Design Patterns in Chroma

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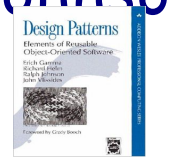
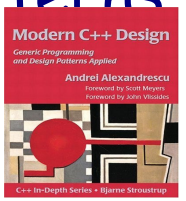
Design Patterns

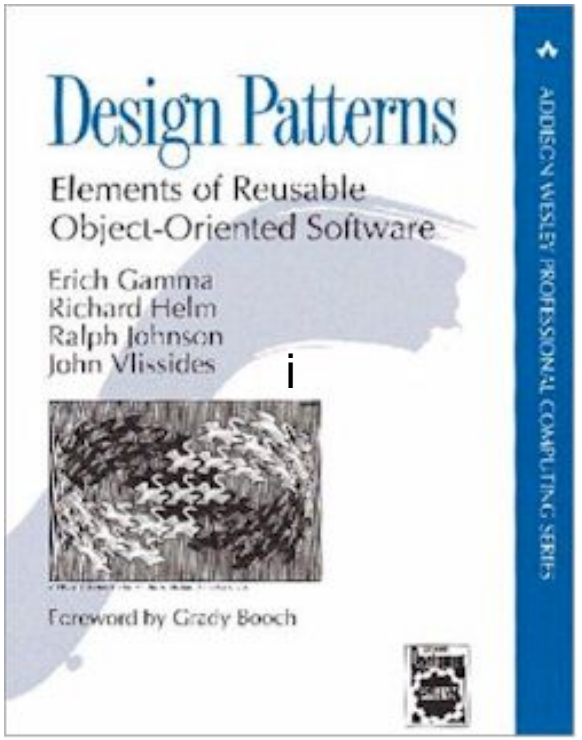
- Tried and tested object oriented techniques to solve commonly occurring problems
- Classic Software Design Book: "Design Patterns: Elements of Reusable Object Oriented Software", E. Gamma, R. Heim, R. Johnson & J. Vlissides (aka The Gang Of Four)

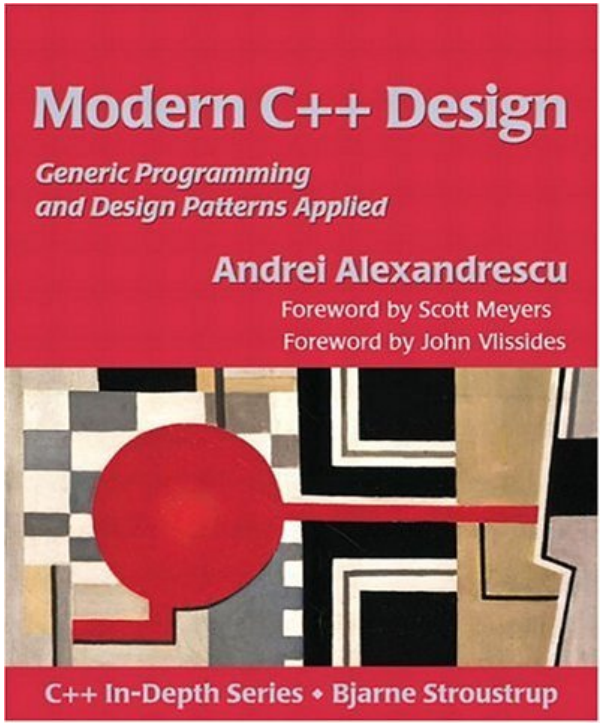


- Our implementations of design patterns come from the LOKI library described in "Modern C++ Design, Generic Programming and Design Patterns Applied", by Andrei Alexandrescu



Read (at least bits of) these books!!!!!!





You can find them in your local library!

(gratuitous plug for librarians everywhere)

Design Patterns I: Smart Pointer (Handle)

- Reference counting "smart pointer"
- Assignment / copy of handle increases ref. count
- Destruction of handle reduces reference count
- When ref. count reaches zero destructor is called.

```
#include <handle.h>
{
  Handle<Foo> f( new Foo() );
  Foo& f_ref = (*f);
  f_ref.method();
  f->method();

}
```

Construct with newly allocated pointer. Reference count is set to 1

Dereference like normal pointer

Handle goes out of scope, reference count is decreased, reaches 0, so delete is called and memory is freed

