LAPP
Laboratoire d'Annecy de Physique des Particules

Introduction : Compilation

Pierre Aubert

ESCAPE
cta cherenkov telescope array
cnrs
UNIVERSITÉ SAVOIE MONT BLANC

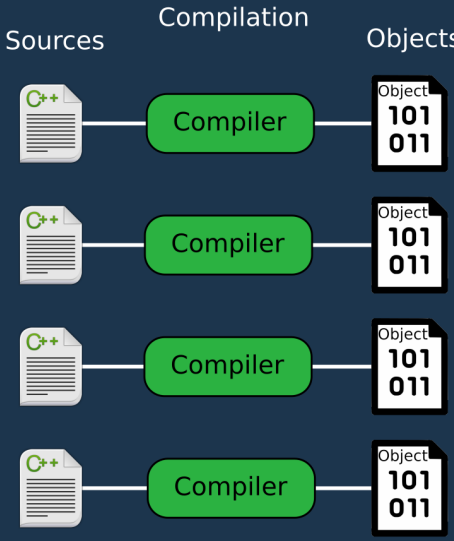
Compilation : From Text to Binary

Compilation : From Text to Binary

Sources




Compilation : From Text to Binary



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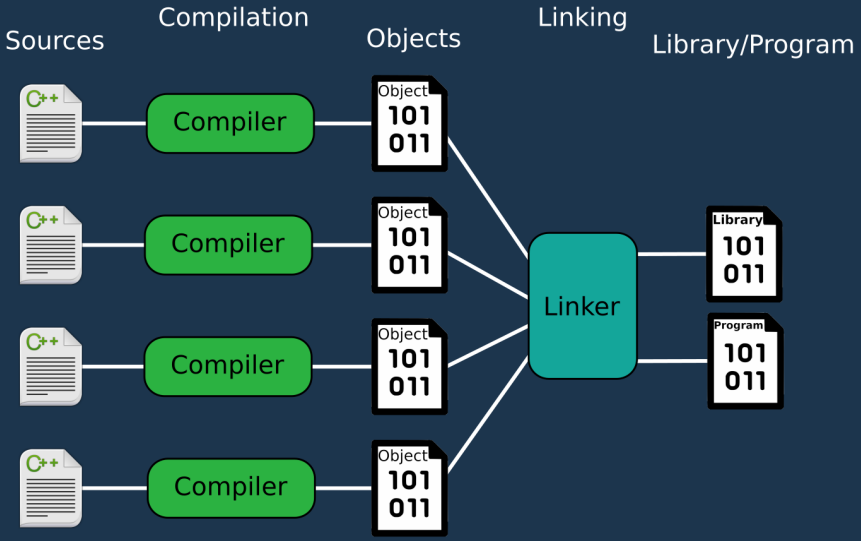

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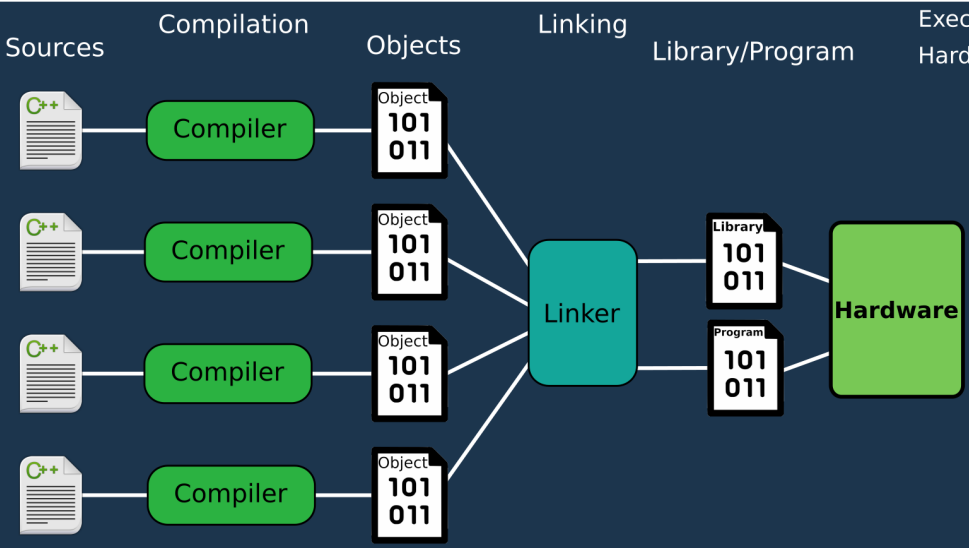

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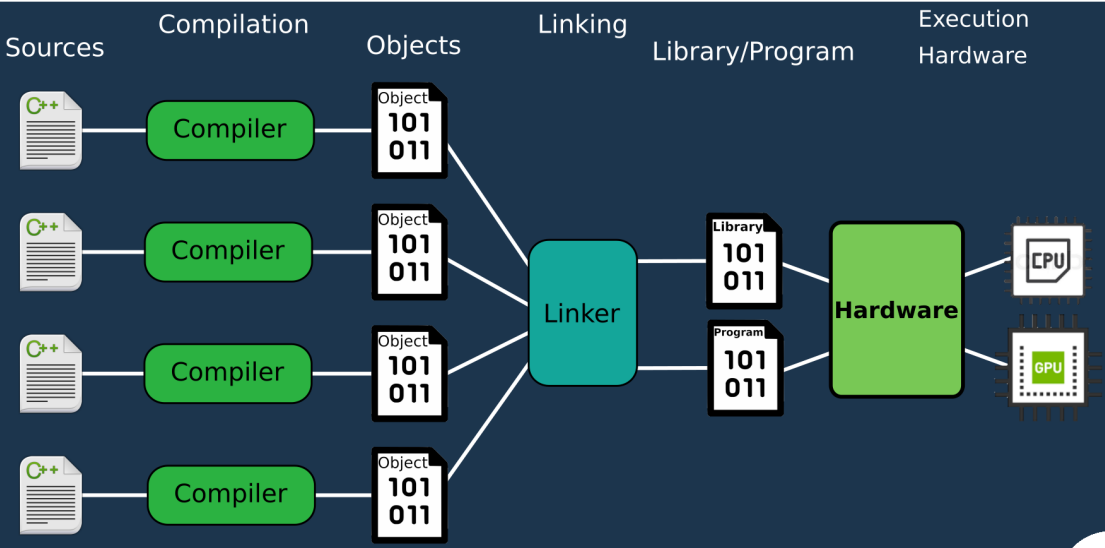

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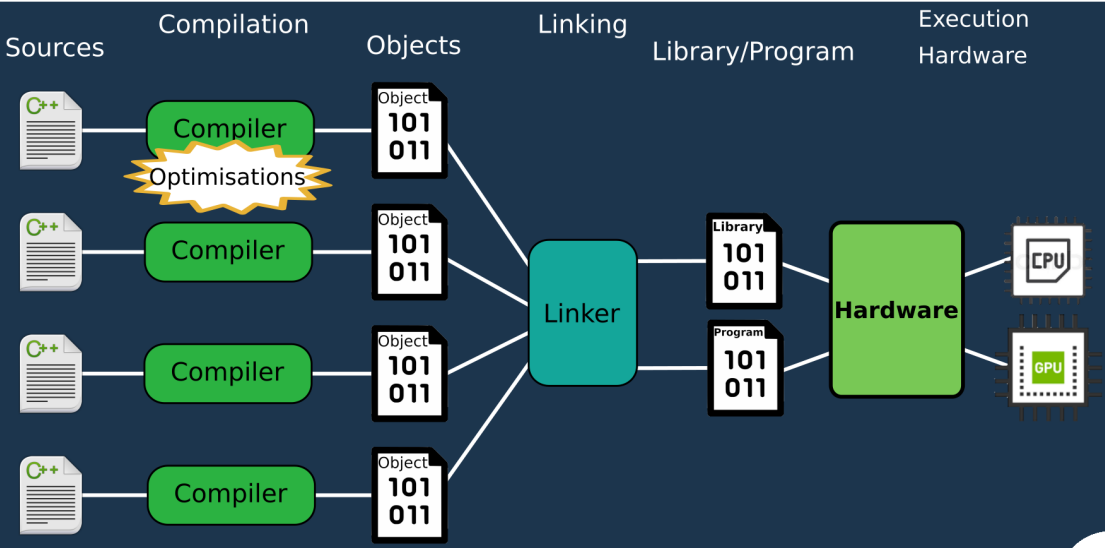

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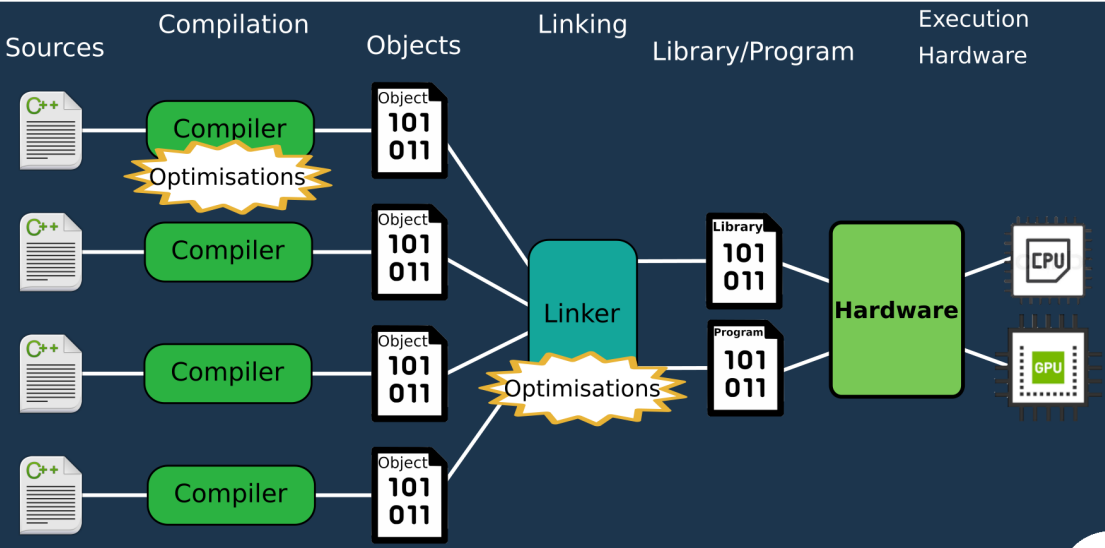

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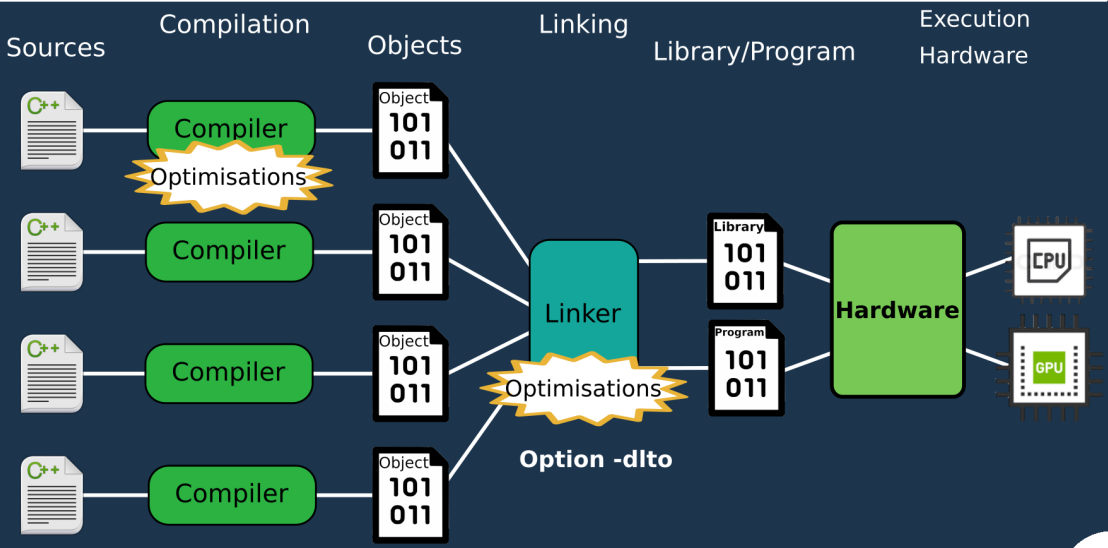

