TDD56

Lab 3: Skeleton programming with SkePU

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Labs schedule

		WebReg	Week	
Responsible: August	CPU	Lab 1	v46	Load Balancing
		Lab 2	v47	Non-blocking Data Structures
		Lab 3	v48	High-level Parallel Programming Lesson 2
Responsible: Ingemar	GPU	Lab 4	v49	CUDA 1
		Lab 5	v50	CUDA 2
		Lab 6	v51	OpenCL

C++11

- Shift in the labs from C to C++11 (”modern” C++)

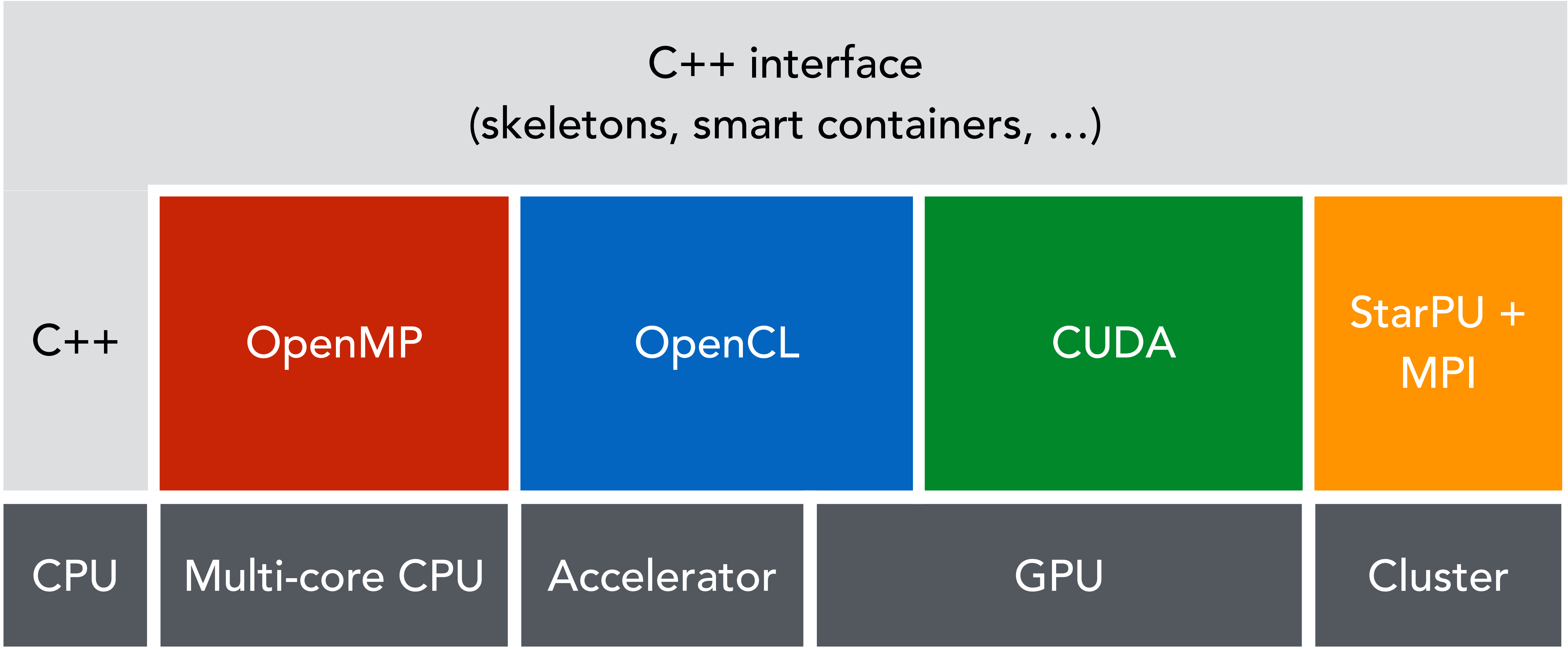
```
// ”auto” type specifier
auto addOneMap = skepu::Map<1>(addOneFunc);

skepu::Vector<float> input(size), res(size);
input.randomize(0, 9);

// Lambda expression
auto dur = skepu::benchmark::measureExecTime([&]
{
   addOneMap(res, input);
});
```

capture by reference

SkePU

- Skeleton programming framework
  - C++11 **library** with skeleton and data container classes
  - A source-to-source **translator tool**
- Smart containers: `Vector<T>, Matrix<T>,` tensors
- For **heterogeneous multicore** systems and clusters
  - Multiple backends
- Active research tool (A good topic for your thesis?)