Design Patterns II: Singleton

- An entity of which there is only one in a program
- Kind of a "virtuous global object"
- Static class + static methods != singleton
- Destruction/Life-time/Co-dependency issues
- Used for eg:
  - Factories (see later)
  - Shared XML Log file
  - QDP++ Memory Allocator
  - Staggered Fermion Phases

Design Patterns II: Singletons

- Define as (eg: in my_singleton.h)

LOKI Singleton implementation template

Policy Templates (eg: staticity, lifetime)

```
typedef SingletonHolder< MyClass,... > TheMySingleton;
```

Class of which there will be only one instance

(Type)Name to refer to singleton. Our convention: singleton names start with "The" or "the"

- Use as

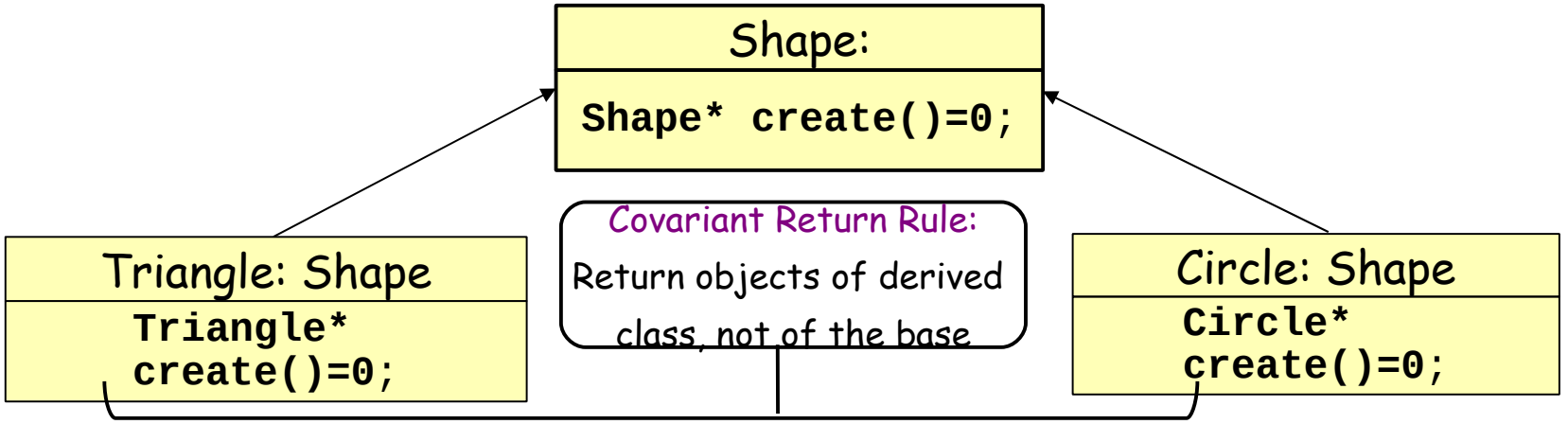
```
#include   my_singleton.h

TheMySingleton::Instance().memberFunction();
```

Member function of instance object

Returns Reference to singleton Instance

Design Patterns III: Factory Function

- A function to create objects of a given kind.
- Abstracts away details involved in creation
- Can create Derived Classes of a given Base Class
  - ie: allows selection of particular implementation for an abstract interface
- Useful as a Virtual Function in a class



Design Patterns III: Factory Function

- A new instance of an object is created
  - Memory is allocated
  - Drop result into a Handle

```
Handle< Shape > my_shape( Circle::create() );
```

- Sometimes a concept needs several objects
  - Fermions: link state with BCs, Fermion Matrix, a propagator solver for the kind of fermion.
- Group together (virtual) factory functions in a (base) class => Factory Class

(Warning: Not every virtual func. is a factory func.)

Design Patterns IV: Factory

- Suppose you want a choice of creating shapes at run time
- What is the best pattern?
- Naively:

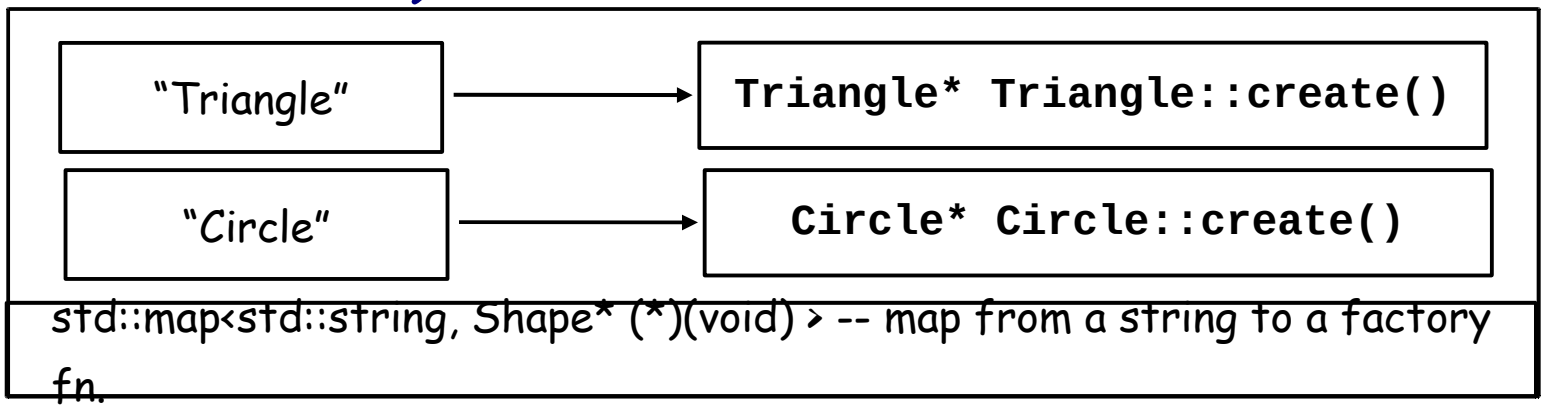
```
int t; read(xml,   /Shape/Type  , t);
Shape *my_shape;
switch(t) {
 case CIRCLE:
      my_shape = Circle::create();
      break;
 case TRIANGLE:
      my_shape = Triangle::create();
    break;
 default:
      QDPIO::cerr <<   Unknown shape   <<
endl;
    QDP_abort(1);
};
Handle<Shape> shape_handle(my_shape);
```

Design Patterns IV: Factory

- Criticism
  - For every new shape I create I need to edit
    - the source files for the shape
    - The switch statement in **EVERY SINGLE PLACE WHERE I CREATE A SHAPE**
  - Having to edit seemingly unrelated files gets error prone
  - As I have more shapes, my switch statement becomes unmanageably long
- Is there a better way? Yes! Use a map!

Design Patterns IV: Factory

- A Map is an associative array (indices don't have to be numbers)



- Can now create shapes by querying the map

Insert factory function and name pairs

```
std::map<std::string, Shape* (*)(void)> shape_factory_map;
shape_factory_map.insert( make_pair(  Triangle, Triangle::create() ) );
shape_factory_map.insert( make_pair(  Circle, Circle::create() ) );

std::string shape_name;
read(xml,   /Shape/Name  shape_name);

Handle<Shape> my_shape(  (shape_factory_map[ shape_name ])() );
```

Look up name in map, invoke returned function

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Exploring the Nature of Matter

Design Pattern IV: Factory

- Details of creation localized in the map.
- Individual creations simplified.
- BUT Name,Function pairs need to be added to map
  - If there was a global map, each Shape could call the insert function in own source file
  - Implement map as a Singleton

triangle.cc:

```
class Triangle : public Shape {
public:
  Triangle* create() { ... };
};
static bool registered =
              theShapeMap::Instance().insert(make_pair(  Triangle  ,
                                             &(Triangle::create()));
```

