An intro to Boost.PolyCollection

using std::cpp 2017

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Before the show begins: some news from the Boost front

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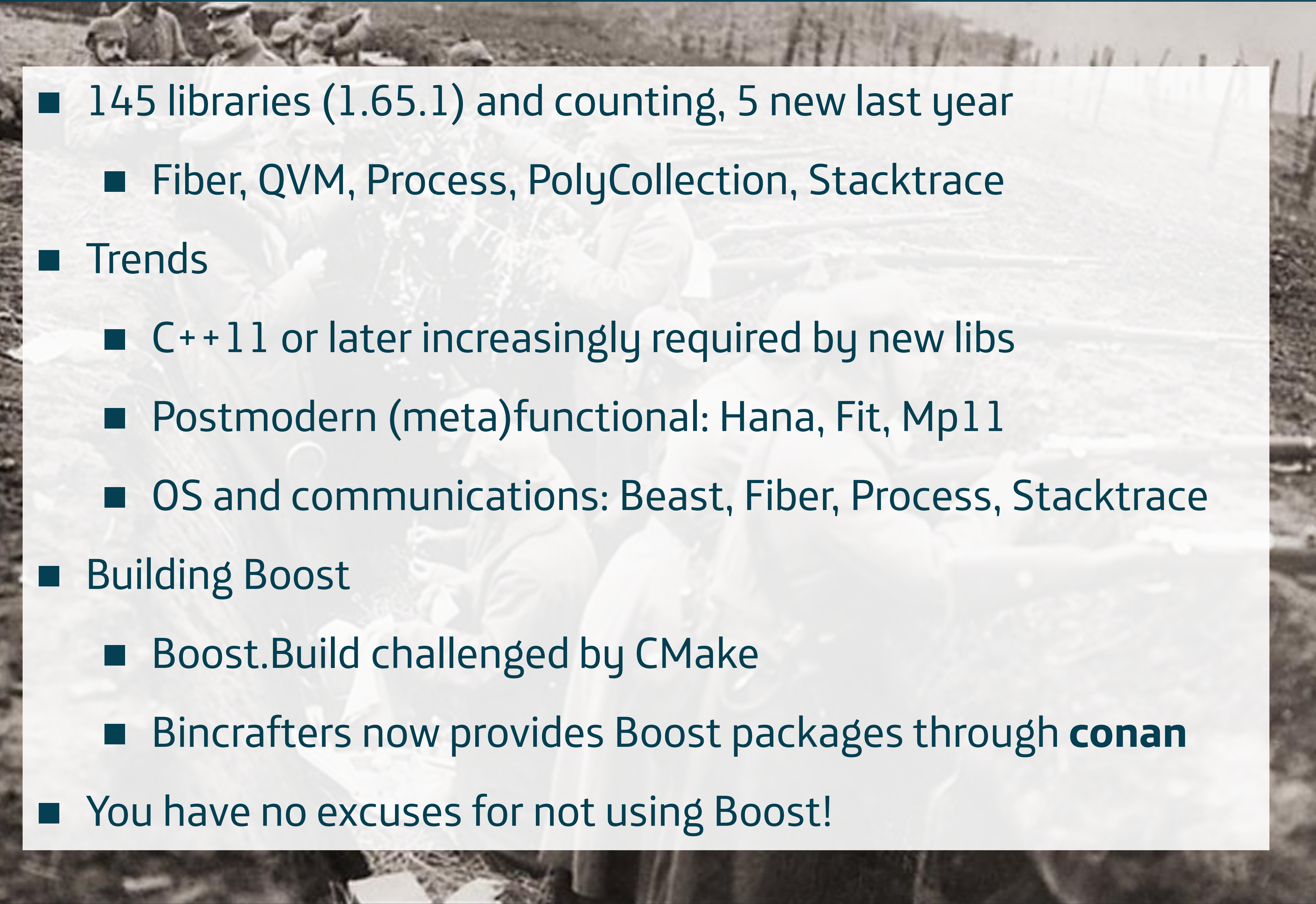


- 145 libraries (1.65.1) and counting, 5 new last year
  - Fiber, QVM, Process, PolyCollection, Stacktrace
- Trends
  - C++11 or later increasingly required by new libs
  - Postmodern (meta)functional: Hana, Fit, Mp11
  - OS and communications: Beast, Fiber, Process, Stacktrace
- Building Boost
  - Boost.Build challenged by CMake
  - Bincrafters now provides Boost packages through **conan**
- You have no excuses for not using Boost!

Let ‘s dive into Boost.PolyCollection

Type hierarchy for a role playing game

```
struct sprite
{
  sprite(int id):id(id){}
  virtual ~sprite()=default;
  virtual void render(std::ostream& os)const=0;

  int id;
};
```

```
struct warrior:sprite
{
  using sprite::sprite;
  warrior(std::string rank,int id):
    sprite{id},rank{std::move(rank)}{}
  void render(std::ostream& os)const override
  {os<<rank<<" "<<id;}
  std::string rank="warrior";
};
```

```
struct juggernaut:warrior
{
  juggernaut(int id):
    warrior{"juggernaut",id}{}
};
```

```
struct goblin:sprite
{
  using sprite::sprite;
  void render(std::ostream& os)
  const override
  {os<<"goblin "<<id;}
};
```