SkePU architecture



C++ interface
(skeletons, smart containers, …)

C++

OpenMP

OpenCL

CUDA

StarPU +
MPI

CPU

Multi-core CPU

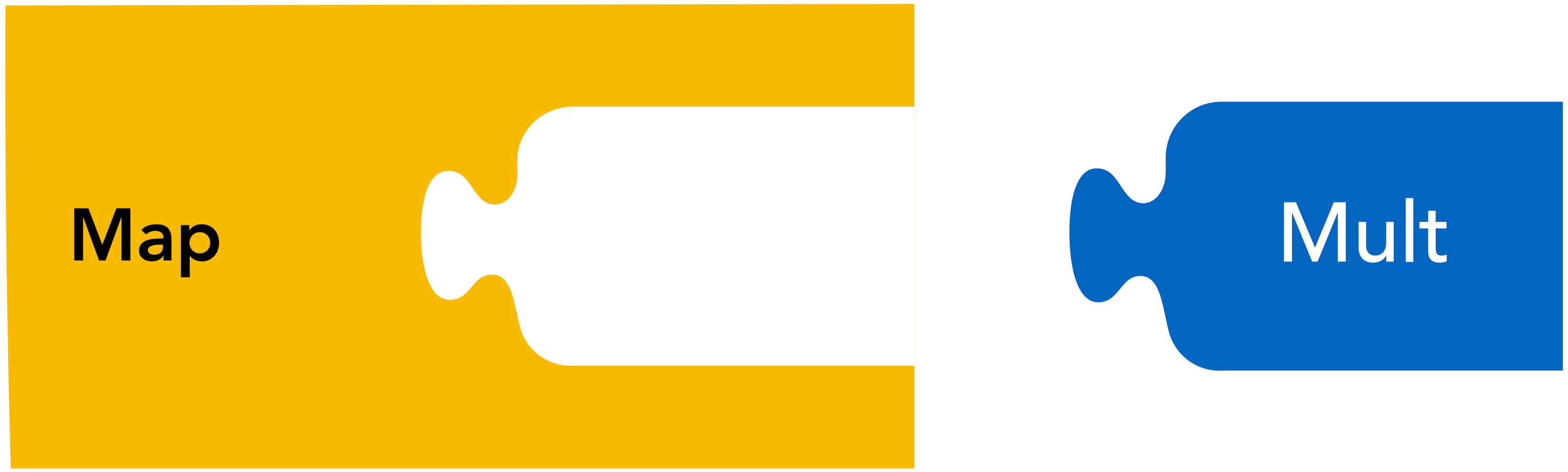
Accelerator

GPU

Cluster

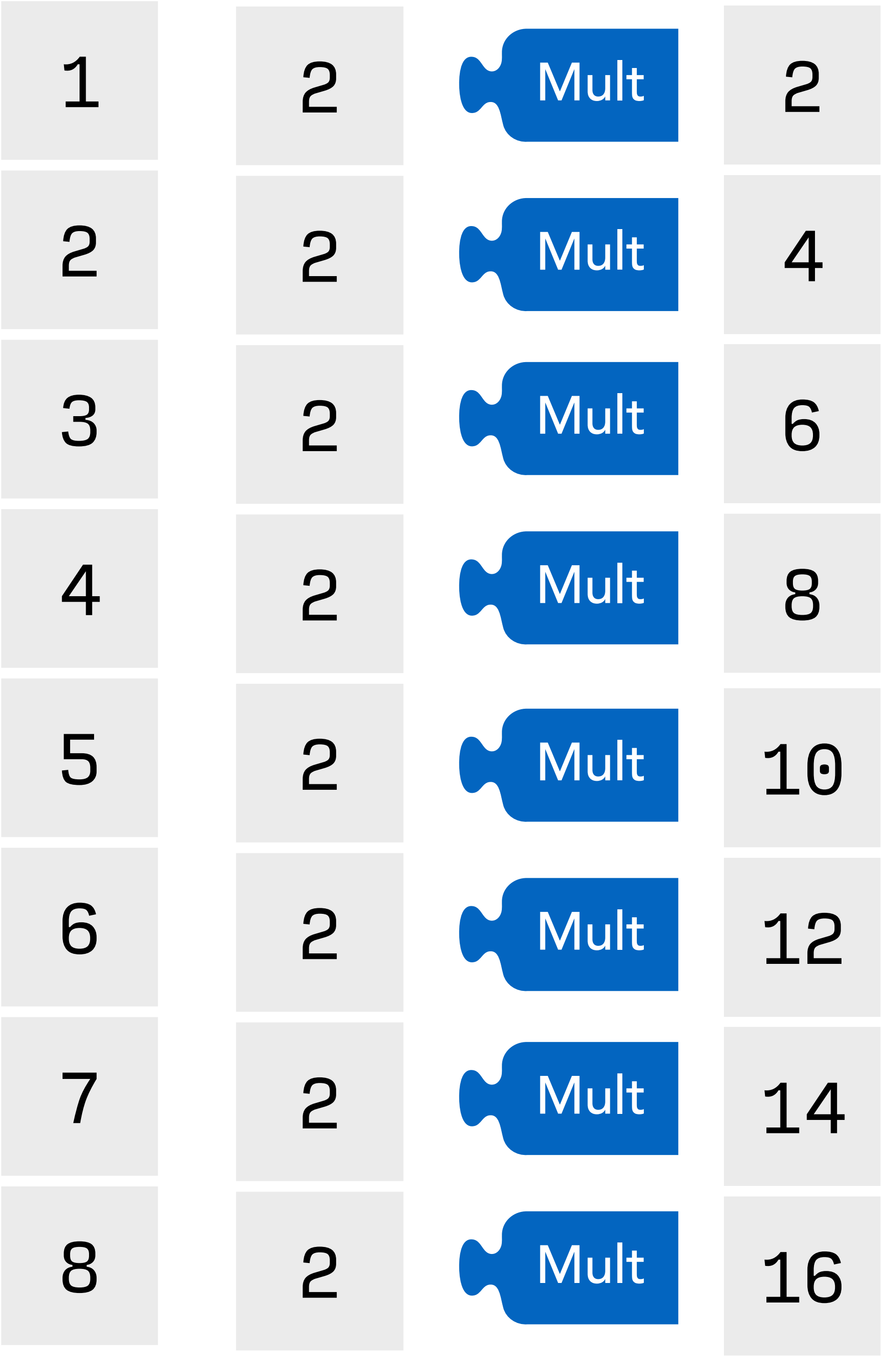
SkePU skeletons

- Parametrizable higher-order functions implemented as C++ template classes
  - **Map**
  - **Reduce**
  - **MapReduce**
  - **MapOverlap**
  - MapPairs
  - MapPairsReduce
  - Scan

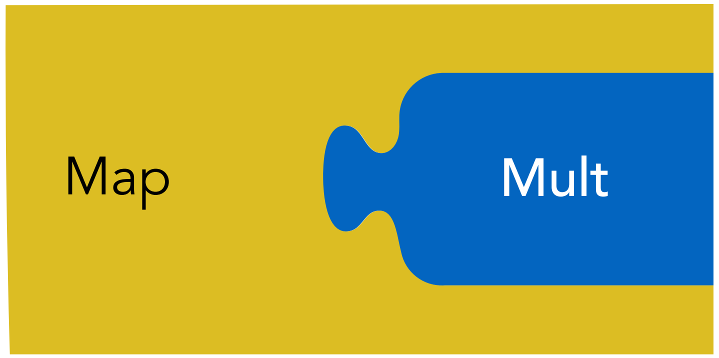


SkePU skeletons

Sequential algorithm



1	2	Mult	2
2	2	Mult	4
3	2	Mult	6
4	2	Mult	8
5	2	Mult	10
6	2	Mult	12
7	2	Mult	14
8	2	Mult	16