Compiler workflow

Compiler workflow

Languages

Fortran

Compiler workflow

Languages

Fortran

Binaries

Compiler workflow

Languages

Front-End

Front-End

Fortran

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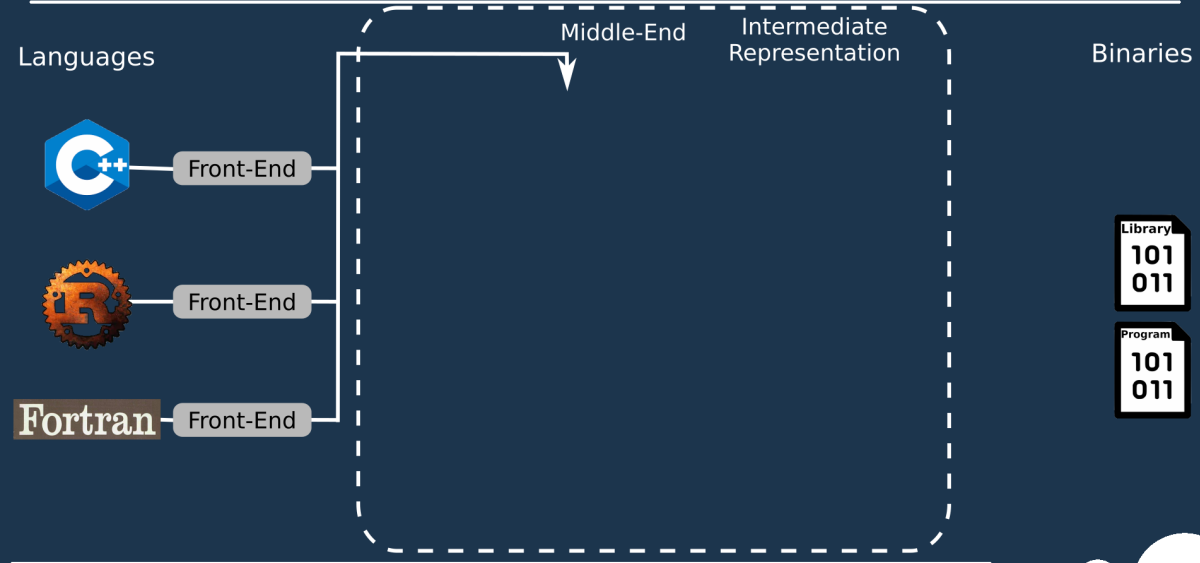
Binaries

Compiler workflow



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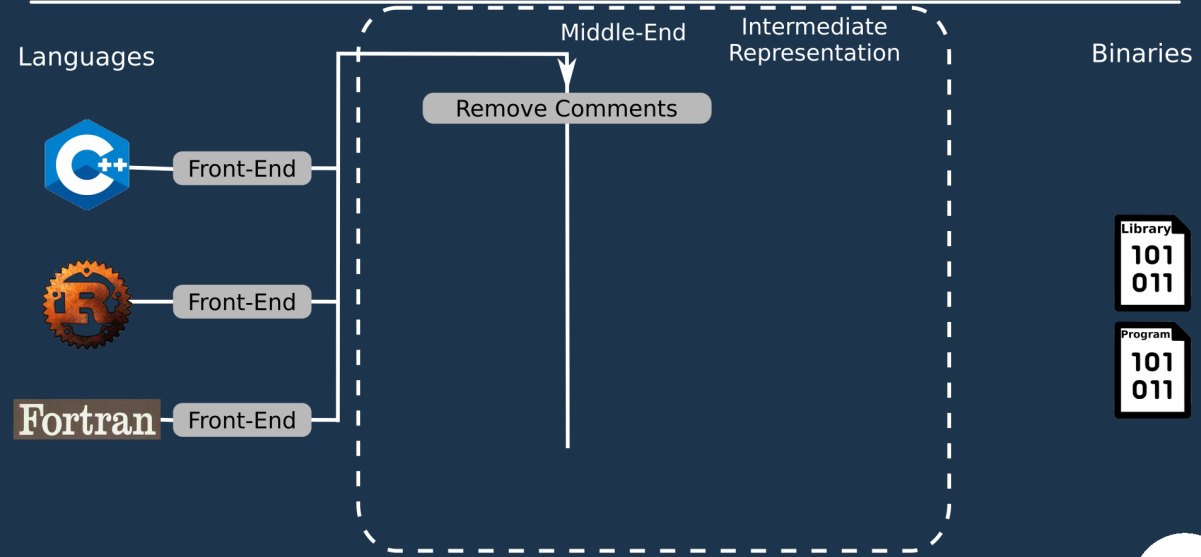

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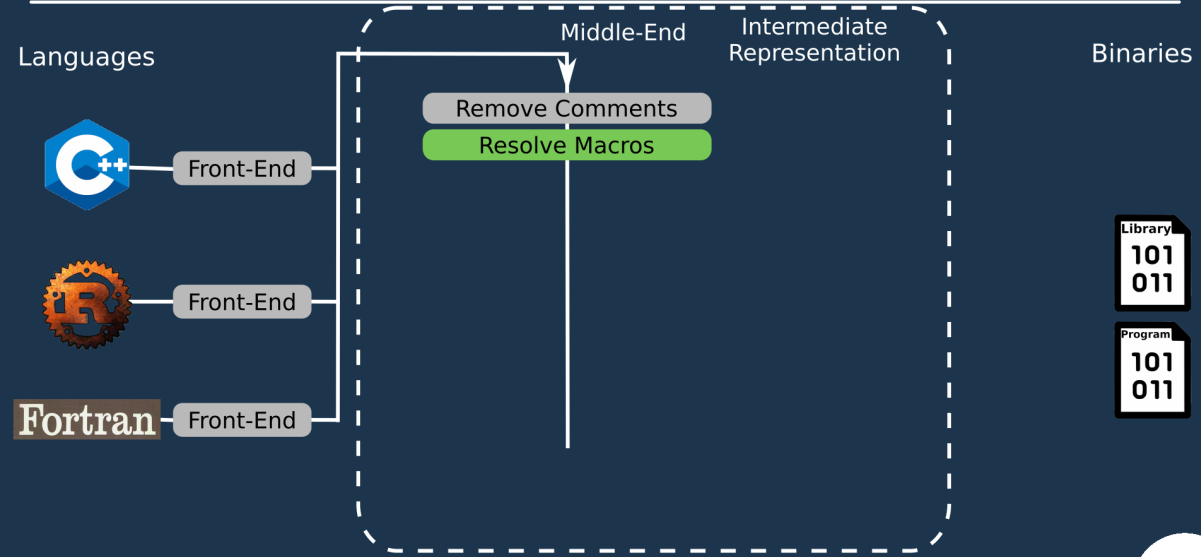

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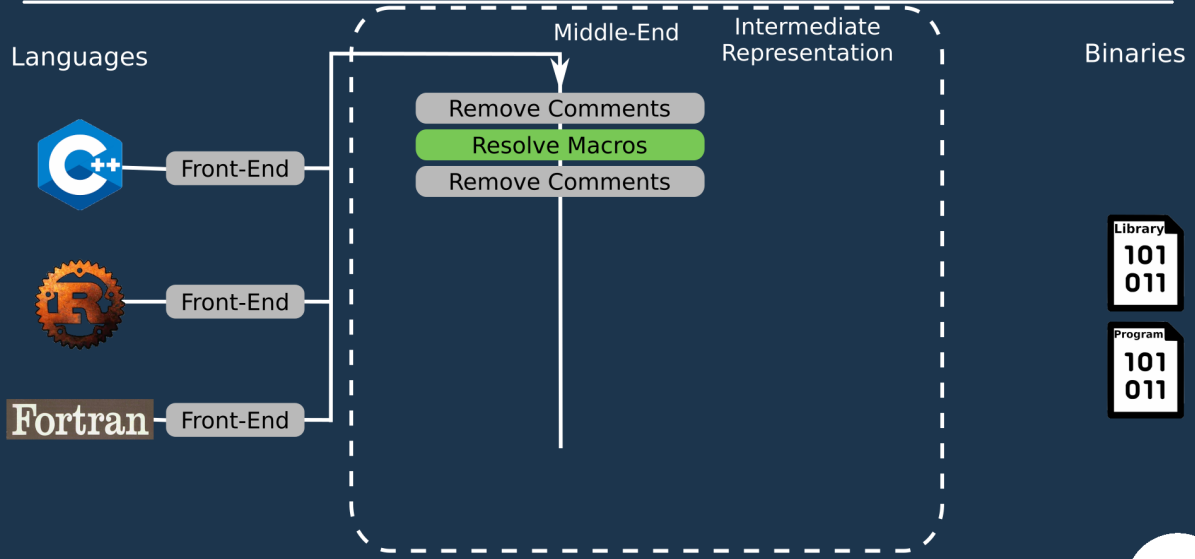

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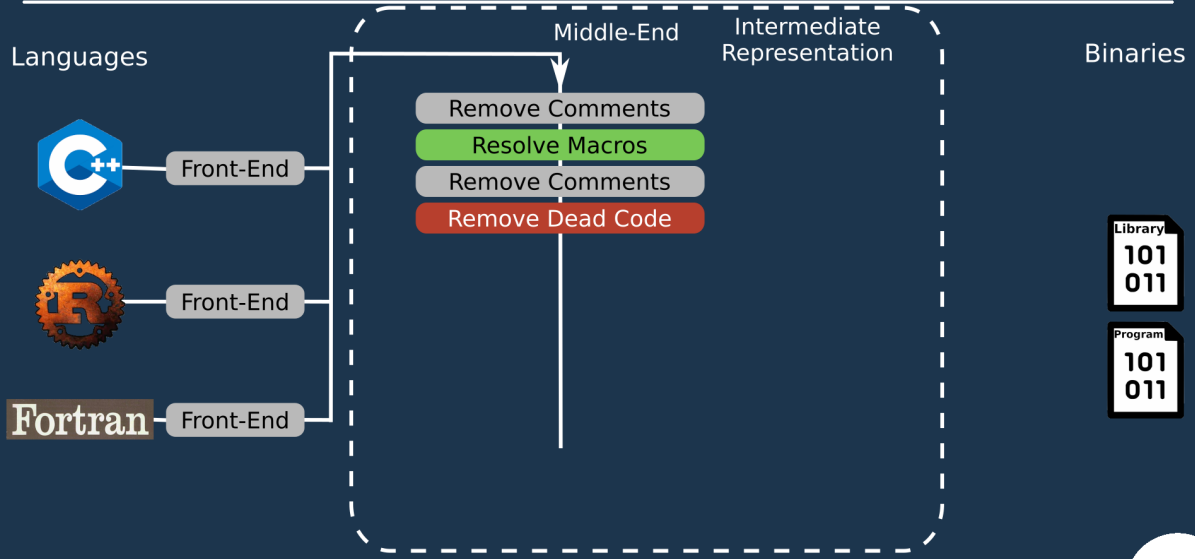

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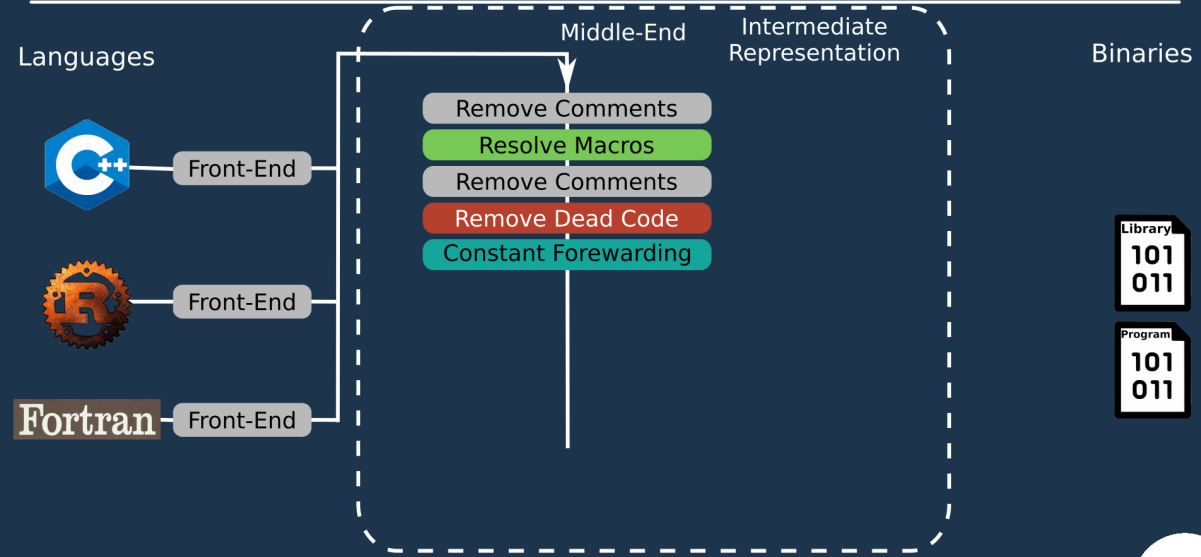