Populate and render

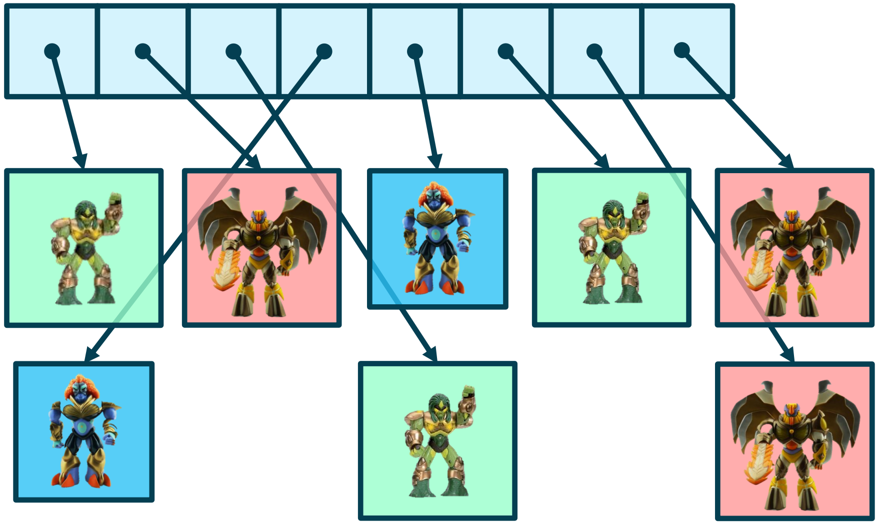
vector.cpp

```
std::vector<std::unique_ptr<sprite>> c;

std::mt19937                 gen{92748}; // some arbitrary random seed
std::discrete_distribution<> rnd{{1,1,1}};
for(int i=0;i<8;++i){        // assign each type with 1/3 probability
  switch(rnd(gen)){
    // watch out: std::make_unique requires C++14
    case 0: c.push_back(std::make_unique<warrior>(i));break;
    case 1: c.push_back(std::make_unique<juggernaut>(i));break;
    case 2: c.push_back(std::make_unique<goblin>(i));break;
  }
}

const char* comma="";
for(const auto& p:c){
  std::cout<<comma;
  p->render(std::cout);
  comma=",";
}
std::cout<<"\n";
```

Piece of cake

GORMITI is a trademark of Giochi Preziosi S.p.A.

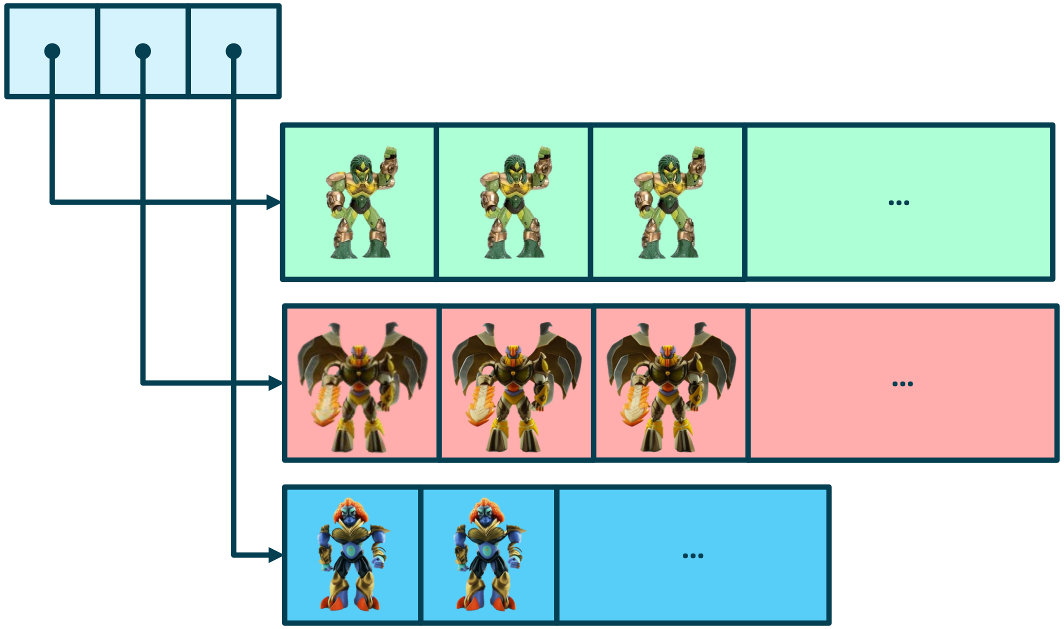
There are hidden inefficiencies, though



- Objects are scattered through memory → CPU cache misses
- Types are mixed up along traversal → CPU branch prediction fails
  - We could sort the vector on type*, object scattering is harder to fix though
- All boils down to OOP requiring pointer indirections

*See my “Mind the cache” talk at github.com/joaquintides/usingstdcpp2015

Packing things together



- `boost::base_collection` stores elements in per-type dedicated **segments**
- `[begin(), end())` traverses each segment in succession
  - So, free ordering of elements is lost (except within segment)
- In return, performance increases spectacularly

Rewrite with Boost.PolyCollection

base_collection.cpp

```
boost::base_collection<sprite> c;

std::mt19937                 gen{92748}; // some arbitrary random seed
std::discrete_distribution<> rnd{{1,1,1}};
for(int i=0;i<8;++i){        // assign each type with 1/3 probability
  switch(rnd(gen)){
    case 0: c.insert(warrior{i});break;
    case 1: c.insert(juggernaut{i});break;
    case 2: c.insert(goblin{i});break;
  }
}

const char* comma="";
for(const sprite& s:c){
  std::cout<<comma;
  s.render(std::cout);
  comma=",";
}
std::cout<<"\n";
```