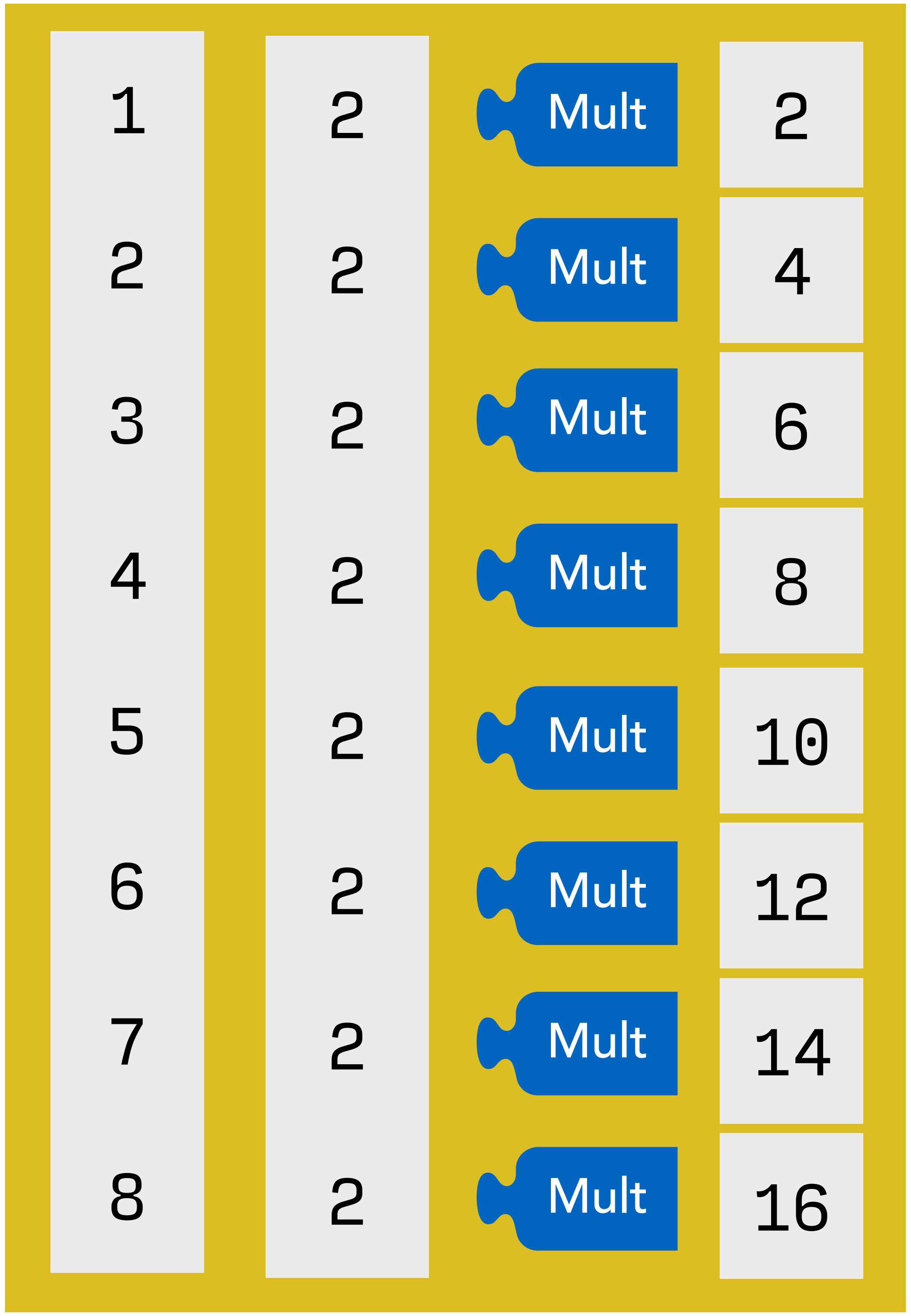


Map

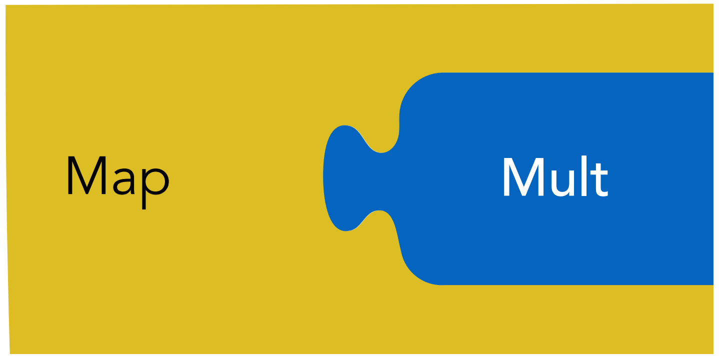
Mult

SkePU skeletons

Parallel algorithm



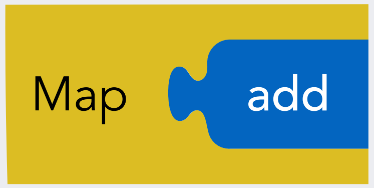
1	2	Mult	2
2	2	Mult	4
3	2	Mult	6
4	2	Mult	8
5	2	Mult	10
6	2	Mult	12
7	2	Mult	14
8	2	Mult	16



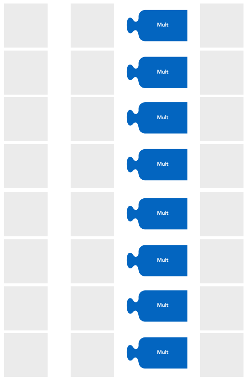
SkePU syntax

```
int add(int a, int b, int m)
{
    return (a + b) % m;
}
```

```
auto vec_sum = Map<2>(add);
```



```
vec_sum(result, v1, v2, 5);
```