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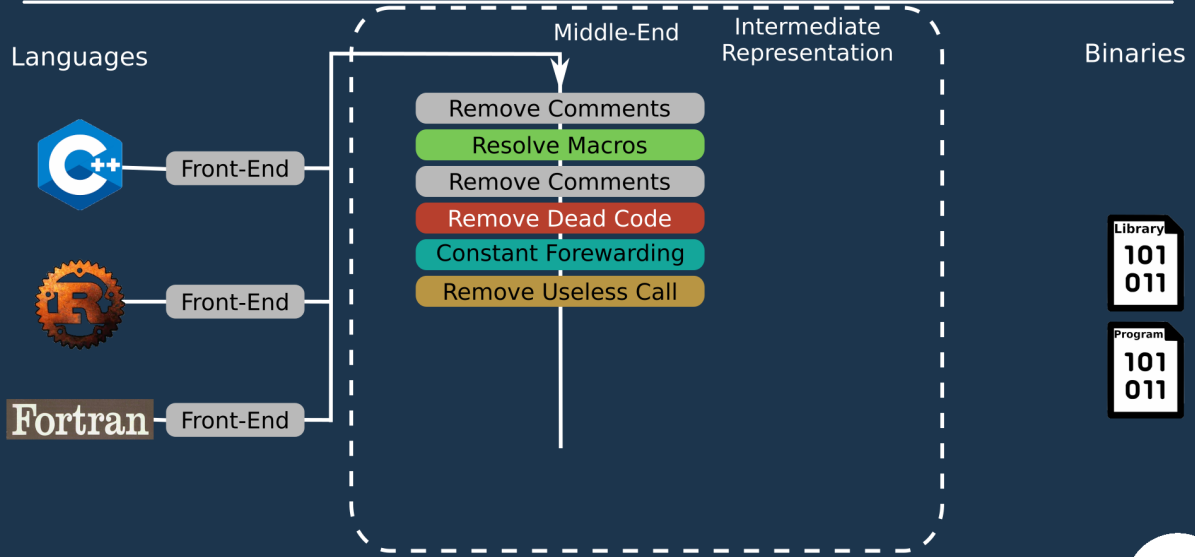

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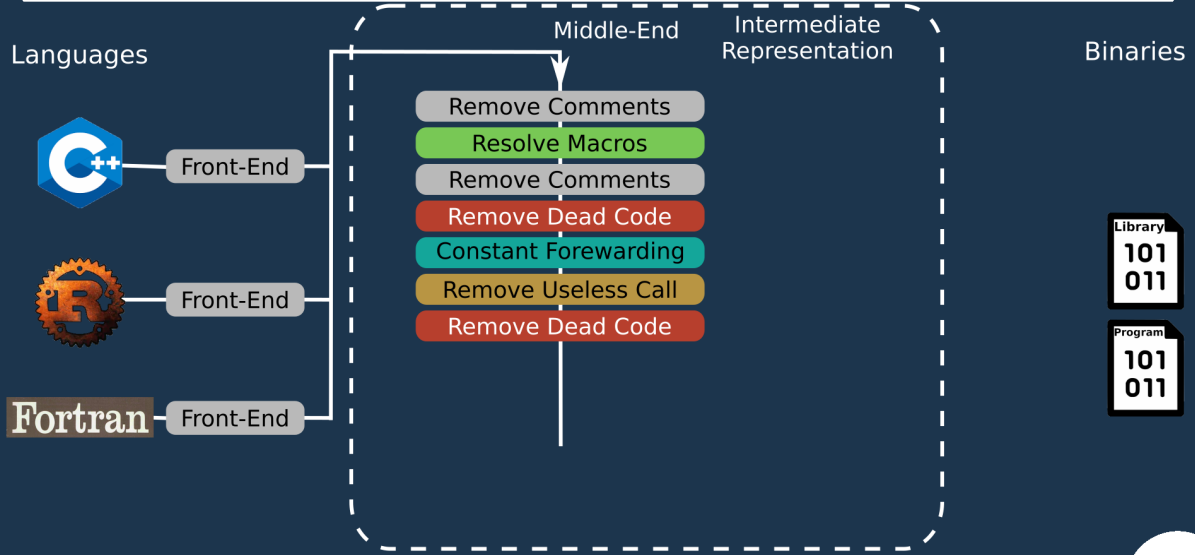

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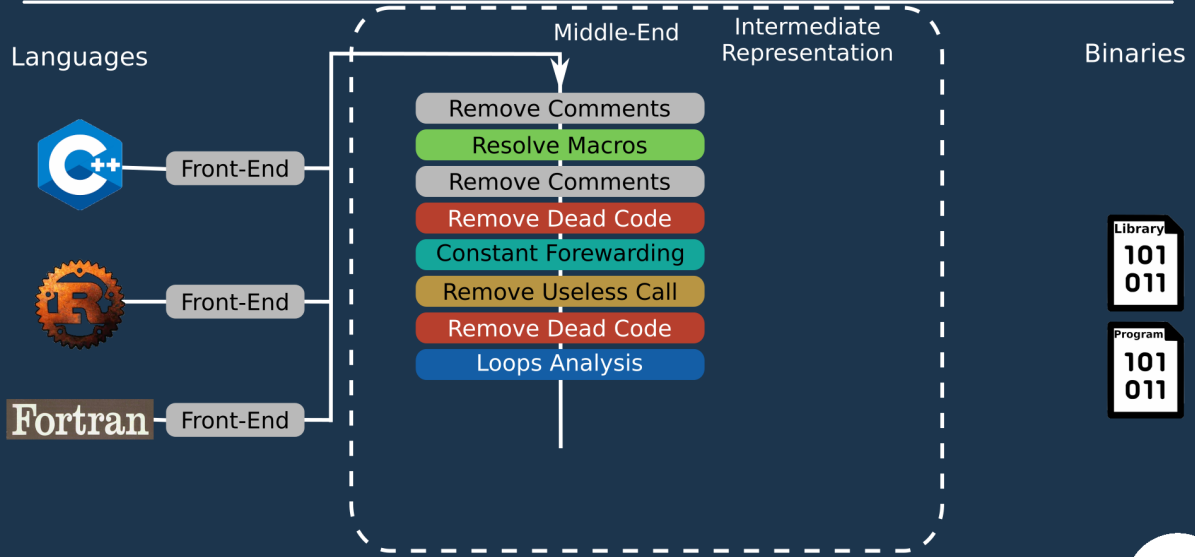

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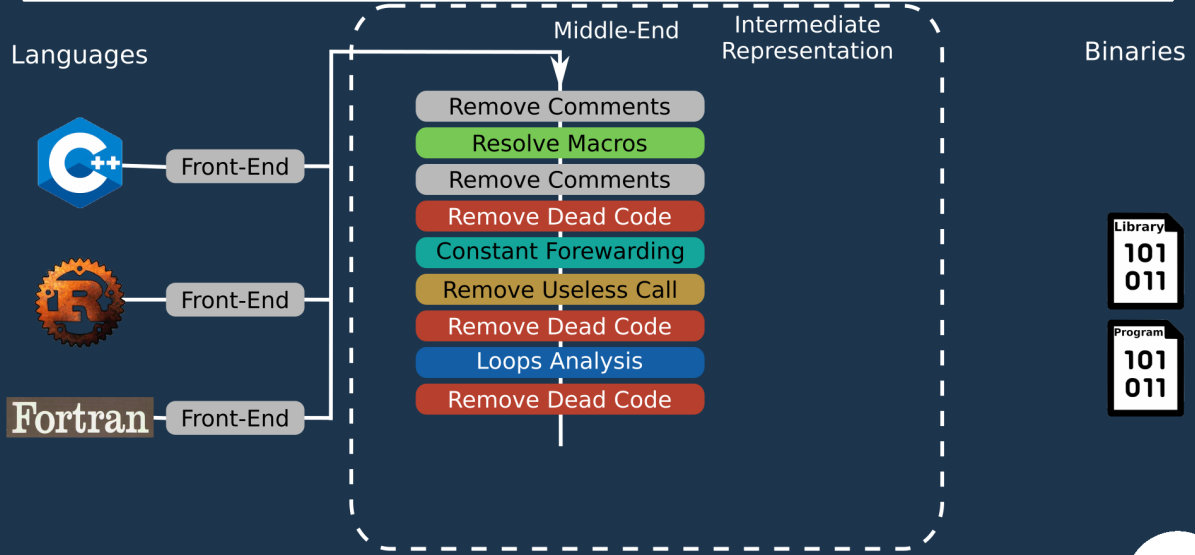

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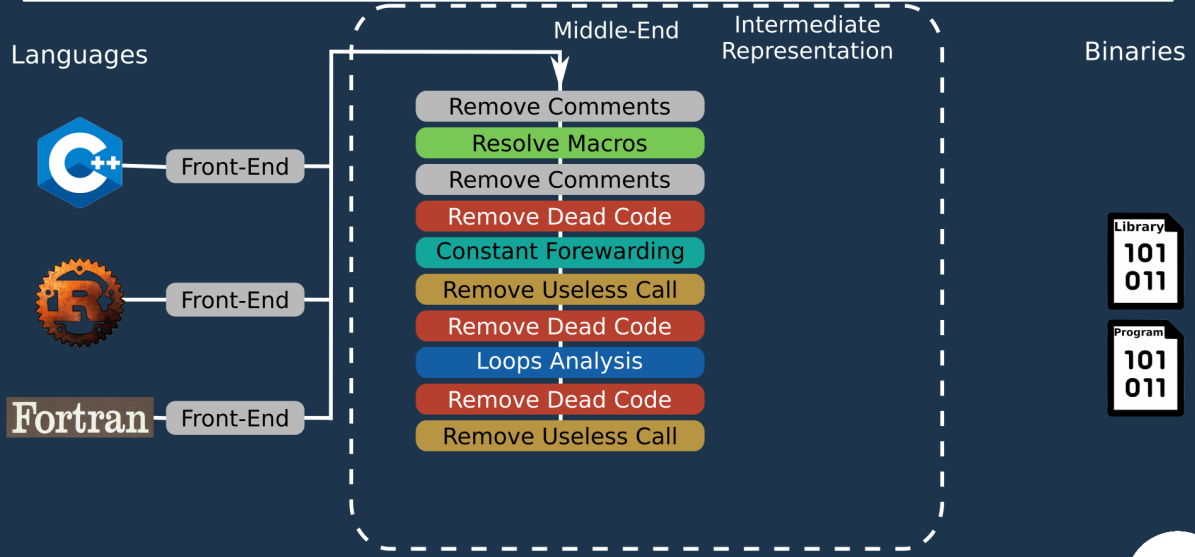

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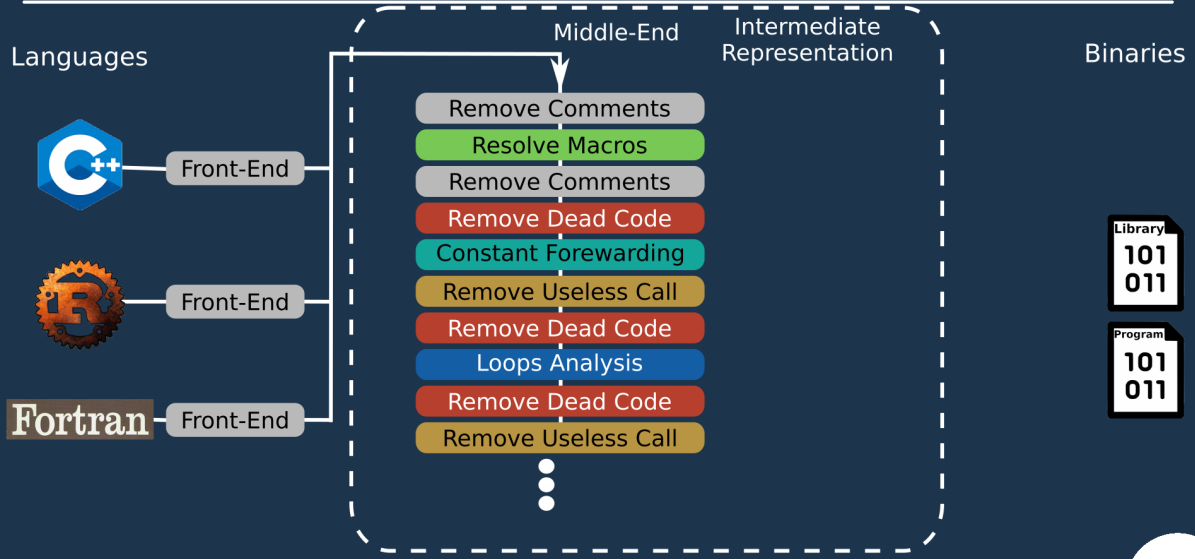

