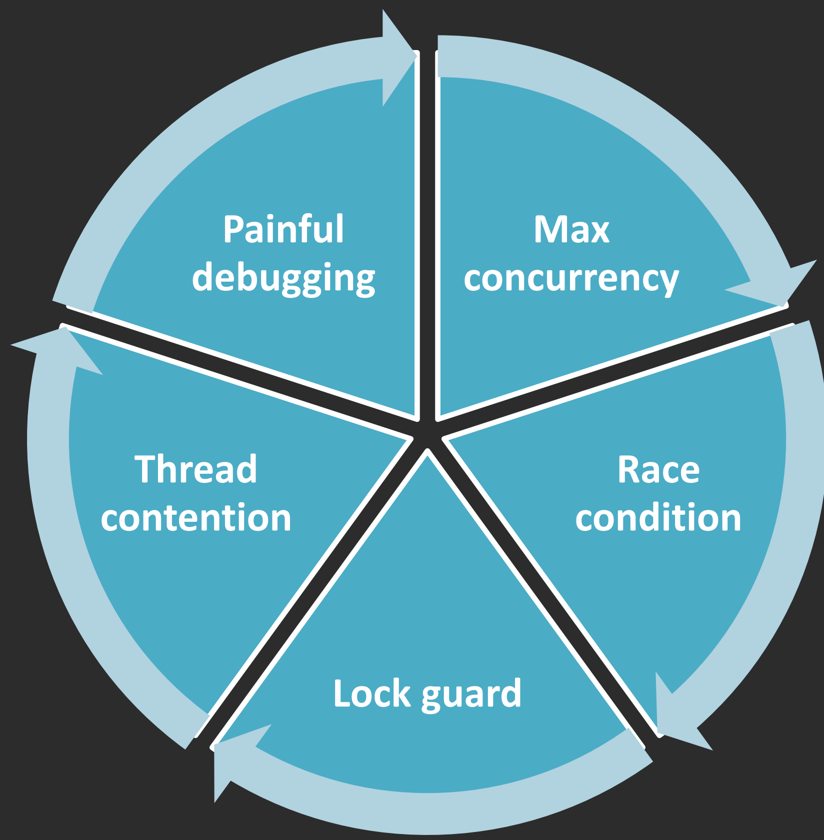
- **Why should I care?**
  - Your computer is forced to design with multiple cores
  - Want performance
  - Want throughput
- **We are in many-core era**

Parallel programming is needed more than ever!



Intel Sandy Bridge quad-core processor

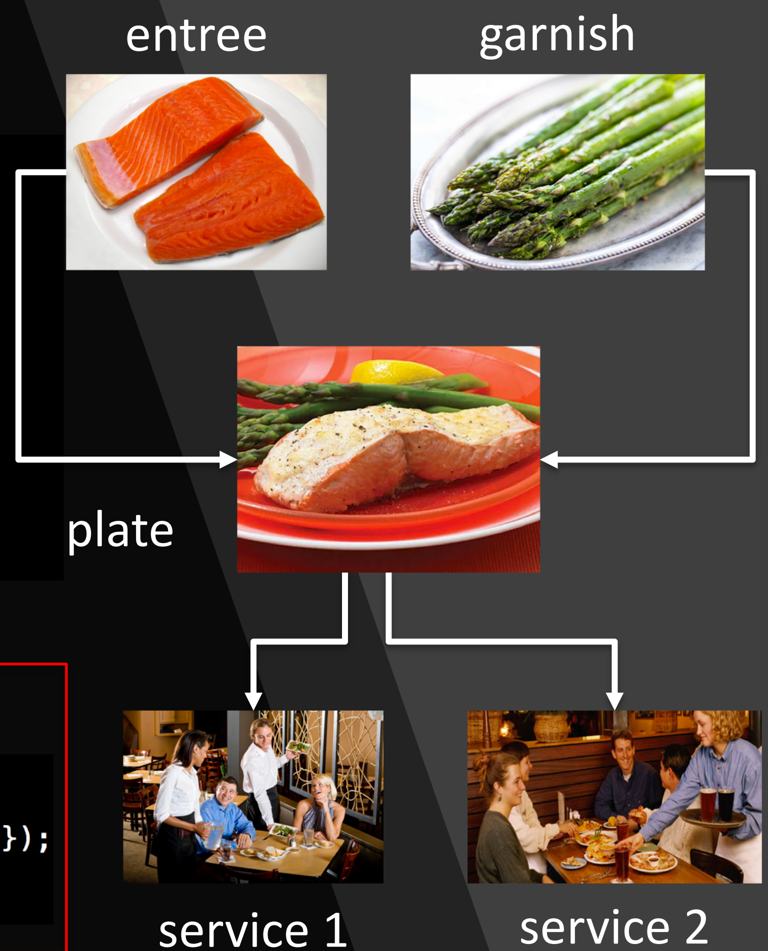
Parallel Programming is VERY Difficult due to Task Dependency