- Spot the differences with the `std::vector` code

Interface at a glance

`base_collection_interface.cpp`

Segments can be targeted individually

Insertion interface mimics `std::multiset` rather than `std::vector`

Emplacement requires that type of element be specified

New segments are created automagically; otherwise, use `register_types`

Interface at a glance

base_collection_interface.cpp

Segments can be targeted individually

```
std::sort( // sort warriors in descending id order
  c.begin<warrior>(),c.end<warrior>(),
  [](const warrior& x,const warrior& y){return x.id>y.id;});

for(const warrior& w:c.segment<warrior>()) // print warrior ids
  std::cout<<w.id<<"\n";

c.erase(c.begin(typeid(warrior))); // erase first warrior

c.clear<warrior>(); // erase all warriors
```

- Watch out: `begin(typeid(warrior)` is not the same as `begin<warrior>()`
- Two kinds of local iterators (prefer the latter)

Insertion interface mimics `std::multiset` rather than `std::vector`

Emplacement requires that type of element be specified

New segments are created automagically; otherwise, use `register_types`

Interface at a glance

base_collection_interface.cpp

Segments can be targeted individually

Insertion interface mimics `std::multiset` rather than `std::vector`

```
c.insert(juggernaut{8}); // at the end of juggernaut segment

c.insert(c.begin(),juggernaut{9}); // hint only useful if
                                   // juggernauts are the first segment
c.insert(c.begin<juggernaut>(),juggernaut{10}); // 1st of juggernauts
```

Emplacement requires that type of element be specified

New segments are created automagically; otherwise, use register_types

Interface at a glance

base_collection_interface.cpp

Segments can be targeted individually

Insertion interface mimics `std::multiset` rather than `std::vector`

Emplacement requires that type of element be specified

```
c.emplace<goblin>(11);

c.emplace_pos<goblin>(c.begin<goblin>(),12); // 1st of goblins
```

New segments are created automagically; otherwise, use `register_types`

Interface at a glance

base_collection_interface.cpp

Segments can be targeted individually

Insertion interface mimics std::multiset rather than std::vector

Emplacement requires that type of element be specified

New segments are created automagically; otherwise, use register_types

```
// new assortment of sprites
std::array<std::unique_ptr<sprite>,3> a{{
  std::make_unique<elf>(13),
  std::make_unique<ghoul>(14),
  std::make_unique<amazon>(15)
}};

c.register_types<elf,ghoul,amazon>(); // otherwise exception is thrown below

for(const auto&p:a)c.insert(*p);
```