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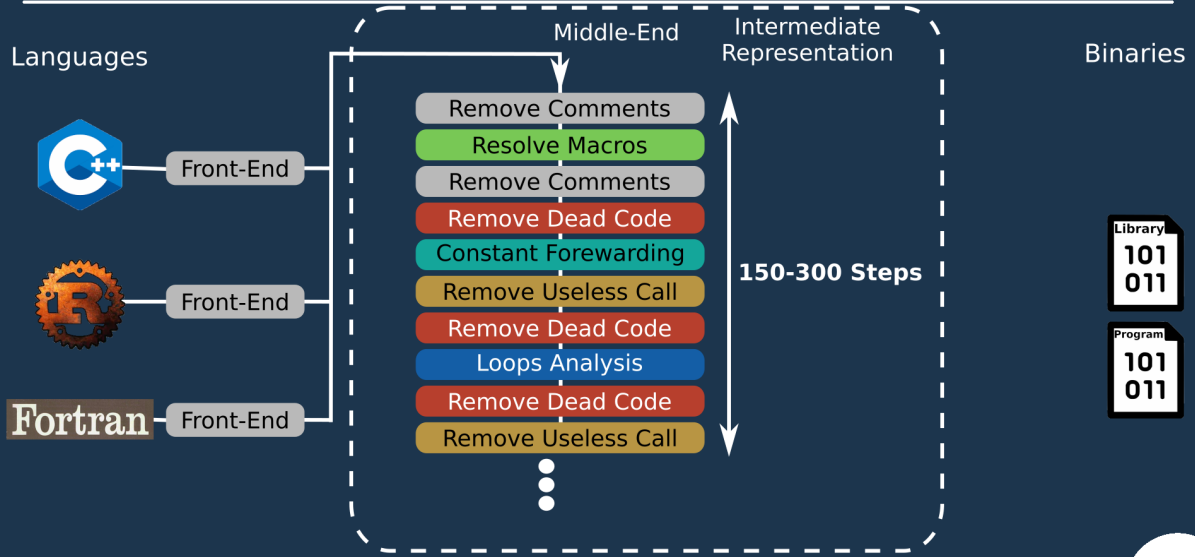

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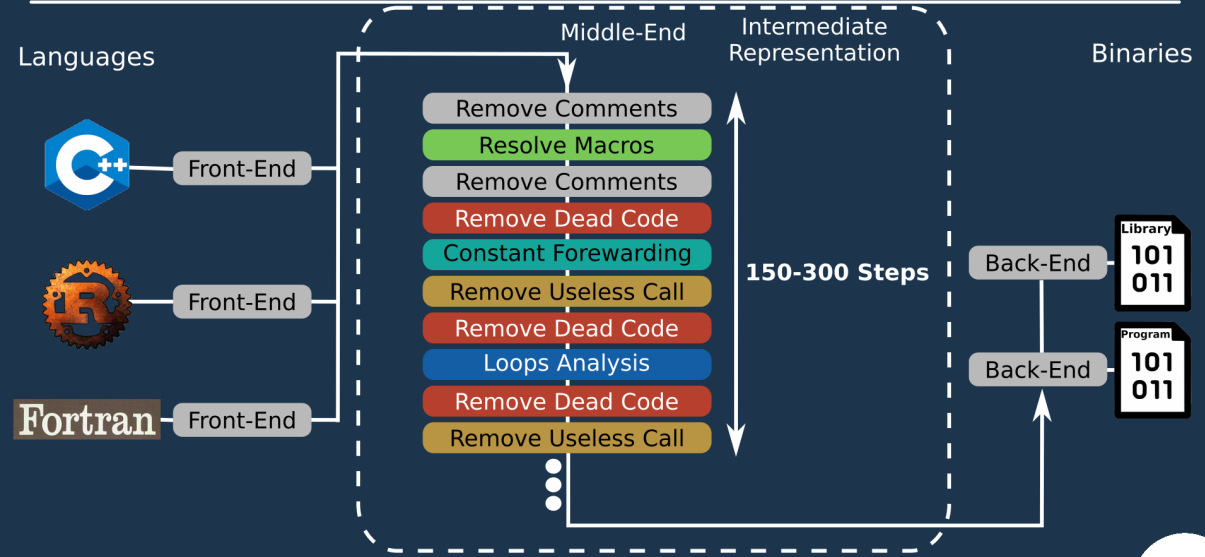

Compiler intermediate representation

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Program

```
float square(float x){
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»       float y(42.0f);
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Graph

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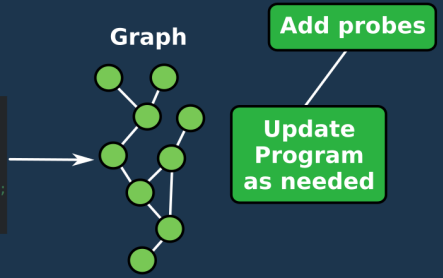

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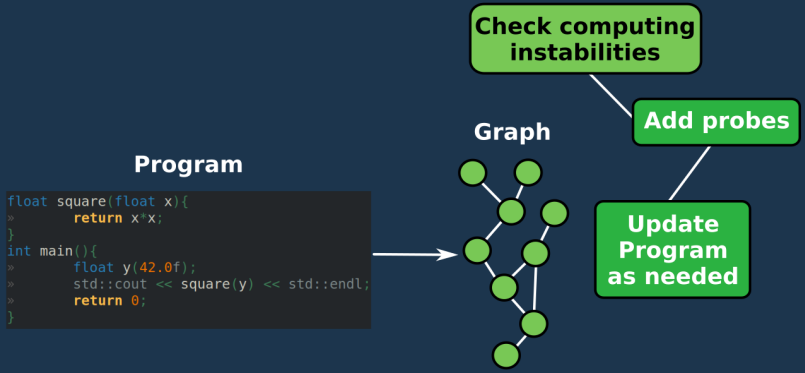

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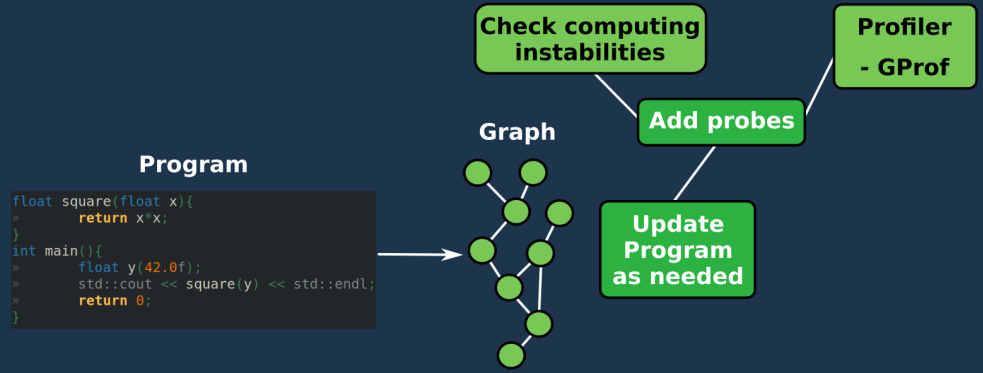

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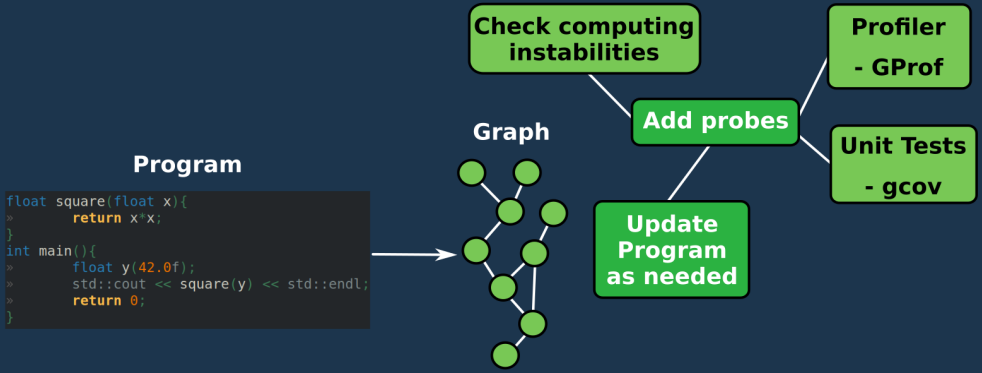

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Check computing instabilities

Profiler - GProf

Add probes

Unit Tests - gcov

Update Program as needed

Counters on lines and branches

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Compiler intermediate representation

Laboratoire d'Annecy de Physique des Particules

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Some optimisations are **forbidden** by **Graph Theory**

Compilation options

https://gcc.gnu.org/onlinedocs/gcc/Optimize-Options.html

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- **-Ofast**
  - Disregard strict standards compliance. Enable **-ffast-math**, stack size is hardcoded to 32 768 bytes (borrowed from **gfortran**). **Possibly degrades the computation accuracy.**

Examples

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No more :
- **Function call**
- **Multiplication**
- **Variable declaration**

Loop Unrolling

Loop Unrolling

```
void hadamard(float* tabRes, const float * tabX, const float * tabY, size_t nbElement){
	for(size_t i(0lu); i < nbElement; ++i){
		tabRes[i] = tabX[i]*tabY[i];
	}
}
```

Base

Loop Unrolling

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Base

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void hadamard(float* tabRes, const float * tabX, const float * tabY, size_t nbElement){
	for(size_t i(0lu); i < nbElement; i += 2lu){
		tabRes[i] = tabX[i]*tabY[i];
		tabRes[i + 1] = tabX[i + 1]*tabY[i + 1];
	}
}
```

Loop unrolled 2 times

Loop Unrolling

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Increase Computing in Iteration

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Increase Computing in Iteration