Parallelize Your Workload using the Right Tools

Sequential version

```
int CookGarnish();
int CookEntree();
pair<int, int> Plate(int, int);
void Serve(int);

int garnish, entree;
pair<int,int> plates;

garnish = CookGarnish();
entree  = CookEntree();
pates   = Plate(garnish, entrees);
Serve(plates.first);
Serve(plates.second);
```



Parallel version (really?)

```
thread cook1  ([&] { garnish = CookGarnish(); });
thread cook2  ([&] { entree  = CookEntree();  });
thread chief  ([&] { plates = Plate(garnish, entree);});
thread waiter1([&] { Serve(plates.first); });
thread waiter2([&] { Serve(plates.second); });
```

```
atomic<bool> garnish_ready {false};
atomic<bool> entree_ready  {false};
atomic<bool> plates_ready  {false};

thread cook1  ([&] {
  garnish = CookGarnish();
  garnish_ready = true;
});

thread cook2  ([&] {
  entree = CookEntree();
  entree_ready = true;
});

thread chief  ([&] {
  while(!(entree_ready && garnish_ready));
  plates = Plate(garnish, entree);
  plates_ready = true;
});

thread waiter1([&] {
  while(!plates_ready);
  Serve(plates.first);
});

thread waiter2([&] {
  while(!plates_ready);
  Serve(plates.second);
});
```

A hard-coded yet "common" solution

- ❑ Limit max concurrency to two
- ❑ Use locks to add dependencies
- ❑ Thread contention
- ❑ Waste CPU resources
- ❑ Replace spin lock with mutex?
- ❑ Wait on conditional variable?
- ❑ How can I debug it?
- ❑ What if I have only one core?
- ❑ Rewrite the program?

Oh my gosh …

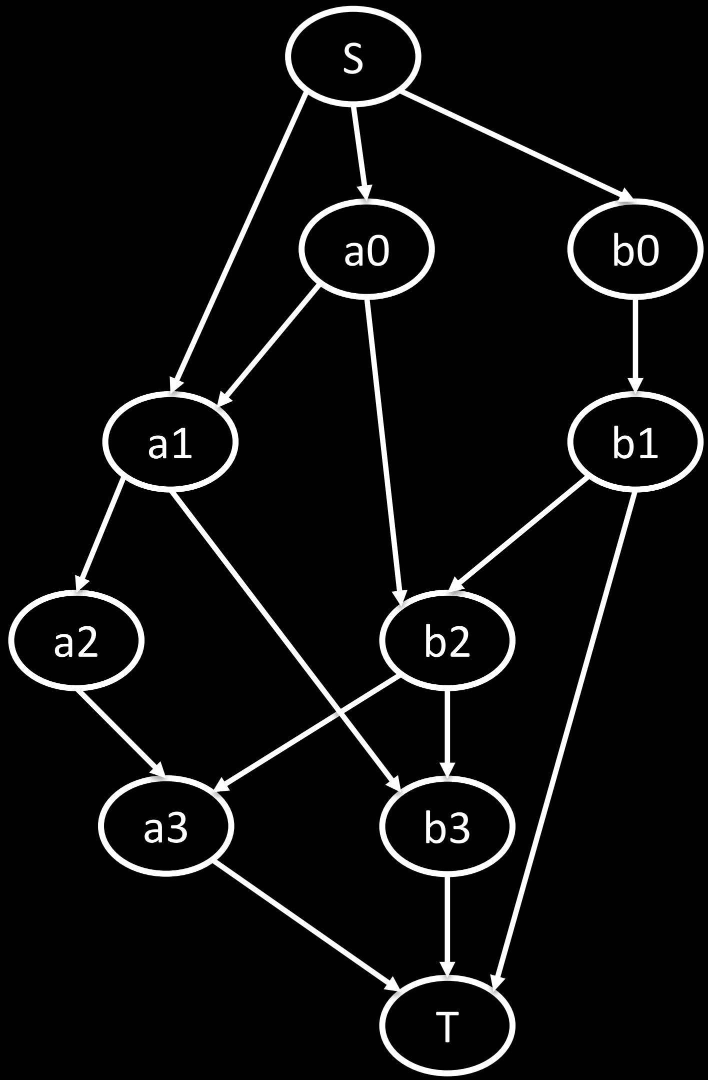
Boost Your Performance in Writing Parallel Code