Interface at a glance

base_collection_interface.cpp

Segments can be targeted individually

Insertion interface mimics `std::multiset` rather than `std::vector`

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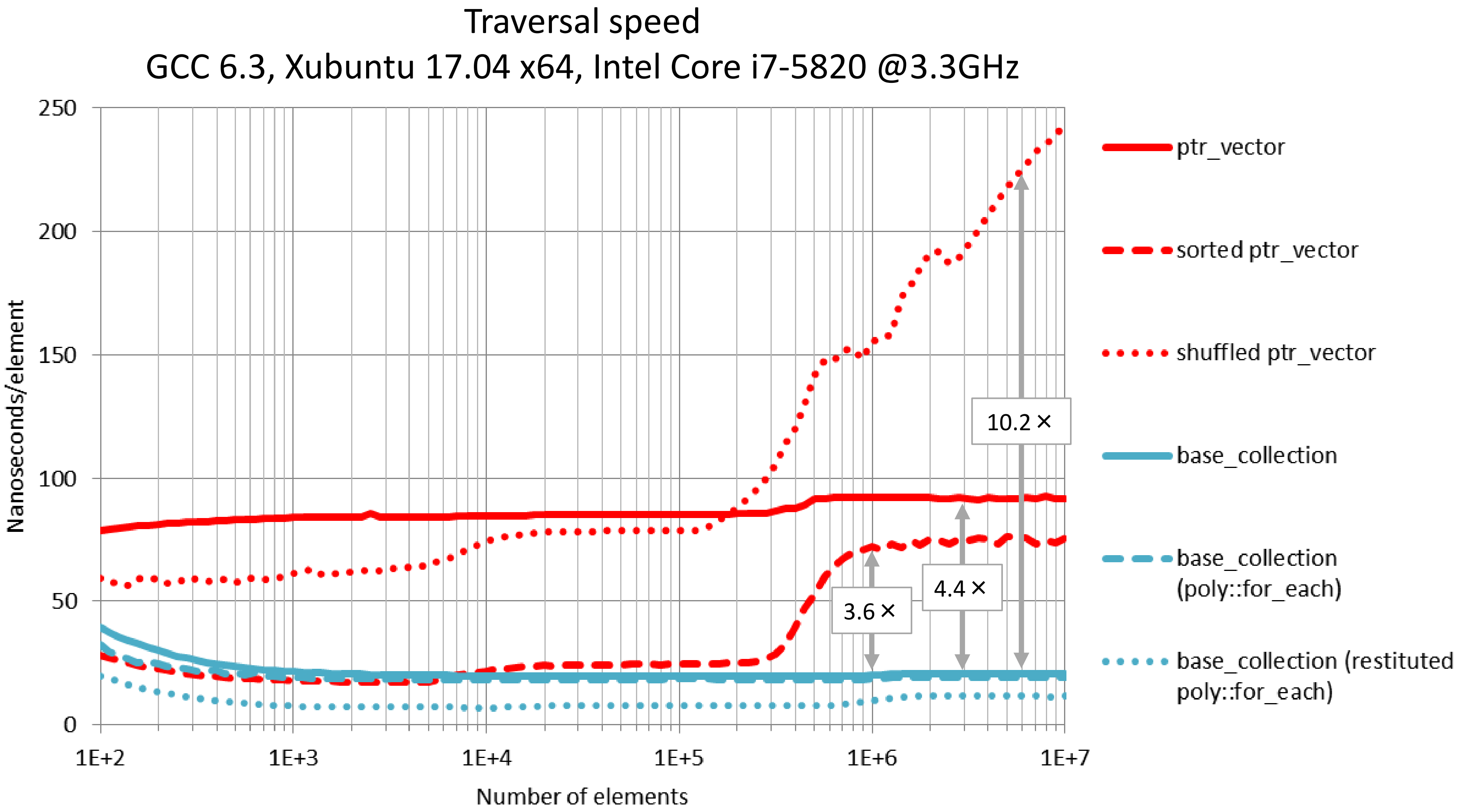
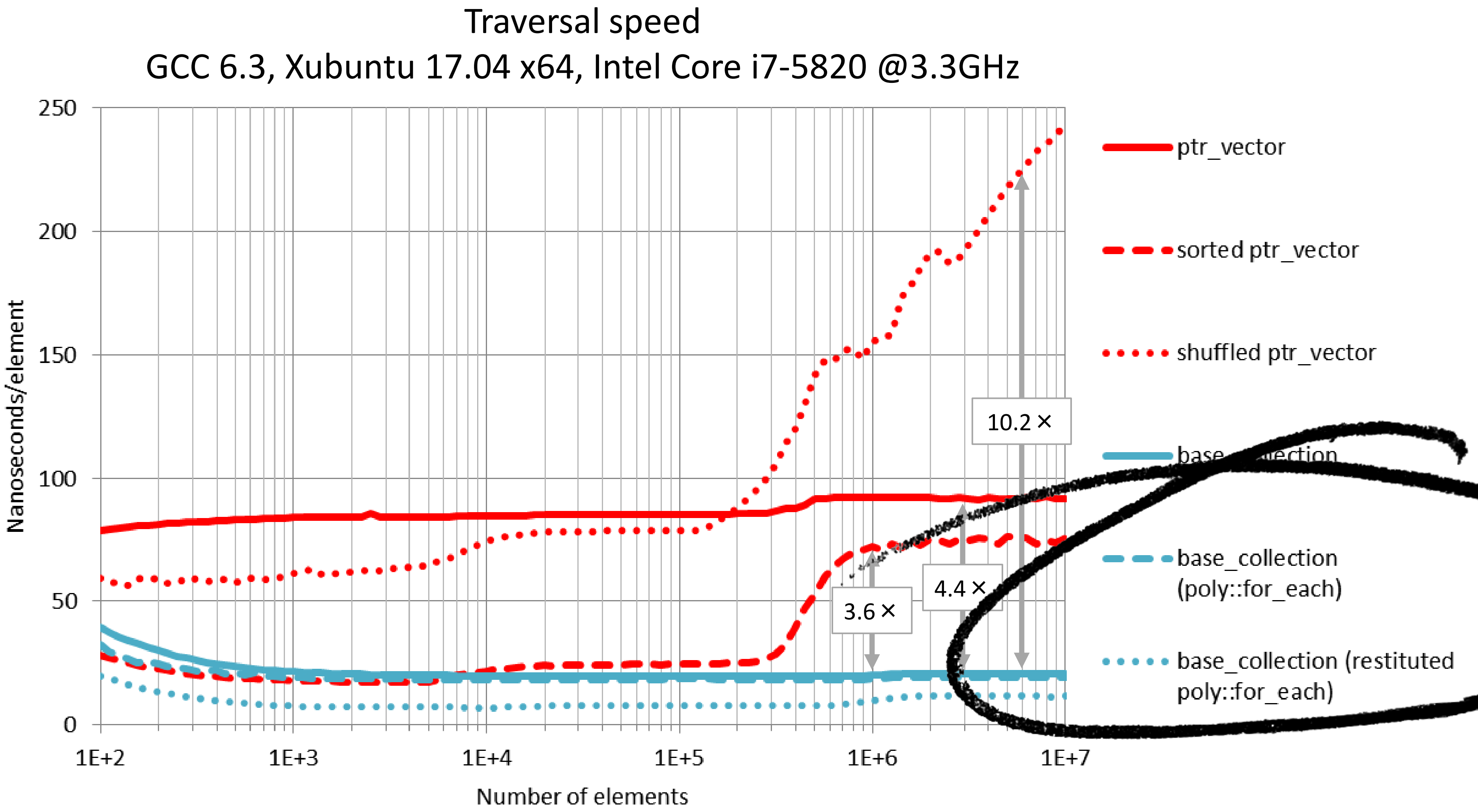
- All of this is well, but is it really faster?

Performance



- Full results at boost.org/doc/html/poly_collection/performance.html

Performance



Traversal speed
GCC 6.3, Xubuntu 17.04 x64, Intel Core i7-5820 @3.3GHz

- Full results at boost.org/doc/html/poly_collection/performance.html

Dedicated algorithms

algorithm.cpp

- Which is fastest?

```
for(const sprite& s:c){
  std::cout<<comma;
  s.render(std::cout);
  comma=",";
}
```

```
for(const auto& seg_info:c.segment_traversal()){
  for(const sprite& s:seg_info){
    std::cout<<comma;
    s.render(std::cout);
    comma=",";
  }
}
```

- Double loop the basis of Boost.PolyCollection dedicated algorithms

```
boost::poly_collection::for_each(c.begin(),c.end(),[&](const sprite& s){
  std::cout<<comma;
  s.render(std::cout);
  comma=",";
});
```