Loop unrolled 2 times

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	for(size_t i(0lu); i < nbElement; i += 4lu){
		tabRes[i] = tabX[i]*tabY[i];
		tabRes[i + 1] = tabX[i + 1]*tabY[i + 1];
		tabRes[i + 2] = tabX[i + 2]*tabY[i + 2];
		tabRes[i + 3] = tabX[i + 3]*tabY[i + 3];
	}
}
```

Loop unrolled 4 times

Loop Unrolling

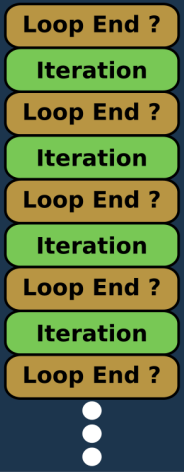
Loop Unrolling

Less end loop check

Loop Unrolling

Less end loop check

No Loop Unrolling



Loop Unrolling

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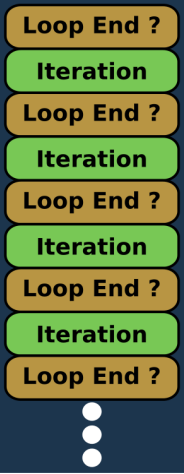
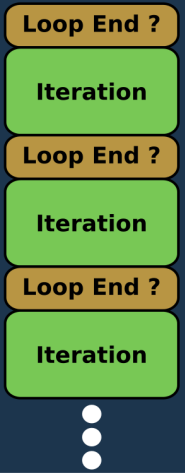


Loop Unrolling 2x



Loop Unrolling

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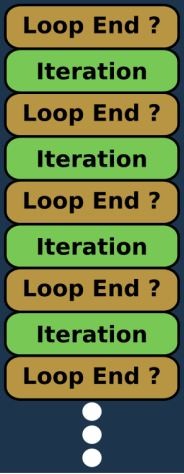

Loop Unrolling 2x

Loop Unrolling

Less end loop check

Load / Computing optimisation

No Loop Unrolling

Loop End ?

Iteration

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Loop Unrolling 2x

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Ite

Branching Predicator Stays cool

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Loop Unrolling 2x

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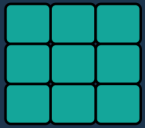
Load / Computing optimisation

No Loop Unrolling

3x3 Kernel Load



Loop Unrolling

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Branching Predicator Stays cool

Load / Computing optimisation

No Loop Unrolling

3x3 Kernel Load

Loop Unrolling

Less end loop check

No Loop Unrolling

Loop End ?
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Loop Unrolling 2x

Loop End ?
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Load / Computing optimisation

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3x3 Kernel Load

Computing

Store Result

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Loop End ?
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Loop Unrolling 2x

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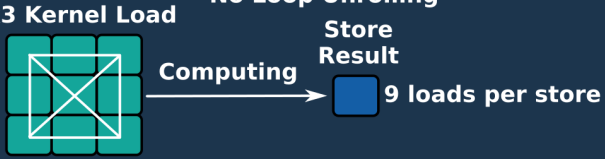
Branching Predicator Stays cool

Load / Computing optimisation

No Loop Unrolling



Loop Unrolling

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Loop Unrolling 2x

Loop End ?
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Ite

Branching Predicator Stays cool

Load / Computing optimisation

No Loop Unrolling

3x3 Kernel Load

Computing

Store Result

9 loads per store

Loop Unrolling 2x

Loop Unrolling

Less end loop check

No Loop Unrolling

- Loop End ?
- Iteration
- Loop End ?
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- Iteration
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Loop Unrolling 2x

- Loop End ?
- Iteration
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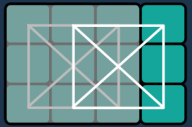

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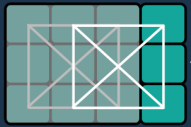

12 loads, 2 stores

Loop Unrolling

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Loop End ?
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Loop Unrolling 2x

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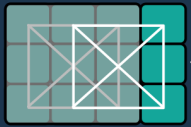

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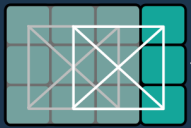

12 loads, 2 stores

6 loads per store

Loop Unrolling 4x

Loop Unrolling