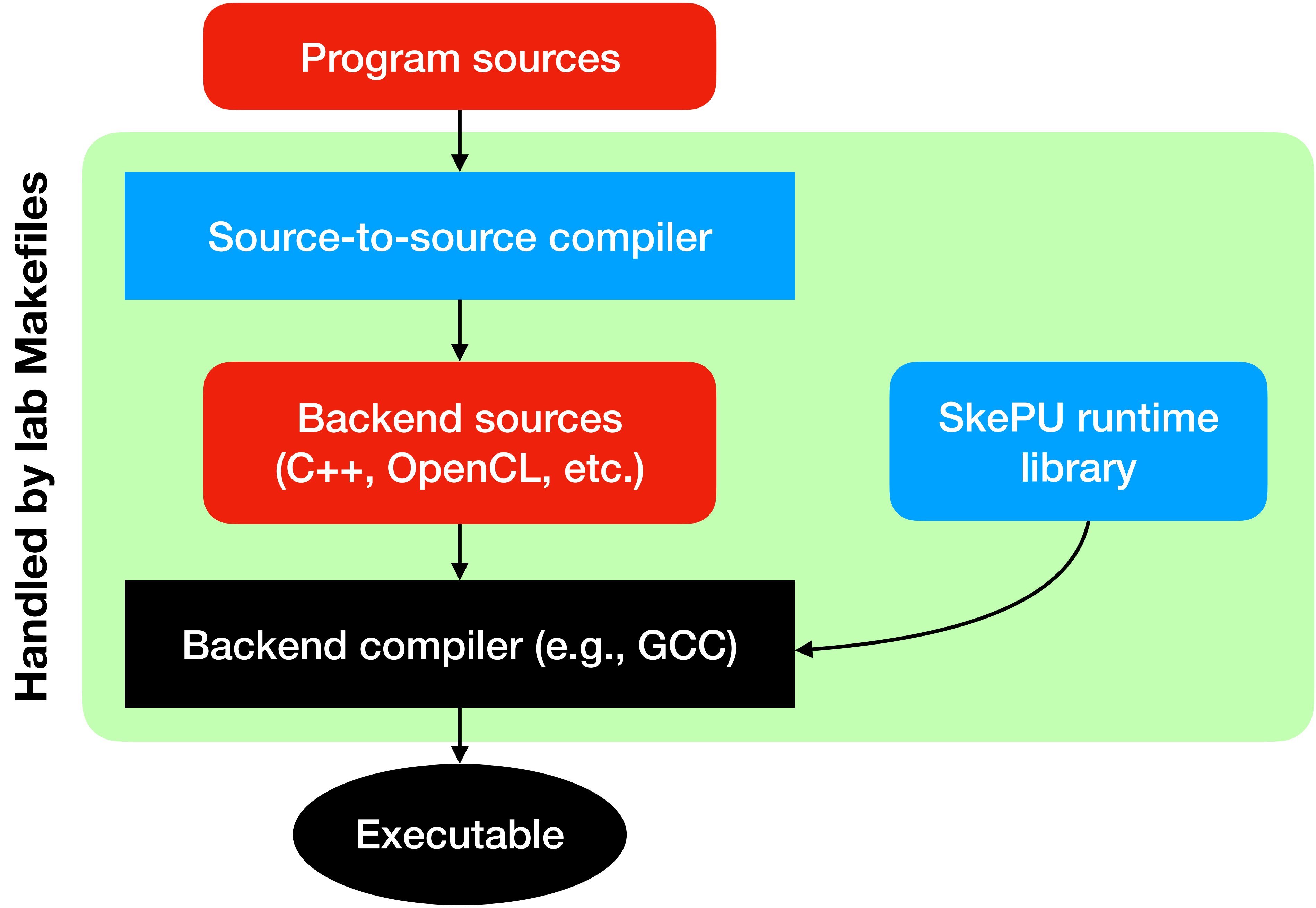
SkePU syntax, advanced

```
template<typename T>
T abs(T input)
{
  return input < 0 ? -input : input;
}


template<typename T>
T userfunc(Index1D row, const Mat<T> m, const Vec<T> v)
{
  T res = 0;
  for (size_t i = 0; i < v.size; ++i)
    res += m[row.i * m.cols + i] * v[i];

  return abs(res);
}
```

SkePU containers

- **Smart** containers: `Vector<T>, Matrix<T>, etc`
- Manages data across CPU and GPU
- No data transfers unless necessary (lazy copying)