- 31 algorithms adapted from `<algorithm>`

Type restitution

algorithm.cpp

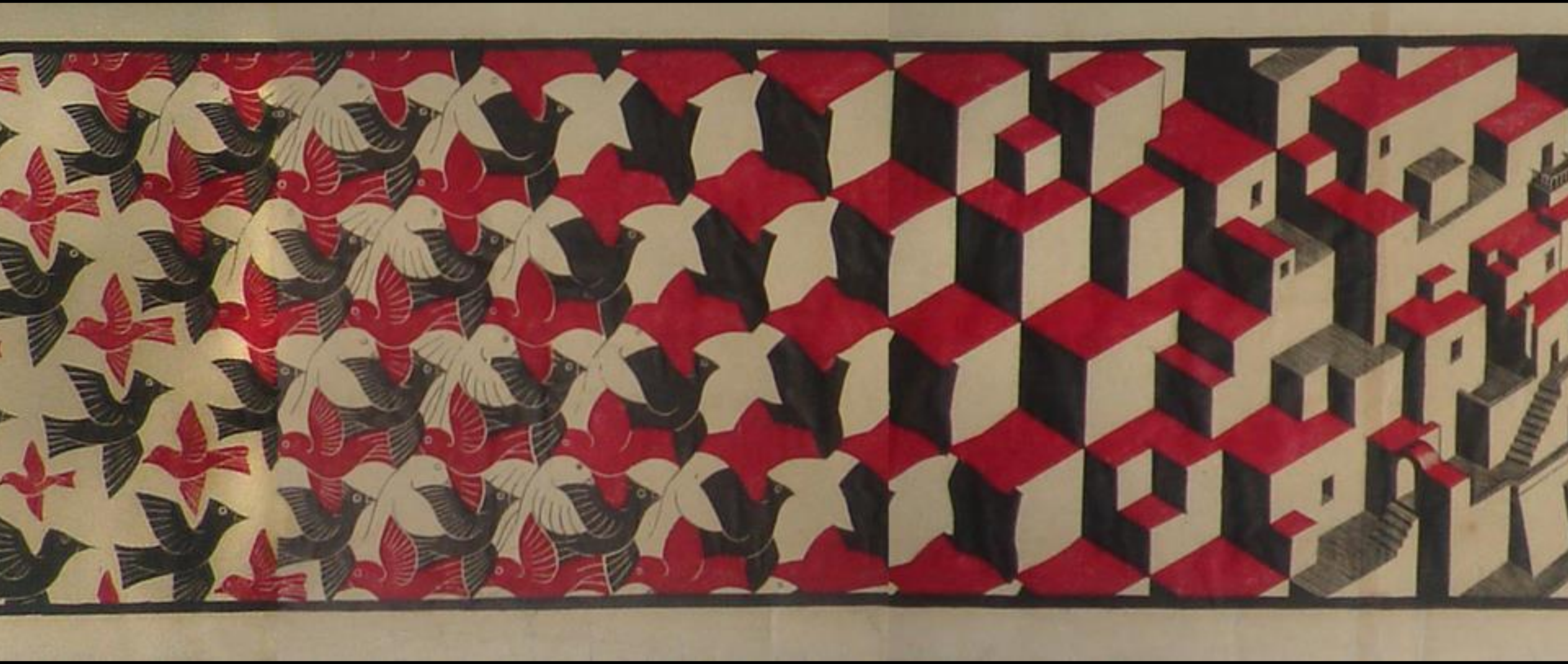
```
boost::poly_collection::for_each<warrior,juggernaut,goblin>(
  c.begin(),c.end(),[&](const auto& s){
    std::cout<<comma;
    s.render(std::cout);
    comma=",";
  }
);
```

- Note the generic lambda
- **Type restitution** is the inverse of type abstraction

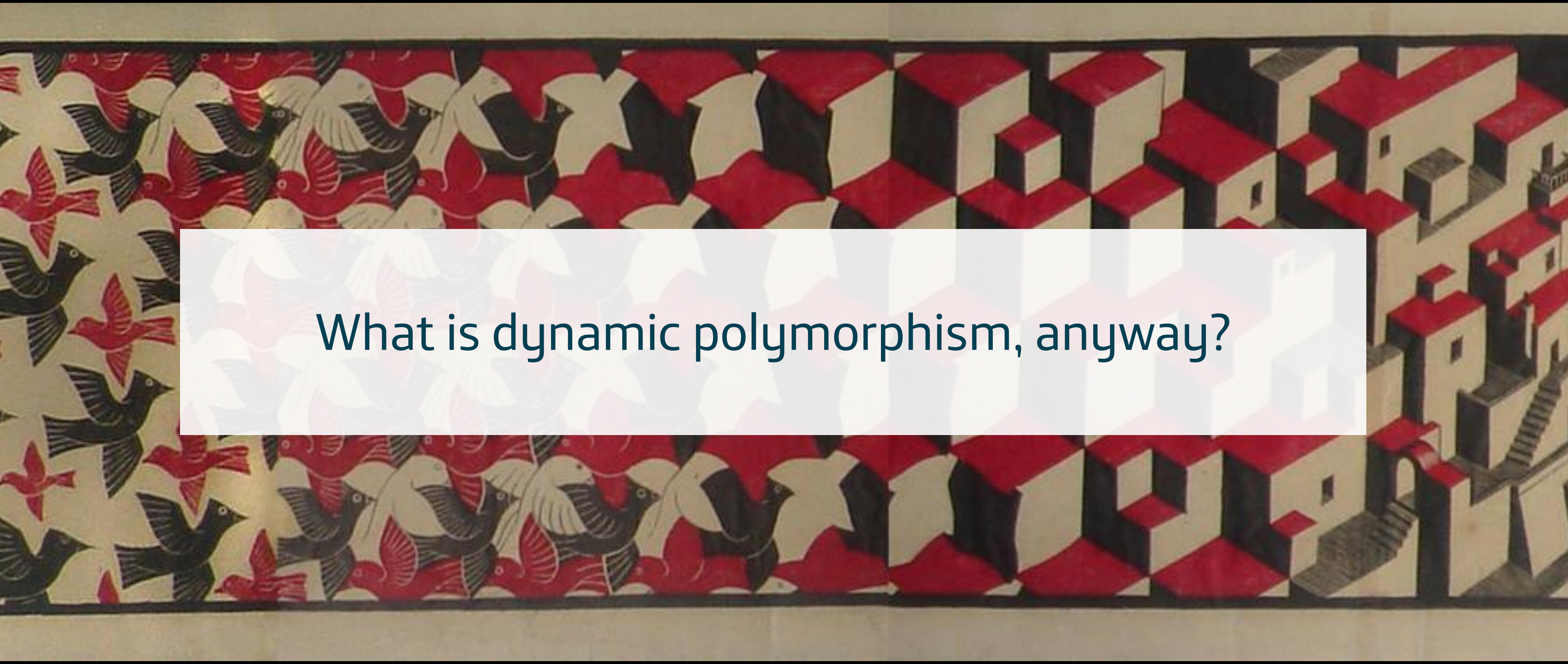
```
warrior* pw=new warrior{16};
sprite*  ps=pw; // abstraction
warrior* pw2=static_cast<warrior*>(ps); // restitution
```