[Cpp-Taskflow: A C++17 Header-only Parallel Programming Library]

```
// create a taskflow object
Taskflow tf;

// create five tasks
auto [cook1, cook2, chief, waiter1, waiter2] = tf.silent_emplace(
  [&] () { garnish = CookGarnish();                },
  [&] () { entree  = CookEntree();                 },
  [&] () { plates  = Plate(garnish, entree); },
  [&] () { Serve(plates.first);                    },
  [&] () { Serve(plates.second);                   }
);

// add dependencies
cook1.precede(chief);
cook2.precede(chief);
chief.precede(waiter1);
chief.precede(waiter2);

// execute
tf.wait_for_all();
```

A Slightly More Complicated Example

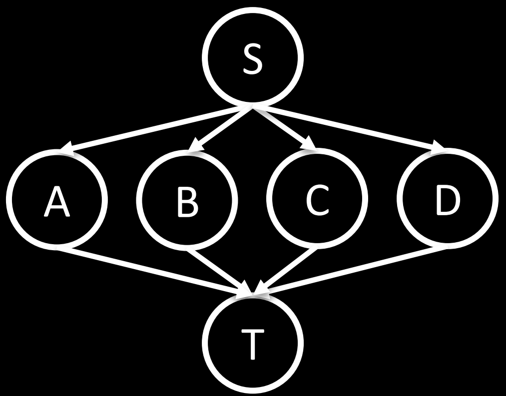
```
// source dependencies
S.precede(a0);    // S runs before a0
S.precede(b0);    // S runs before b0
S.precede(a1);    // S runs before a1

// a_ -> others
a0.precede(a1);   // a0 runs before a1
a0.precede(b2);   // a0 runs before b2
a1.precede(a2);   // a1 runs before a2
a1.precede(b3);   // a1 runs before b3
a2.precede(a3);   // a2 runs before a3

// b_ -> others
b0.precede(b1);   // b0 runs before b1
b1.precede(b2);   // b1 runs before b2
b2.precede(b3);   // b2 runs before b3
b2.precede(a3);   // b2 runs before a3

// target dependencies
a3.precede(T);    // a3 runs before T
b1.precede(T);    // b1 runs before T
b3.precede(T);    // b3 runs before T
```



Taskflow Application Programming Interface

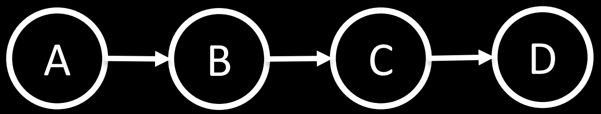
- ❑ parallel_for

```
// apply callable to each container item in parallel
auto v = {'A', 'B', 'C', 'D'};
auto [S, T] = tf.parallel_for(
  v.begin(),    // beg of range
  v.end(),      // end of range
  [] (int i) {
    cout << "parallel in " << i << '\n';
  }
);
// add dependencies via S and T.
```