- Keeps track of most recent writes
  - *Memory consistency* through software

SkePU build process



Lab structure

- Three exercises:

  1. Warm-up: dot product
  2. Averaging image filter + gaussian filter
  3. Median filter

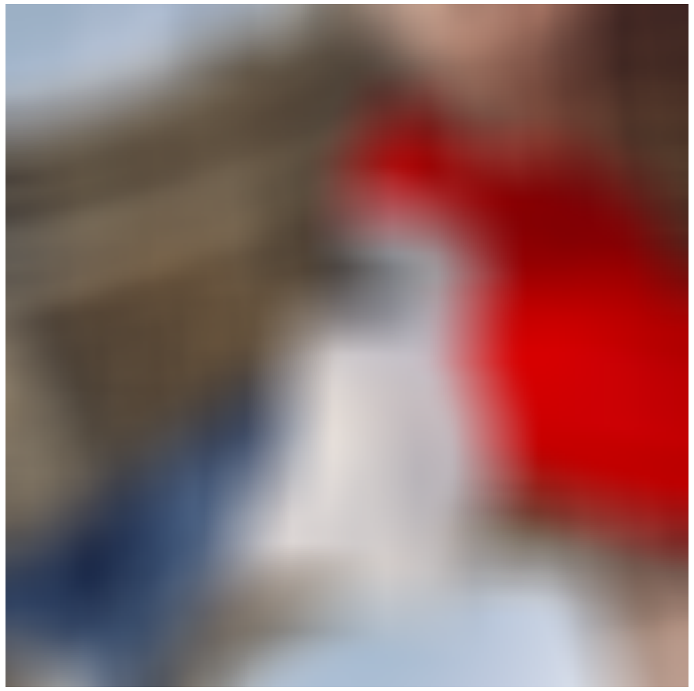
1. Dot product

- Implement two variants of dot product:
  - With **MapReduce** skeleton
  - With **Map** + **Reduce** skeletons
- Compare and contrast the variants
  - Why does SkePU have the MapReduce skeleton?
- Measure with different backends and problem sizes