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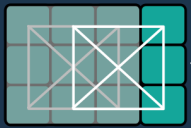

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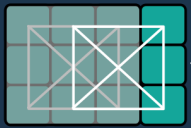

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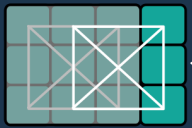

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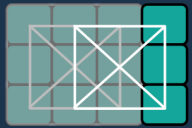

Loop Unrolling

Less end loop check

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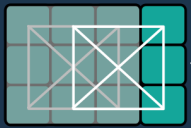

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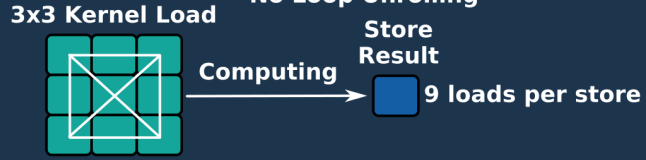

Loop Unrolling 2x

Loop Unrolling 4x

Loop Unrolling

Less end loop check

No Loop Unrolling

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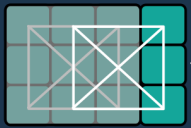

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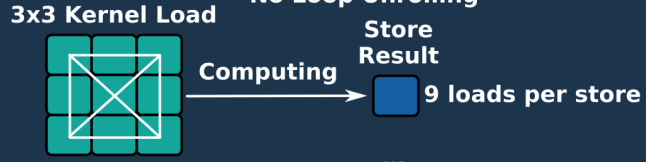

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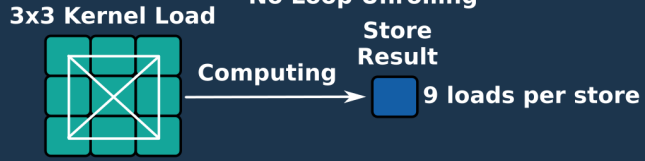

Loop Unrolling

Less end loop check

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Loop Unrolling 2x

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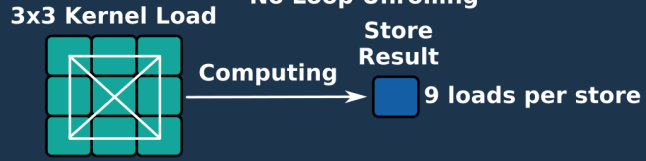
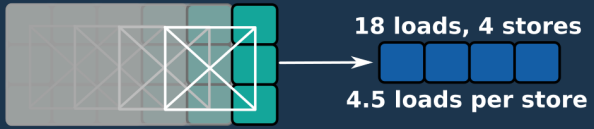
Load / Computing optimisation

No Loop Unrolling



Loop Unrolling 2x

Loop Unrolling 4x



Loop Unrolling

Less end loop check

No Loop Unrolling

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Loop Unrolling 2x

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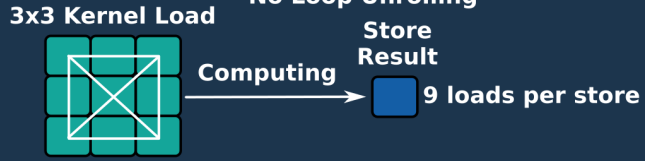
Load / Computing optimisation

No Loop Unrolling

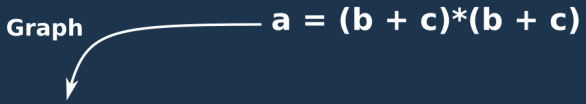


Then it is a problem of number of available registers

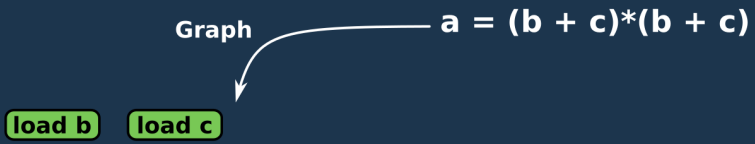
Common subexpression elimination

a = (b + c)*(b + c)

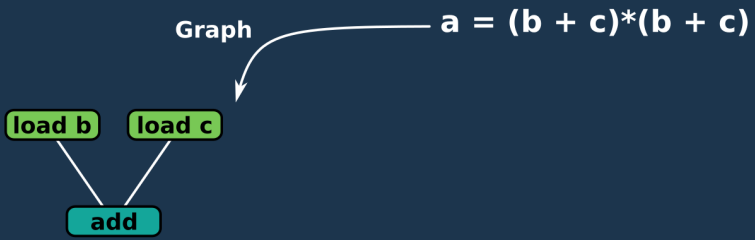
Common subexpression elimination



Common subexpression elimination



Common subexpression elimination



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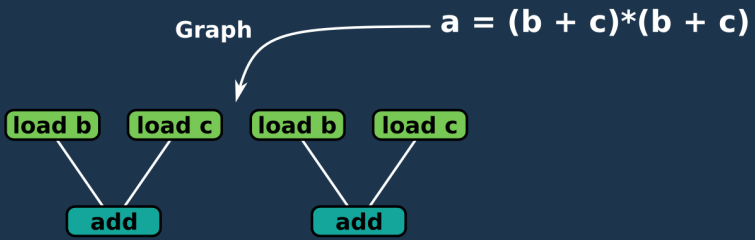

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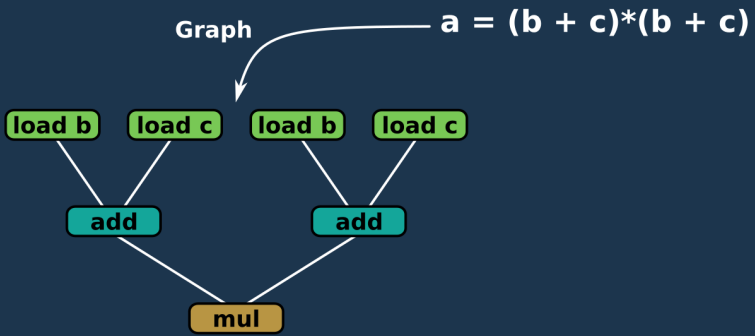
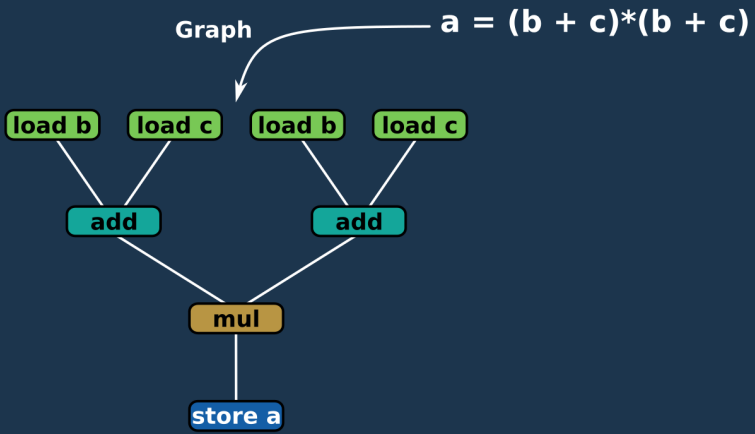
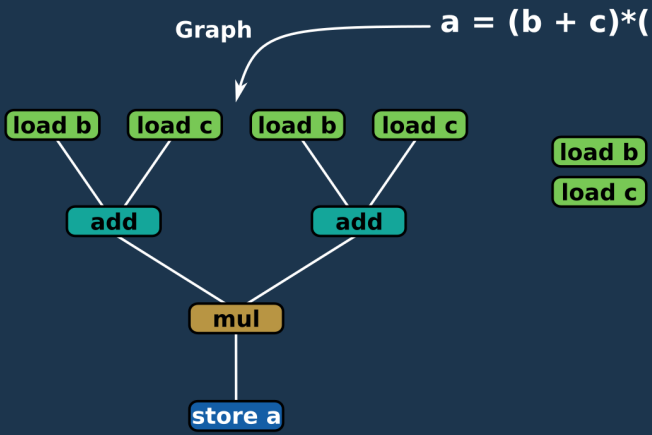


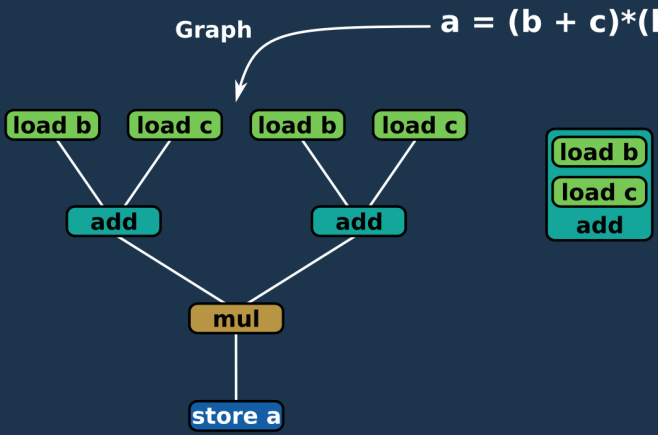
Common subexpression elimination



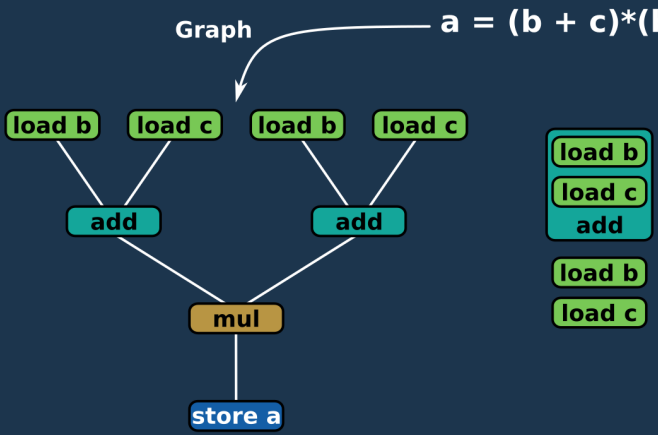
Common subexpression elimination



Common subexpression elimination



Common subexpression elimination



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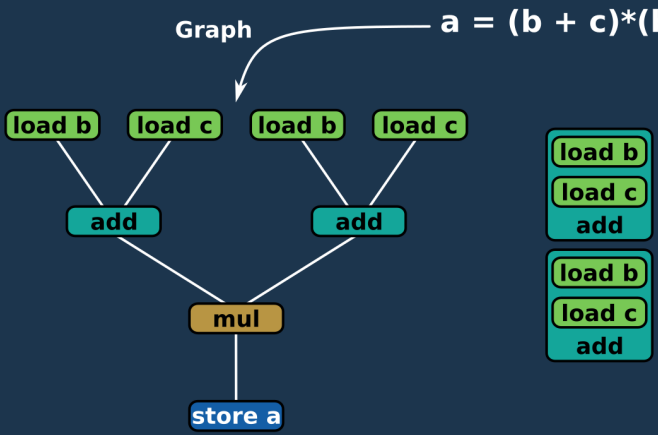

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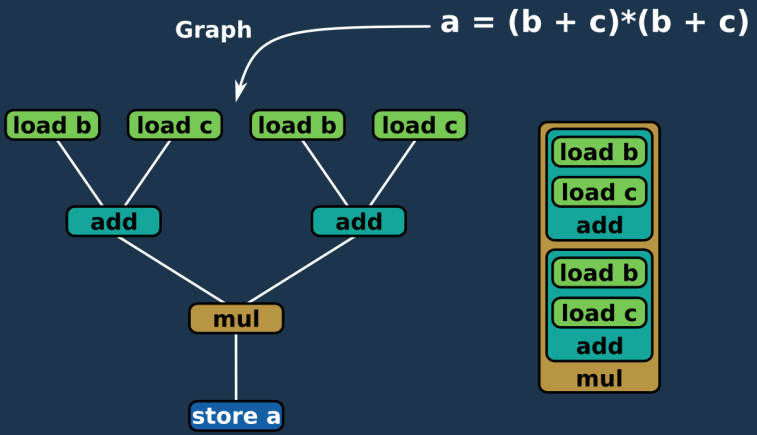

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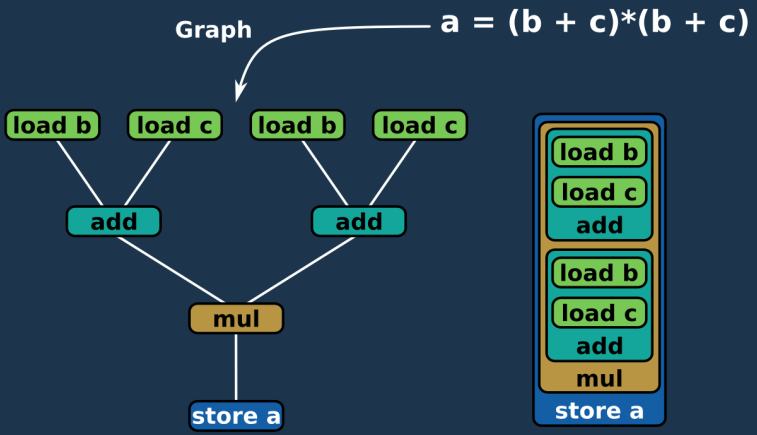

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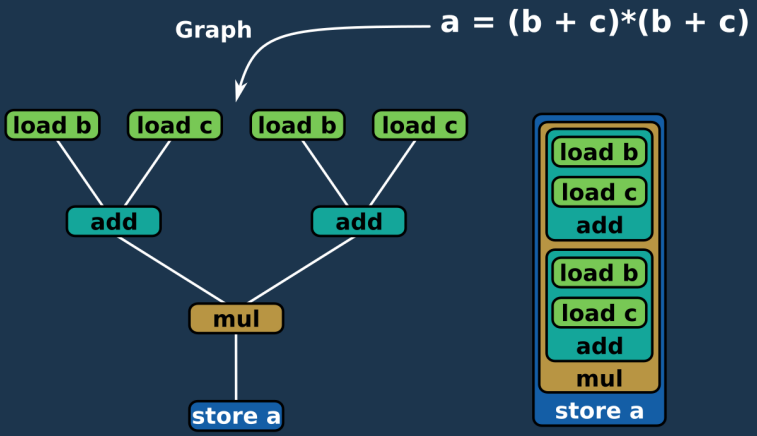
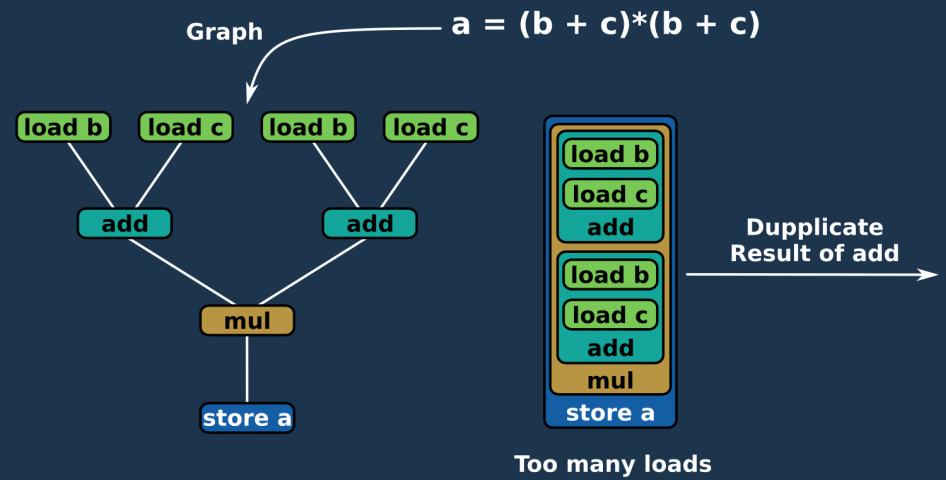


Too many loads

Common subexpression elimination



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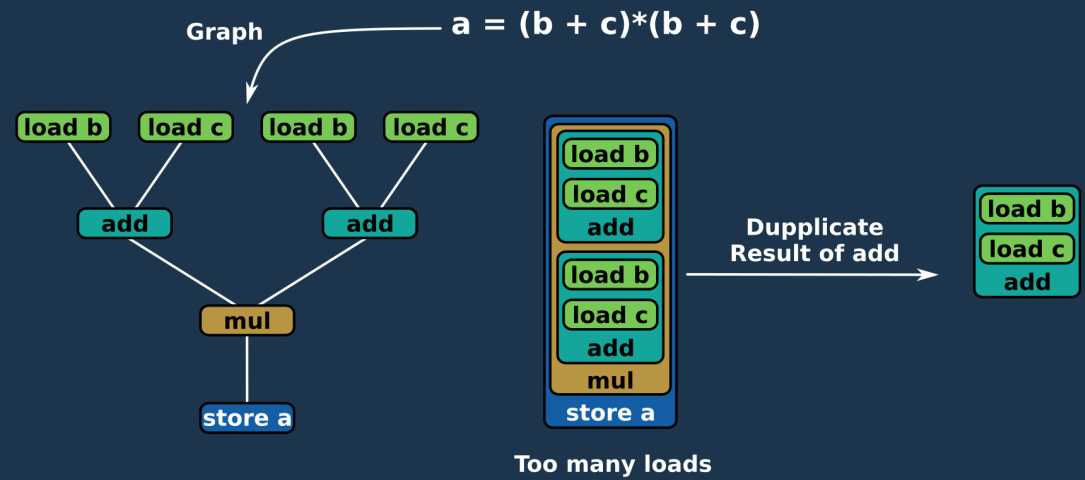

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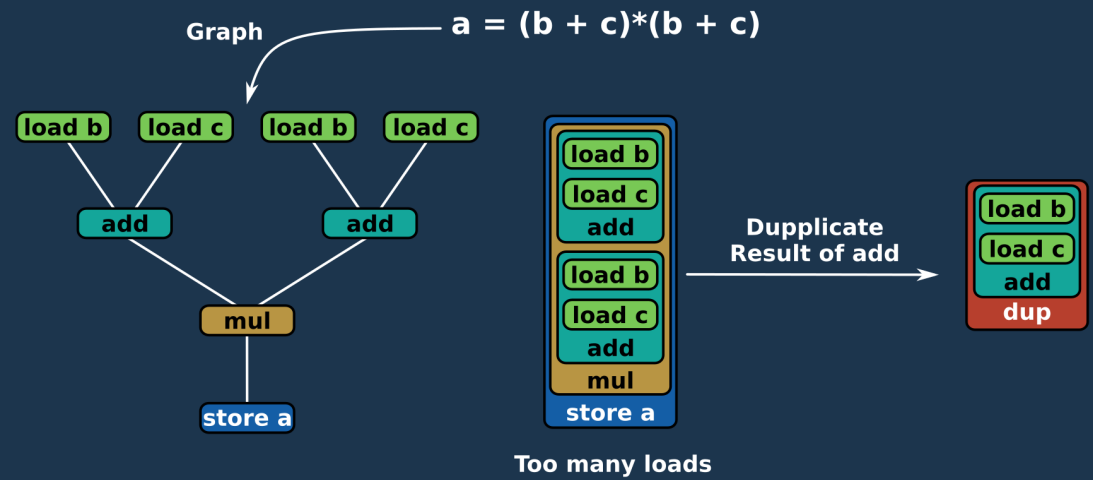

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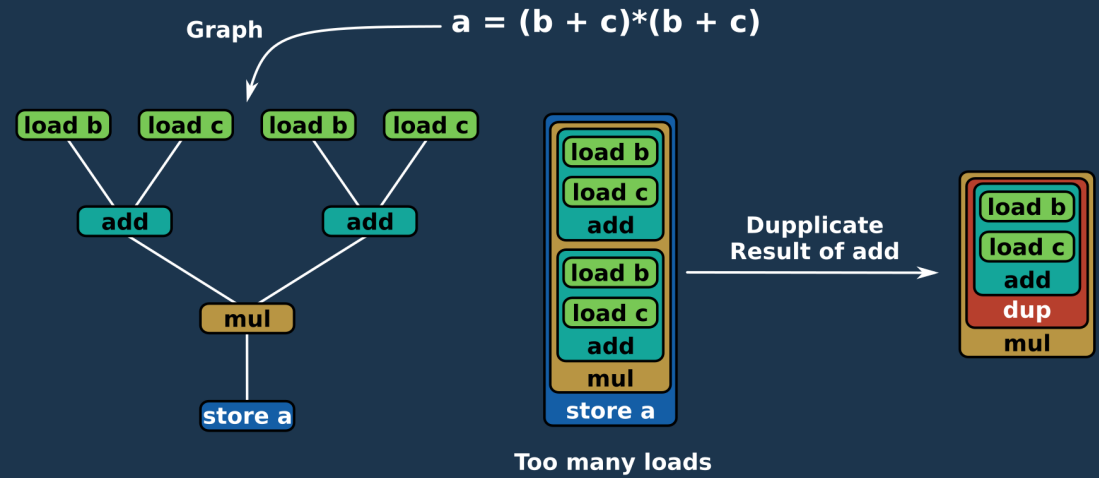
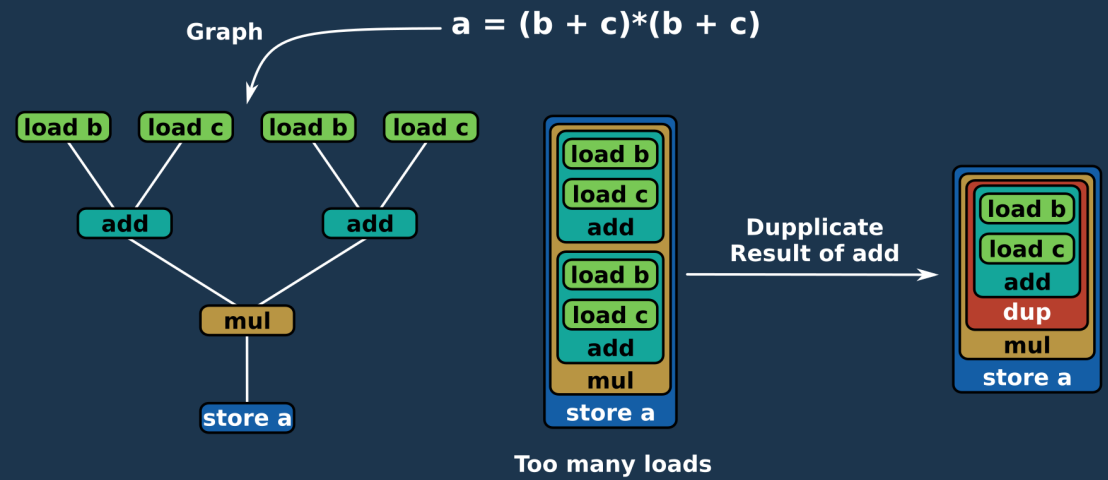


Common subexpression elimination



Implementation

Implementation