- Opportunities for **devirtualization** and inlining → more performance

A new look on dynamic polymorphism

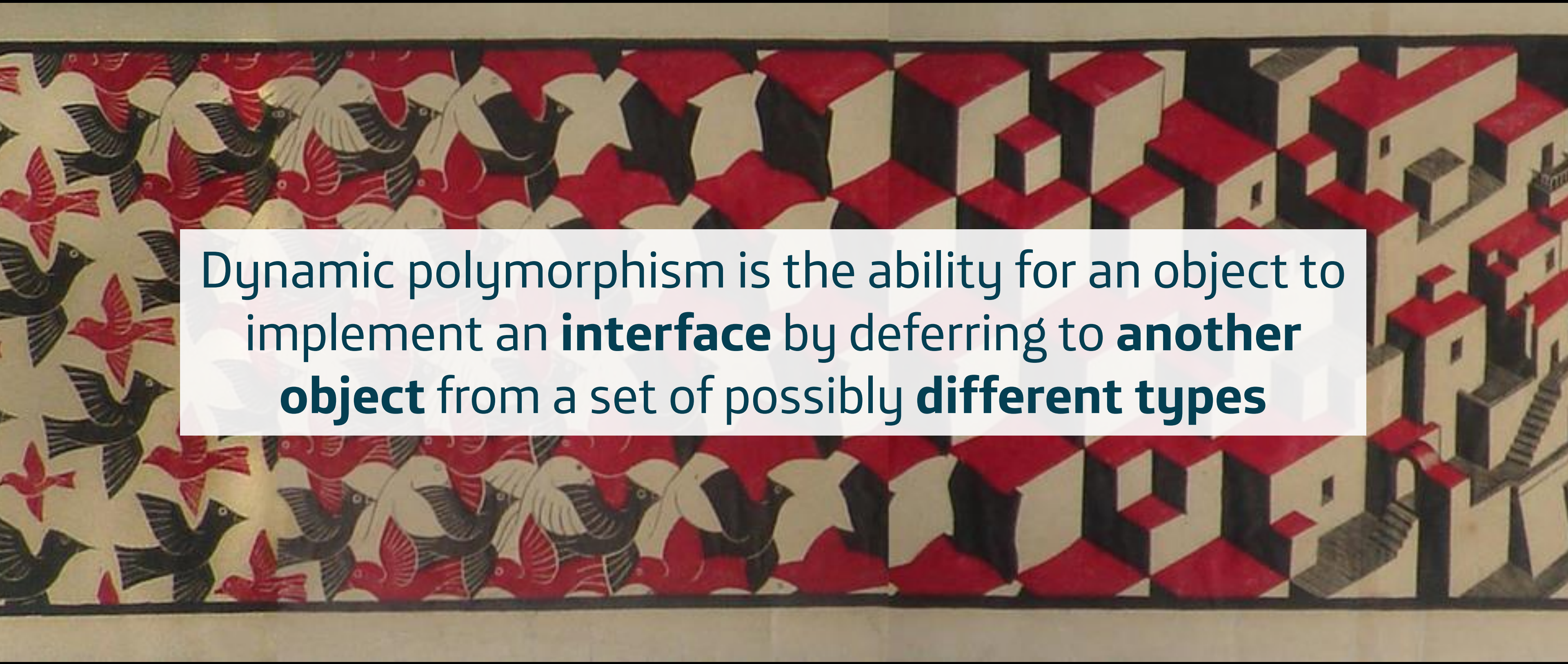


A new look on dynamic polymorphism



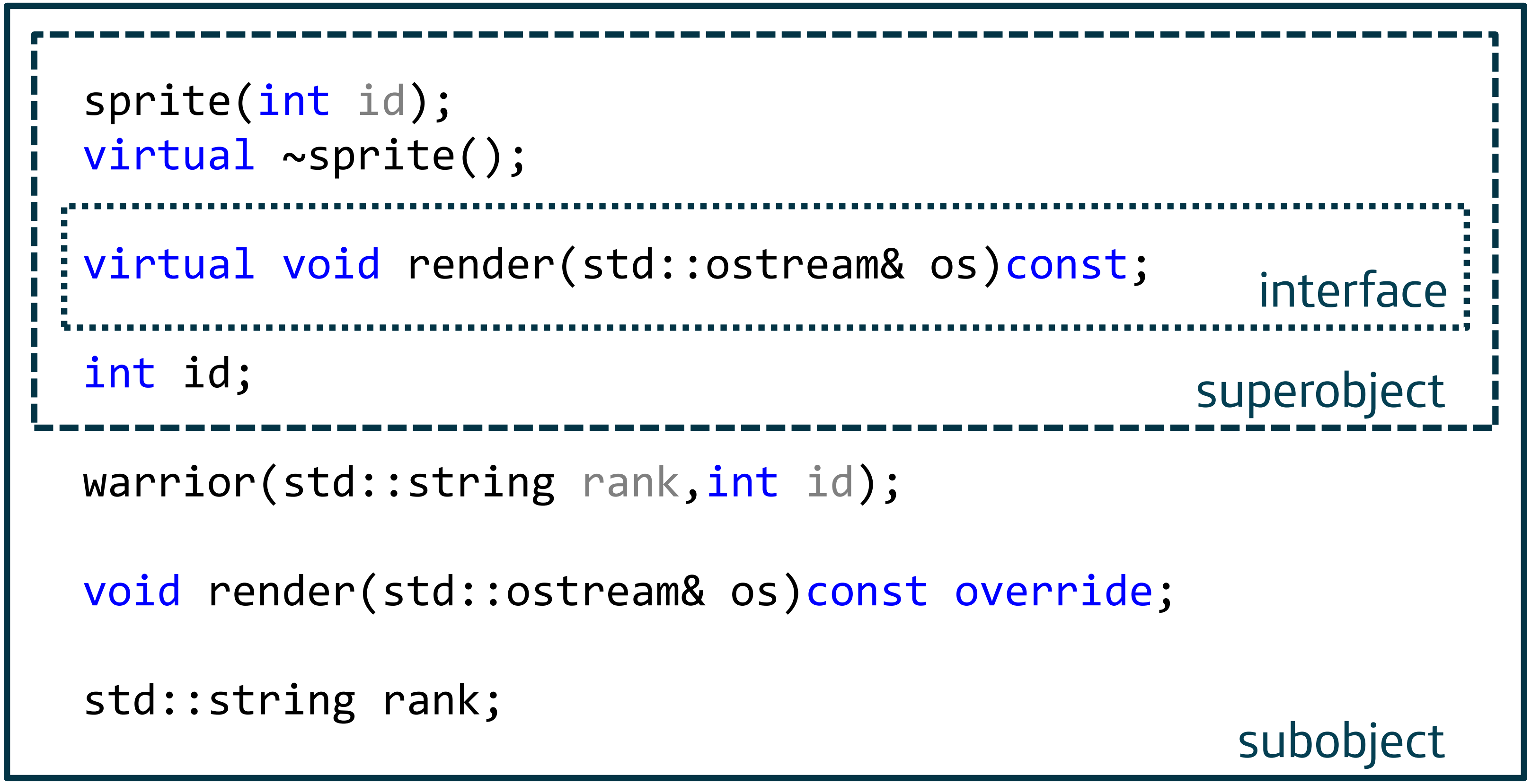
What is dynamic polymorphism, anyway?

A new look on dynamic polymorphism



Dynamic polymorphism is the ability for an object to implement an **interface** by deferring to **another object** from a set of possibly **different types**

OOP is *just one model* of dynamic polymorphism…



```
sprite(int id);
virtual ~sprite();

virtual void render(std::ostream& os)const;

int id;

warrior(std::string rank,int id);

void render(std::ostream& os)const override;

std::string rank;
```

…and not a particularly flexible one at that

- Implementation and subtyping are coupled together by inheritance
- Implementation is intentional (again, through inheritance)
- Intersecting interfaces require forethought and virtual inheritance
  - `dynamic_cast` comes into play
  - Ever heard of the diamond problem?*
  - Believe me, you just don't want to enter this hell

*Nothing to do with choosing a wedding ring

Type erasure is the new cool...

- ...and `std::function` its most accessible example

```
int foo(int x){return x;}
struct bar{int operator()(int x)const{return 2*x;}};

using signature=int(int);
std::function<signature> f=&foo,g=bar{},h=[](int x){return 3*x;};

std::cout<<f(1)+g(2)+h(3)<<"\n";
```

- This is a new model of dynamic polymorphism
  - Interface: `signature`
  - Superobject: `std::function<signature>`
  - Subobjects: `int(*)(int)`, bar, compatible lambdas
- Interface compliance is checked at **compile time**

function_collection

function_collection.cpp

```
boost::function_collection<int(int)> c;

std::mt19937                 gen{92748}; // some arbitrary random seed
std::discrete_distribution<> rnd{{1,1,1}};
for(int i=0;i<8;++i){        // assign each type with 1/3 probability
  switch(rnd(gen)){
    case 0: c.insert(&foo);break;
    case 1: c.insert(bar{});break;
    case 2: c.insert([](int x){return 3*x;});break;
  }
}

int res=0;
for(const auto& f:c)res+=f(1);
std::cout<<res<<"\n";
```

- Same interface as `boost::base_collection`
- How's this different from `std::vector<std::function<int(int)>>`?