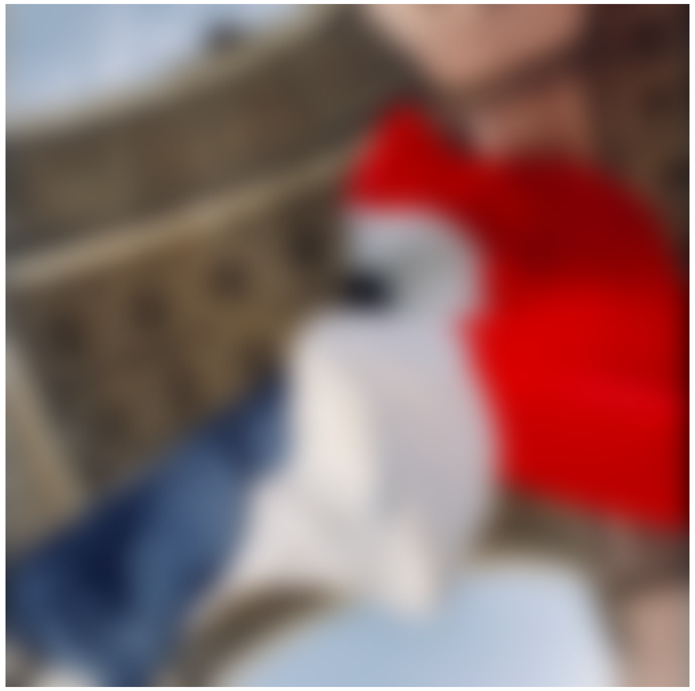
2. Averaging filters

- Averaging filter: find average color value in surrounding region
- Gaussian filter: averaging filter with **non-uniform** weights
- Use the MapOverlap skeleton

Original



Average

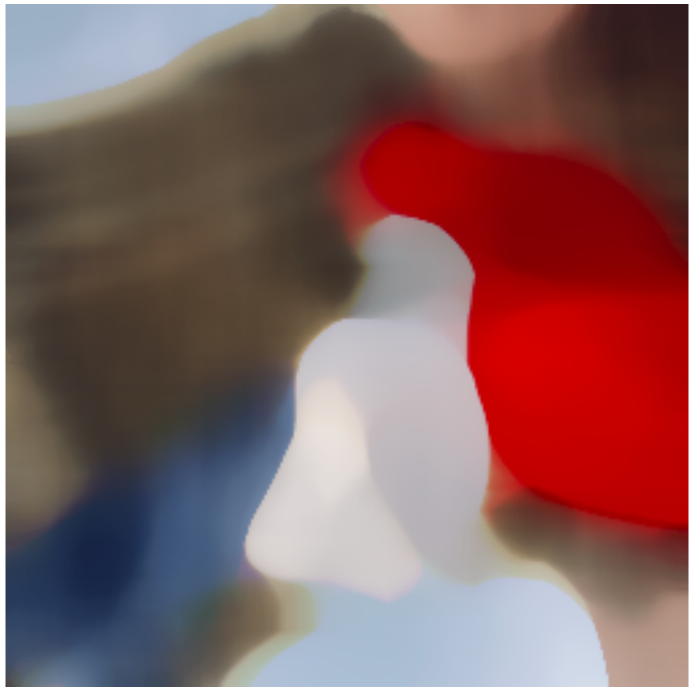


Gaussian

3. Median filter

- Median filter: find **median** color value in surrounding region
- Requires sorting the pixel values in some way