```
void hadamard_product(float * vecRes, const float * vecX, const float * vecY, size_t nbElement){
»       for(size_t i(0lu); i < nbElement; ++i){
»       »       vecRes[i] = vecX[i]*vecY[i];
»       }
}
```

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Performance Evaluation

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Performance Evaluation

Stop Chrono

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Performance Evaluation

Stop Chrono

Time Computation

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Performance Evaluation

Stop Chrono

Time Computation

Print Results

Implementation

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Allocation

Initialisation

Start Chrono

Performance Evaluation

Stop Chrono

Time Computation

Print Results

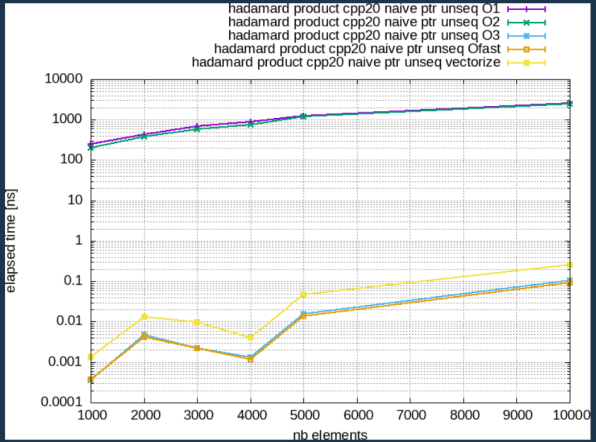
Deallocation

Implementation

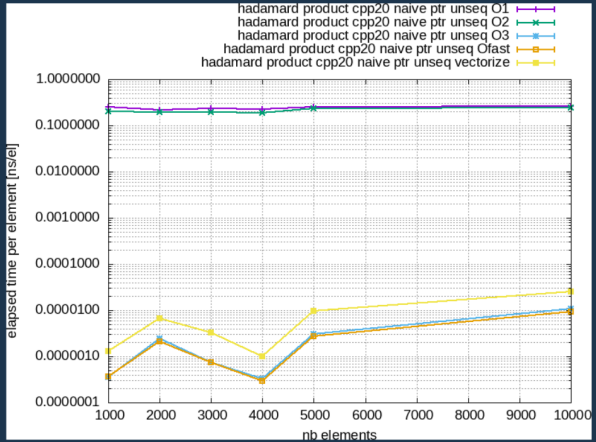
```
int main(int argc, char** argv){
»       evaluateHadamardProduct(1000lu, 1000000lu);
»       evaluateHadamardProduct(2000lu, 500000lu);
»       evaluateHadamardProduct(3000lu, 300000lu);
»       evaluateHadamardProduct(4000lu, 2500000lu);
»       evaluateHadamardProduct(5000lu, 200000lu);
»       evaluateHadamardProduct(10000lu, 100000lu);
»       return 0;
}
```

Performance G++11

Total time

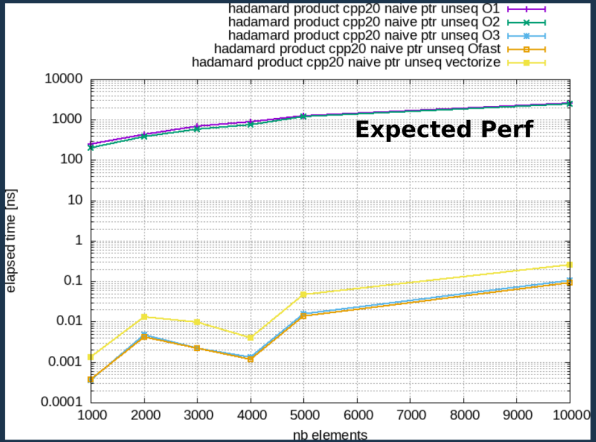


Time per element

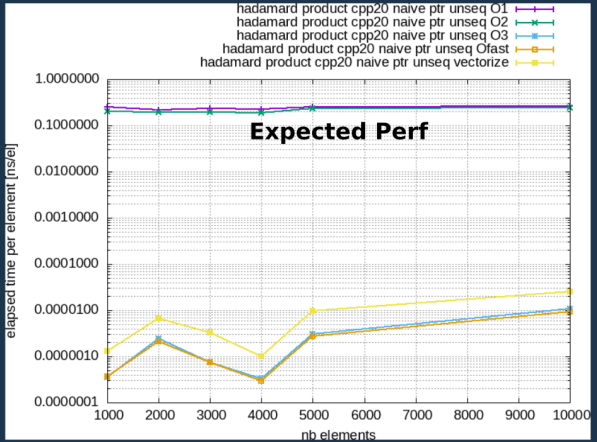


Performance G++11

Total time

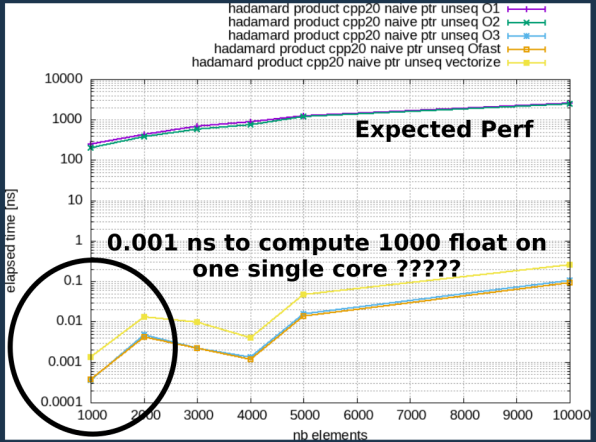


Time per element

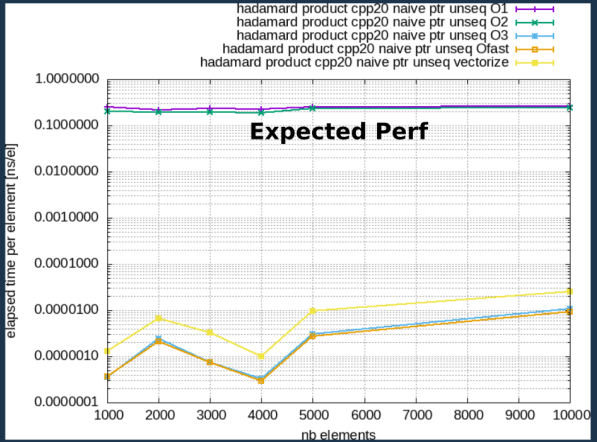


Performance G++11

Total time

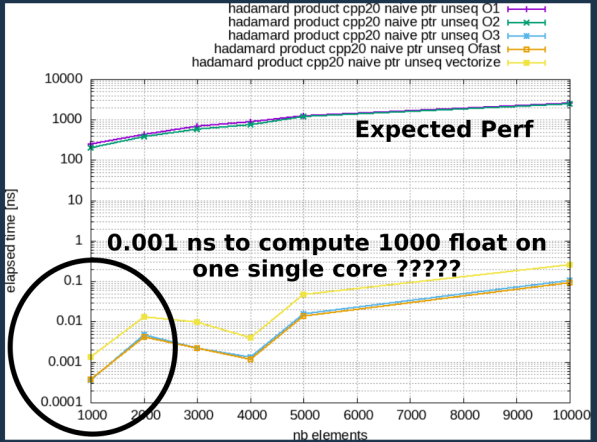


Time per element

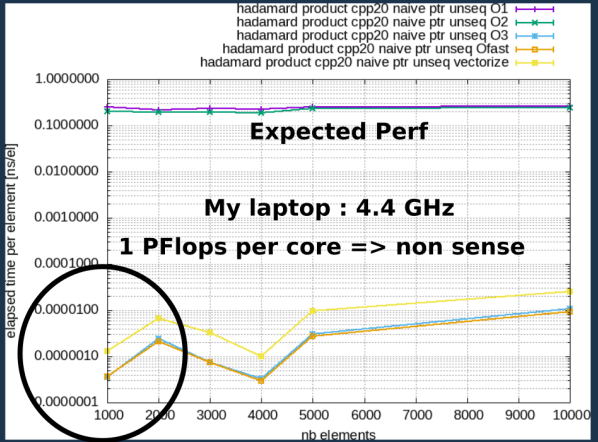


Performance G++11

Total time

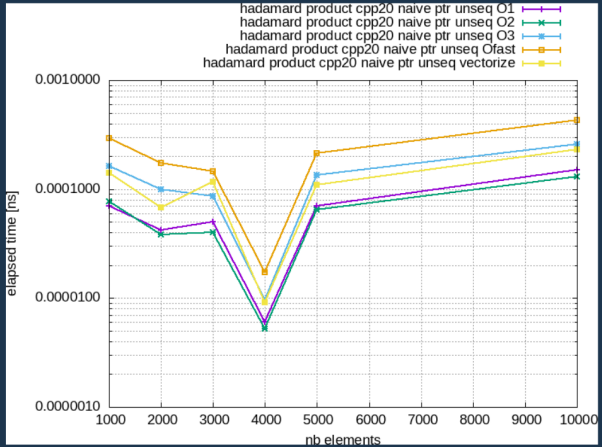


Time per element

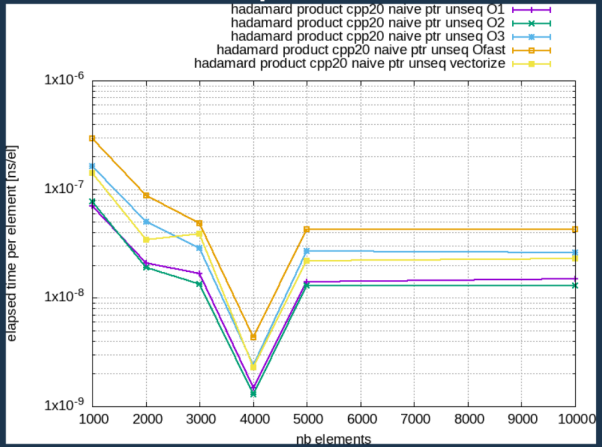


Performance Clang++14

Total time

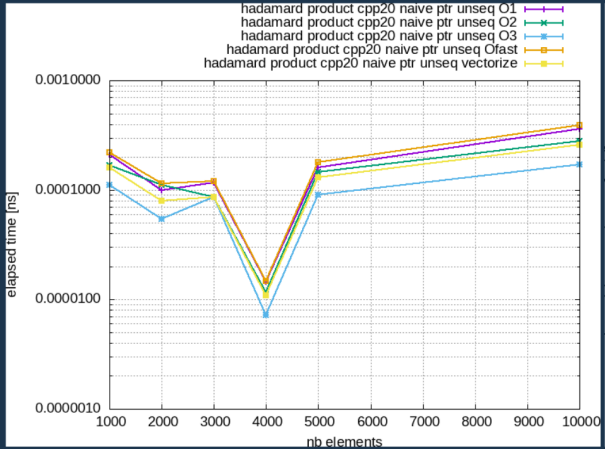


Time per element

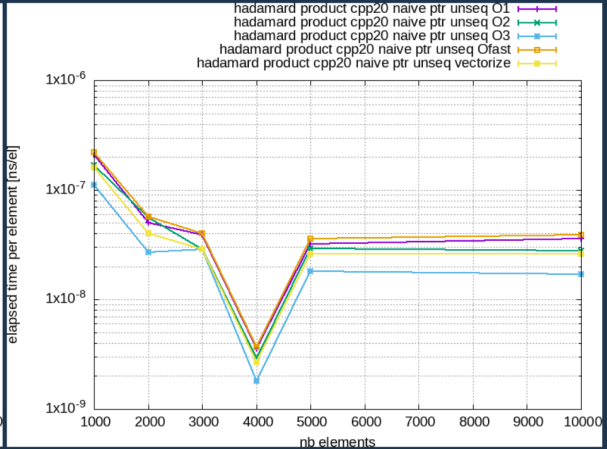


Performance ICPX 2020 00 02

Total time



Time per element



Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float* vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float* vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Result of computation is not used

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Useless loop

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
    //{On déclare nos tableaux et on les initialise :
    float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
    float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
    float *vecRes = (float *)std::malloc(sizeof(float)*nbElement);

    for(size_t i=0lu; i < nbElement; ++i){
        vecX[i] = i*32lu%17lu;
        vecY[i] = i*57lu%31lu;
    }
    size_t fullNbElement(nbElement*nbRepetition);
    //Stating the timer
    HiPeTime beginTime = phoenix_getTime();
    //Let's call the kernel several times
    for(size_t i=0lu; i < nbRepetition; ++i){
        hadamard_product(vecRes, vecX, vecY, nbElement);
    }
    //Stop the timer
    NanoSecs elapsedTime(phoenix_getTime() - beginTime);
    double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
    double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

    std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
    "<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
    std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
    ellapsedTimeErrorNs << std::endl;

    std::free(vecX);
    std::free(vecY);
    std::free(vecRes);
}
```