- ❑ transform_reduce
- ❑ linearize

```
tf.linearize(A, B, C, D)
```



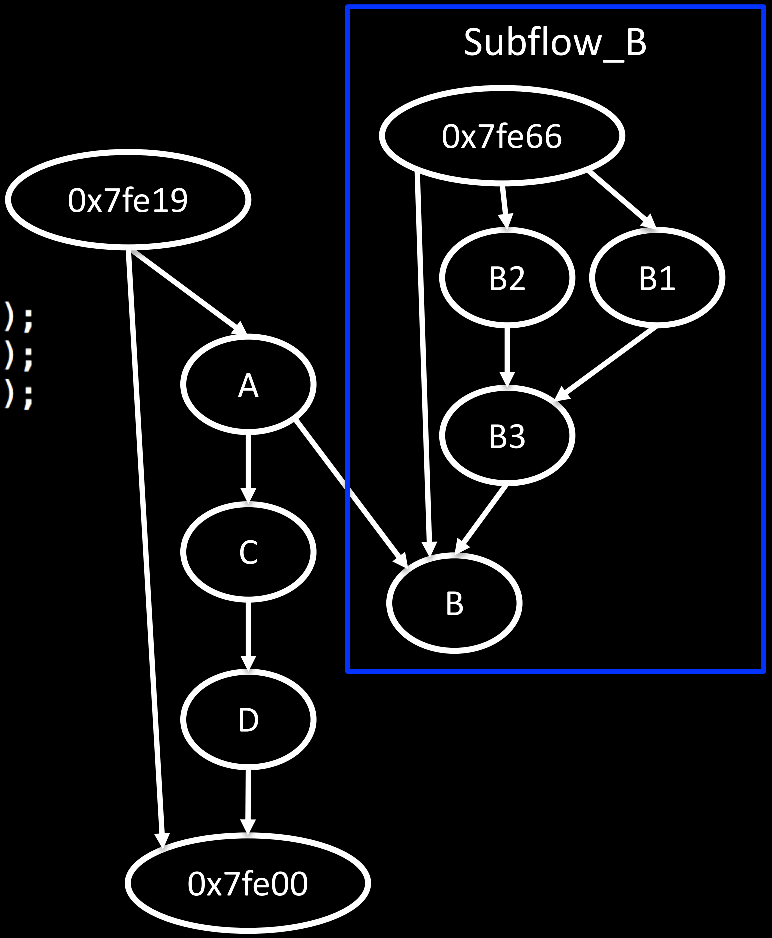
- ❑ dump

…

Dynamic Tasking

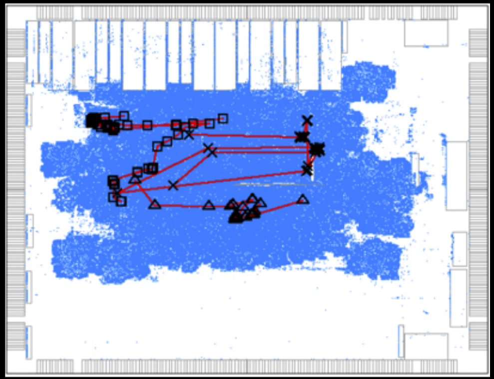
Create a task dependency graph at runtime

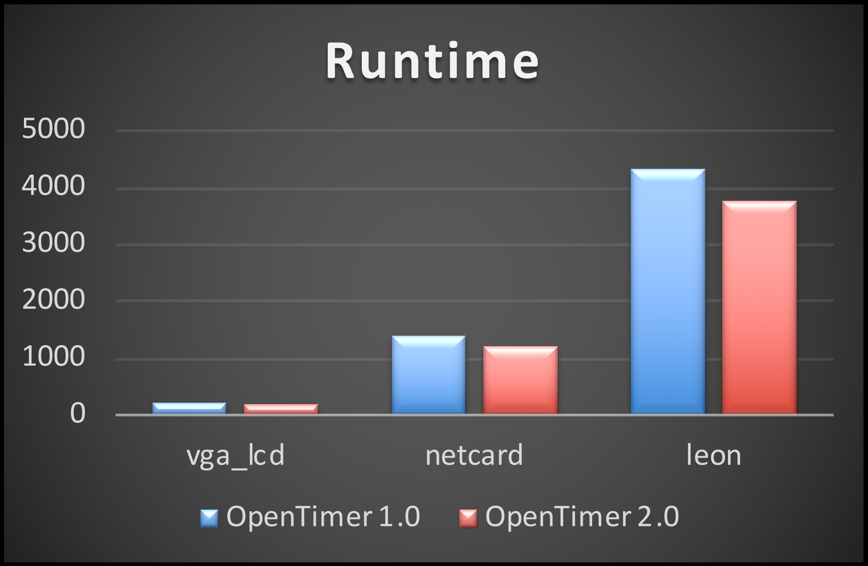
```
// create three regular tasks
auto A = tf.silent_emplace([](){}).name("A");
auto C = tf.silent_emplace([](){}).name("C");
auto D = tf.silent_emplace([](){}).name("D");

// create a subflow graph (dynamic tasking)
auto B = tf.silent_emplace([] (auto& subflow) {
  auto B1 = subflow.silent_emplace([](){}).name("B1");
  auto B2 = subflow.silent_emplace([](){}).name("B2");
  auto B3 = subflow.silent_emplace([](){}).name("B3");
  B1.precede(B3);
  B2.precede(B3);
}).name("B");

A.precede(B);  // B runs after A
A.precede(C);  // C runs after A
B.precede(D);  // D runs after B
C.precede(D);  // D runs after C

// execute the graph without cleanning up topologies
tf.dispatch().get();
cout << tf.dump_topologies();
```