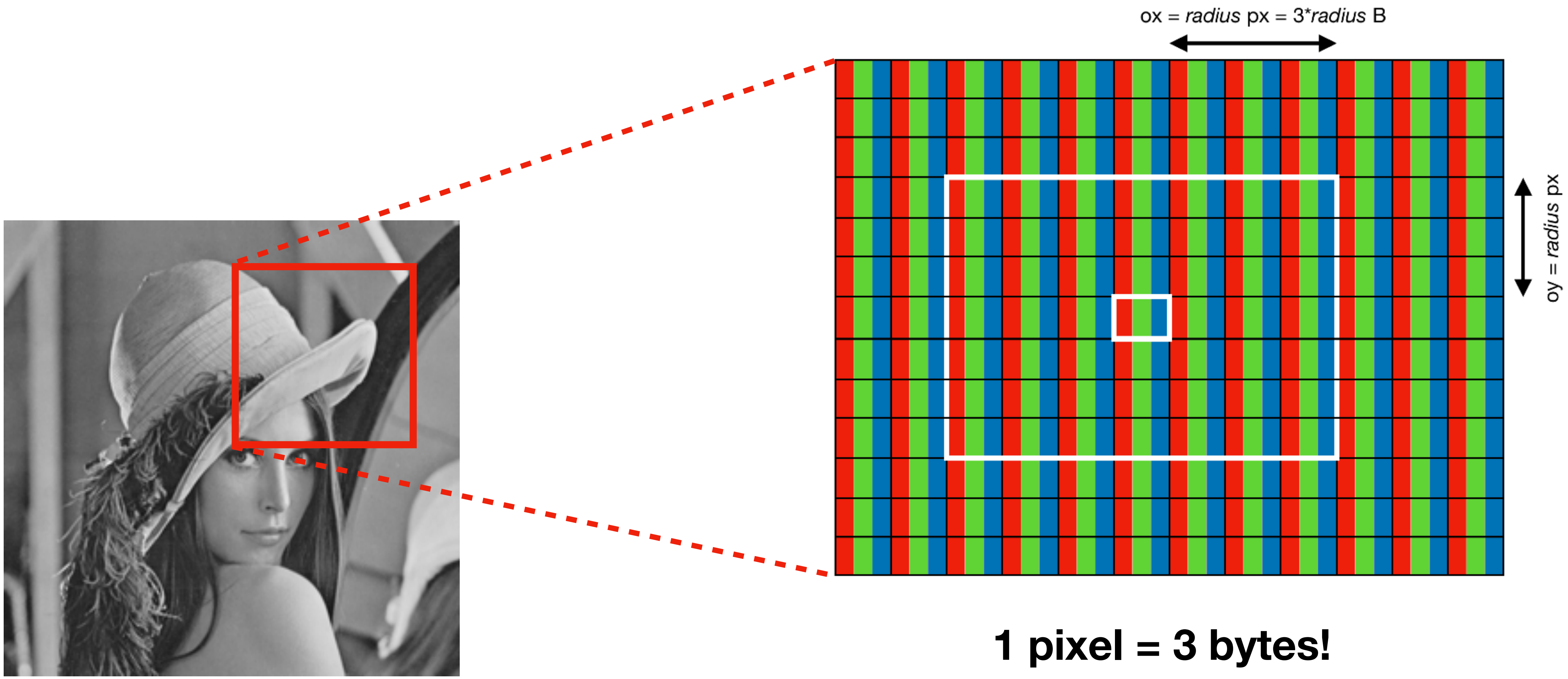
Original



Median

Image filters

- Layout of image data in memory



1 pixel = 3 bytes!

Lab installation

- Get from course website as usual
- Slightly different from public SkePU distribution!
  - Pre-built binary
  - Runs on 64-bit Linux

Lab build process

Build lab program:

```
> make bin/addone
```

Run lab program:

```
> bin/addone 100 CPU
```

CPU:	**Use sequential backend**
OpenMP:	**Use multithreaded backend**
OpenCL:	**Use GPU backend**

A warning about warnings (and errors)

- SkePU is a C++ template library
- As such, gets very long and unreadable diagnostic messages if used incorrectly!
- Following the structure of the lab files should minimize errors
- Otherwise, be careful, and avoid using `const`!

Questions?