Variables set but not used

Implementation + Compiler

```cpp
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float *vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float *vecRes = (float*)std::malloc(sizeof(float)*nbElement);
	
	for(size_t i(0lu); i < nbElement; ++i){
		vecX[i] = i*32lu%17lu;
		vecY[i] = i*57lu%31lu;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i(0lu); i < nbRepetition; ++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);
	
	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ± "<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" << ellapsedTimeErrorNs << std::endl;
	
	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
        //{On déclare nos tableaux et on les initialise :
        [illegible]
        [illegible]
        [illegible]

        for(size_t i(0lu); i < nbElement; ++i){
                [illegible]
                [illegible]
        }
        size_t fullNbElement(nbElement*nbRepetition);
        //Stating the timer
        HiPeTime beginTime = phoenix_getTime();
        //Let's call the kernel several times
        [illegible]
                [illegible]
        }
        //Stop the timer
        NanoSecs elapsedTime(phoenix_getTime() - beginTime);
        double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
        double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

        std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
        "<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
        std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
        ellapsedTimeErrorNs << std::endl;

        [illegible]
        [illegible]
        [illegible]
}
```

Useless loop

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
	//{On déclare nos tableaux et on les initialise :
	float* vecX = (float*)std::malloc(sizeof(float)*nbElement);
	float* vecY = (float*)std::malloc(sizeof(float)*nbElement);
	float* vecRes = (float*)std::malloc(sizeof(float)*nbElement);

	for(size_t i=0;i<nbElement;++i){
		vecX[i] = 2.0f*i+1.0f;
		vecY[i] = 2.0f*i+2.0f;
	}
	size_t fullNbElement(nbElement*nbRepetition);
	//Stating the timer
	HiPeTime beginTime = phoenix_getTime();
	//Let's call the kernel several times
	for(size_t i=0;i<nbRepetition;++i){
		hadamard_product(vecRes, vecX, vecY, nbElement);
	}
	//Stop the timer
	NanoSecs elapsedTime(phoenix_getTime() - beginTime);
	double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
	double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);

	std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
	"<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
	std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
	ellapsedTimeErrorNs << std::endl;

	std::free(vecX);
	std::free(vecY);
	std::free(vecRes);
}
```

Implementation + Compiler

```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
      //{On déclare nos tableaux et on les initialise :
      float* vecX = (float*) std::malloc(sizeof(float)*nbElement);
      float* vecY = (float*) std::malloc(sizeof(float)*nbElement);
      float* vecRes = (float*) std::malloc(sizeof(float)*nbElement);

      for(size_t i=0;i<nbElement;++i){
            vecX[i] = 2.0f*i+1.0f;
            vecY[i] = 2.0f*i-1.0f;
      }
      size_t fullNbElement(nbElement*nbRepetition);
      //Stating the timer
      HiPeTime beginTime = phoenix_getTime();
      //Let's call the kernel several times
      for(size_t i=0;i<nbRepetition;++i){
            hadamard_product(vecRes, vecX, vecY, nbElement);
      }
      //Stop the timer
      NanoSecs elapsedTime(phoenix_getTime() - beginTime);
      double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
      double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);
      std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
      "<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
      std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
      ellapsedTimeErrorNs << std::endl;

      std::free(vecX);
      std::free(vecY);
      std::free(vecRes);
}
```

Stop next to Start

Implementation + Compiler

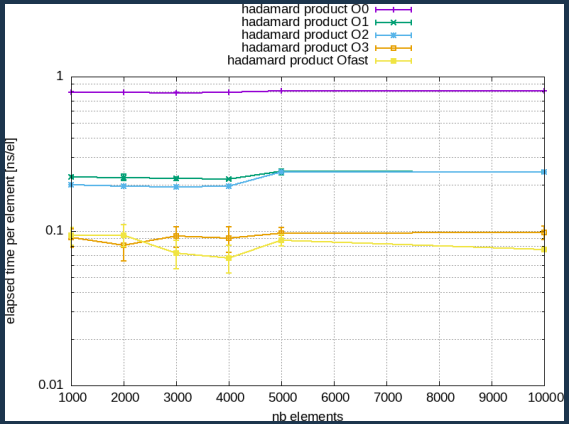
```
void evaluateHadamardProduct(size_t nbElement, size_t nbRepetition){
        //{On déclare nos tableaux et on les initialise :
        [illegible]
        [illegible]
        [illegible]

        [illegible]

        [illegible]
        [illegible]
        [illegible]

        size_t fullNbElement(nbElement*nbRepetition);
        //Stating the timer
        HiPeTime beginTime = phoenix_getTime();
        //Let's call the kernel several times
        [illegible]
                hadamard_product(vecRes, vecX, vecY, nbElement);
        }
        //Stop the timer
        NanoSecs elapsedTime(phoenix_getTime() - beginTime);
        double ellapsedTimeNs(elapsedTime.count()/((double)nbRepetition));
        double timePerElement = ellapsedTimeNs/((double)nbElement), timeErrorPerElement(0.0), ellapsedTimeErrorNs(0.0);
        std::cout << "Hadamard product naive ptr : nbElement = "<<fullNbElement<<", timePerElement = " << timePerElement << " ns/el ±
        "<<timeErrorPerElement<<", elapsedTime = " << ellapsedTimeNs << " ns ± "<<ellapsedTimeErrorNs << std::endl;
        std::cerr << nbElement << "\t" << timePerElement << "\t" << ellapsedTimeNs << "\t" << timeErrorPerElement << "\t" <<
        ellapsedTimeErrorNs << std::endl;

        [illegible]
        [illegible]
        [illegible]
}
```

Stop next to Start

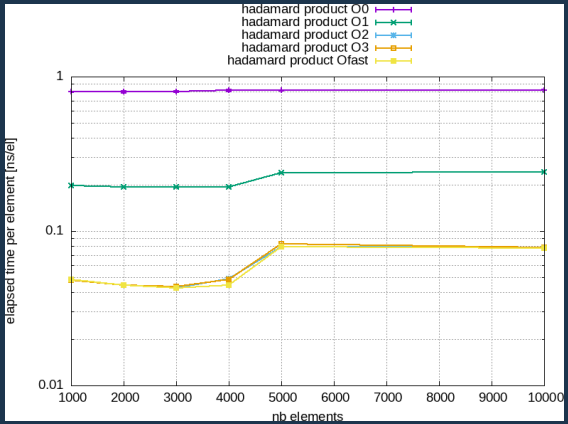
This happends because kernel is in the same file
Avoid problem if the result of the computation is used
No Problem with std::vector

The Hadamard product : Basic Options

G++ 11

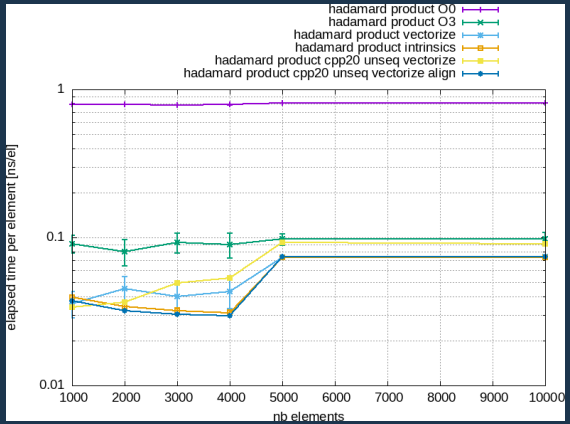


CLang++ 14

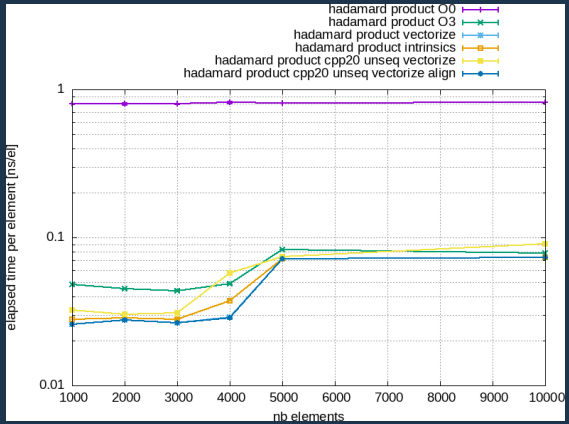


The Hadamard product : Vectorization

G++ 11



CLang++ 14



Performance Test Reminder

Performance Test Reminder

Are we measuring what we think we are measuring ?

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

With a more or less **precise chrono**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

With a more or less **precise chrono**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

With a more or less **precise chrono**

Of more or less **quality**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

Of an **algorithm**

With a more or less **precise chrono**

Of more or less **quality**

Performance Test Reminder

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A performance test evaluates :

With a given **method**

The **implementation**

Of an **algorithm**

With a more or less **precise chrono**

Of more or less **quality**

More or less **relevant**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

- With a given **method**
- The **implementation**
- Of an **algorithm**
- **Compiled**
- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**

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- The **implementation**
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- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**

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A performance test evaluates :

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- Of an **algorithm**
- **Compiled**
- On a **computer**

- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

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On a **computer**

With a more or less **precise chrono**

Of more or less **quality**

More or less **relevant**

With more or less **usefull flags**

More or less **efficient**

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- Of an **algorithm**
- **Compiled**
- On a **computer**

- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**
- More or less **efficient**
- With more or less **shared ressources**

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

- With a given **method**
- The **implementation**
- Of an **algorithm**
- **Compiled**
- On a **computer**
- With a **dataset**

- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**
- More or less **efficient**
- With more or less **shared ressources**

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- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**
- More or less **efficient**
- With more or less **shared ressources**
- More or less **representative** of the problem

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

Of an **algorithm**

Compiled

On a **computer**

With a **dataset**

During an **ellapsed time**

With a more or less **precise chrono**

Of more or less **quality**

More or less **relevant**

With more or less **usefull flags**

More or less **efficient**

With more or less **shared ressources**

More or less **representative** of the problem

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

With a given **method**

The **implementation**

Of an **algorithm**

Compiled

On a **computer**

With a **dataset**

During an **ellapsed time**

With a more or less **precise chrono**

Of more or less **quality**

More or less **relevant**

With more or less **usefull flags**

More or less **efficient**

With more or less **shared ressources**

More or less **representative** of the problem

Cleverly determined or not

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

- With a given **method**
- The **implementation**
- Of an **algorithm**
- **Compiled**
- On a **computer**
- With a **dataset**
- During an **ellapsed time**
- On an **Operating System**

- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**
- More or less **efficient**
- With more or less **shared ressources**
- More or less **representative** of the problem
- **Cleverly** determined or not

Performance Test Reminder

Are we measuring what we think we are measuring ?

A performance test evaluates :

- With a given **method**
- The **implementation**
- Of an **algorithm**
- **Compiled**
- On a **computer**
- With a **dataset**
- During an **ellapsed time**
- On an **Operating System**

- With a more or less **precise chrono**
- Of more or less **quality**
- More or less **relevant**
- With more or less **usefull flags**
- More or less **efficient**
- With more or less **shared ressources**
- More or less **representative** of the problem
- **Cleverly** determined or not
- More or less **horrible** to use

Certification and compilers testing

Certification and compilers testing

Certification and compilers testing

Certification and compilers testing

Certification and compilers testing

Very difficult to develop — **Compiler** — **Certification Needed** — **Airplane Control**

Certification and compilers testing

Very difficult to develop → Compiler → Certification Needed → Airplane Control

CSmith

https://github.com/csmith-project/csmith

Certification and compilers testing

Very difficult to develop → Compiler → Certification Needed → Airplane Control

C Generator designed to **break compilers**

CSmith

https://github.com/csmith-project/csmith

Certification and compilers testing

Very difficult to develop → Compiler → Certification Needed → Airplane Control

C Generator designed to **break compilers** → CSmith

100+ bugs found in G++4 / Clang (2009-2011)

https://github.com/csmith-project/csmith

Certification and compilers testing

Very difficult to develop → Compiler → Certification Needed → Airplane Control

C Generator designed to **break compilers**

100+ bugs found in G++4 / Clang (2009-2011)

CSmith → **CompCert**

https://github.com/csmith-project/csmith

https://compcert.org/

Certification and compilers testing

Very difficult to develop → Compiler → Certification Needed → Airplane Control

C Generator designed to **break compilers**

CSmith

100+ bugs found in G++4 / Clang (2009-2011)

Mathematically Proved C Compiler

CompCert

https://github.com/csmith-project/csmith

https://compcert.org/

Conclusion

Conclusion

- Use **both** compilers
- Test **compilation options**
- Check with **Maqao** and **Valgrind**
- Check with **Performance Tests** (**MicroBenchmark**)

MAQAO