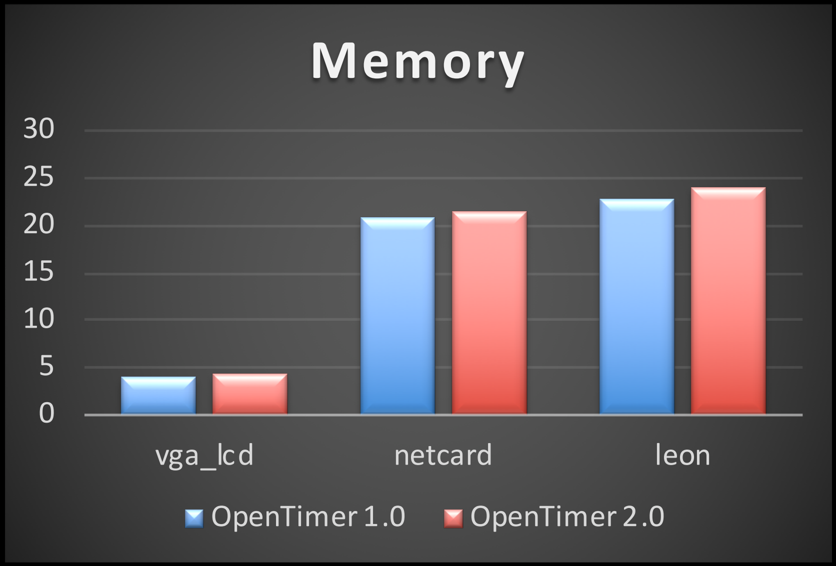


Real Application – VLSI Timing Analysis

- ❑ **OpenTimer 1.0 (OpenMP)**
- ❑ **OpenTimer 2.0 (Cpp-Taskflow)**
  - ❑ 10-30% faster than OpenMP
- ❑ **Circuit graphs with 10-100M gates**



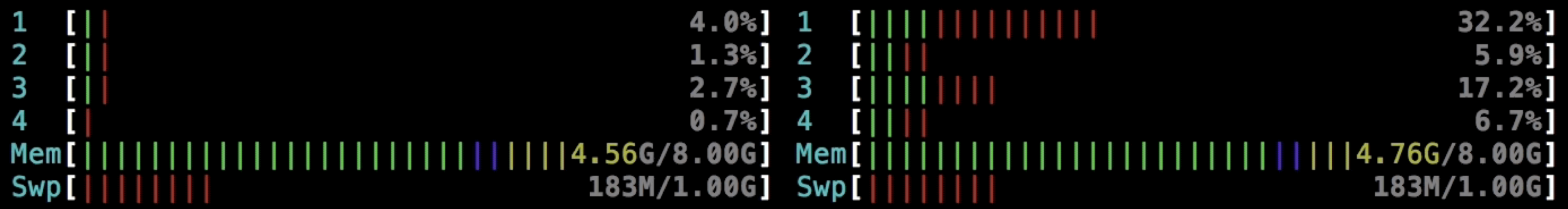




Thank you!

Tsung-Wei Huang
thuang19@Illinois.edu
402 CSL MC 228

Witout cpp-taskflow | With cpp-taskflow



Cpp-Taskflow Github: https://github.com/cpp-taskflow/cpp-taskflow

Acknowledgment: Chun-Xun Lin, Guannan Guo, Martin Wong
Sponsor: DARPA, NSF