Duck typing: type erasure on steroids

```
std::ostream& operator<<(std::ostream& os,const sprite& s)
{s.render(os);return os;}

using concept_=boost::mpl::vector<
  boost::type_erasure::ostreamable<>,
  boost::type_erasure::copy_constructible<>
>;
boost::type_erasure::any<concept_> a=5,b=std::string{"hello"},c=warrior{16};

std::cout<<a<<", "<<b<<", "<<c<<"\n";
```

- Interface: `concept_`
- Superobject: `boost::type_erasure::any<concept_>`
- Subobjects: anything satisfying `concept_`
- Boost.TypeErasure not the only duck typing framework: see for instance Louis Dionne's **Dyno**
- Ultimate solution: native run-time C++ concepts (some day)

any_collection

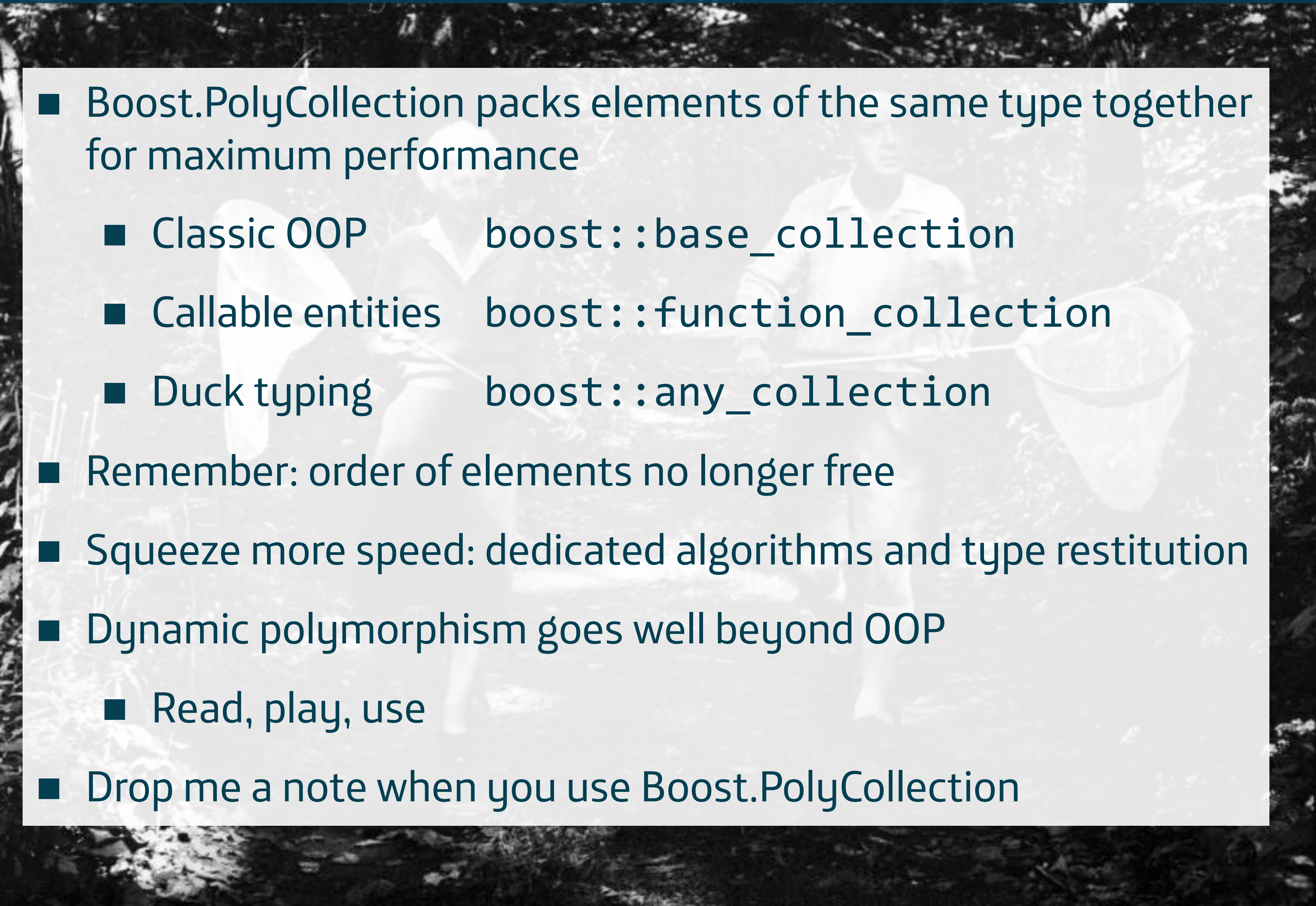
any_collection.cpp

```
boost::any_collection<boost::type_erasure::ostreamable<>> c;

std::mt19937                 gen{92748}; // some arbitrary random seed
std::discrete_distribution<> rnd{{1,1,1,1,1}};
for(int i=0;i<12;++i){       // assign each type with 1/5 probability
  switch(rnd(gen)){
    case 0: c.insert(warrior{i});break;
    case 1: c.insert(juggernaut{i});break;
    case 2: c.insert(goblin{i});break;
    case 3: c.insert(boost::format{"message %1%"}%i);break;
    case 4: c.insert(i);break;
  }
}

const char* comma="";
for(const auto& x:c){
  std::cout<<comma<<x;
  comma=",";
}
std::cout<<"\n";
```

- Same interface as before… you get the idea

So many butterflies, so little time

So many butterflies, so little time



- Boost.PolyCollection packs elements of the same type together for maximum performance

Classic OOP	`boost::base_collection`
Callable entities	`boost::function_collection`
Duck typing	`boost::any_collection`

- Remember: order of elements no longer free
- Squeeze more speed: dedicated algorithms and type restitution
- Dynamic polymorphism goes well beyond OOP
  - Read, play, use
- Drop me a note when you use Boost.PolyCollection

An intro to Boost.PolyCollection

Thank you

boost.org/libs/poly_collection
github.com/joaquintides/usingstdcpp2017

using std::cpp 2017
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