Singleton access

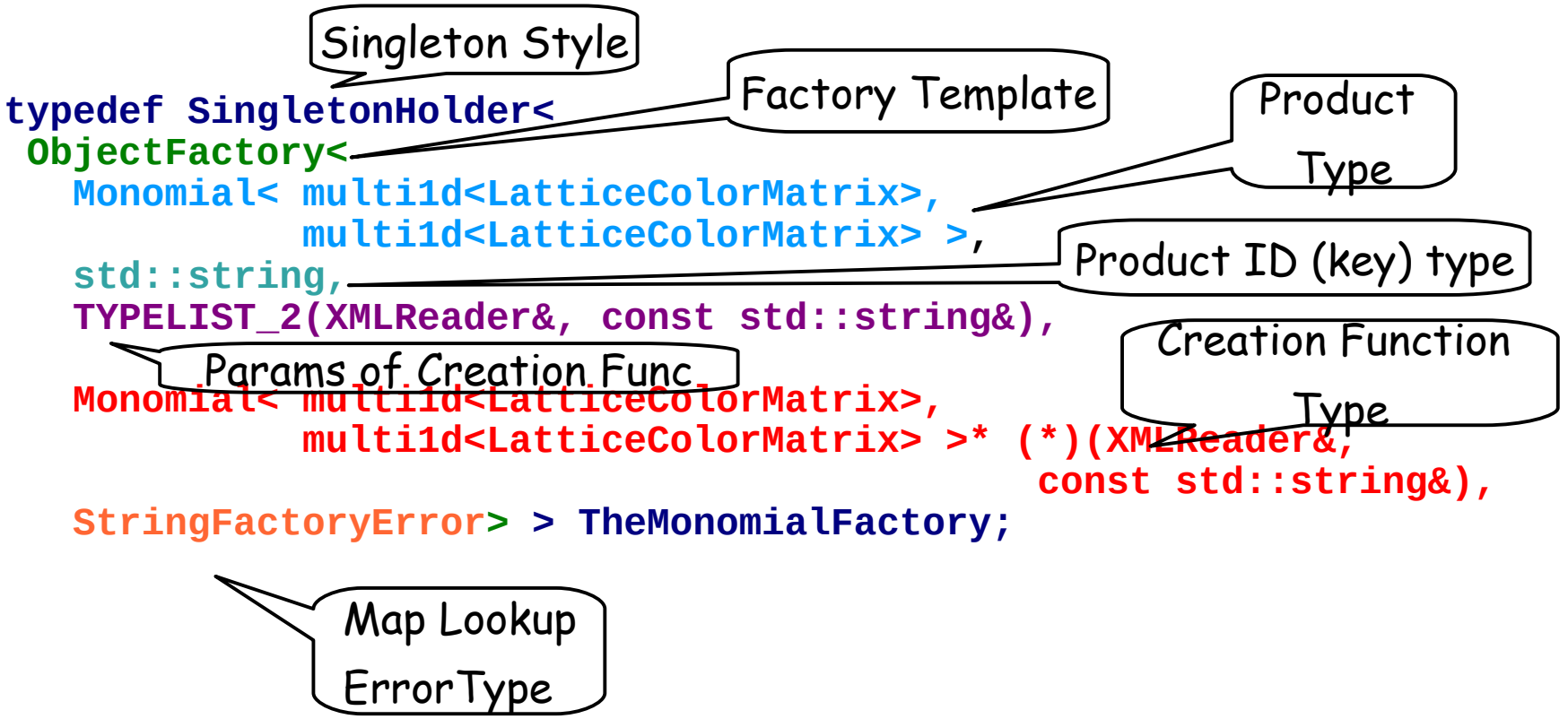
Design Patterns IV: Factory

- This pattern is the Factory pattern
- The essence is a map from ProductID to Product Creation Function
- We use the LOKI implementation from Alexandrescu's book (ObjectFactory<> template)
  - Provides registerObject function for map insertion.
  - Provides createObject function for map look-up
  - Allows control of parameters to createObject
  - Allows us to customize policies (eg create using new, create using malloc, etc etc)

Our Typical Scenario in Chroma

Define Factory in xxx_factory.h – specialise SingletonHolder and Object Factory templates

(eg: chroma/lib/update/molecdyn/monomial/monomial_factory.h)



Our Typical Scenario in Chroma

In xxx_product.h – define the product and a product specific namespace

(eg: chroma/lib/update/molecdyn/monomial/unprec_two_flavor_monomial_w.h)

```
namespace UnprecTwoFlavorWilsonTypeFermMonomialEnv
{
  extern const std::string name;
  extern const bool registered;
};
```

key in map(defined in .cc)

is product registered/linkage

Namespace for product so we can reuse the "name" and "registered" elsewhere

```
class UnprecTwoFlavorWilsonTypeFermMonomial :
  public  TwoFlavorExactUnprecWilsonTypeFermMonomial<
  multi1d<LatticeColorMatrix>,
  multi1d<LatticeColorMatrix>,
  LatticeFermion>
  {
    ...
};
```

The actual class declaration

Our Typical Scenario in Chroma

In xxx_product.cc – almost everything else:

(eg: chroma/lib/update/molecdyn/monomial/unprec_two_flavor_monomial_w.cc)

```
namespace UnprecTwoFlavorWilsonTypeFermMonomialEnv
{
   Monomial< multi1d<LatticeColorMatrix>, multi1d<LatticeColorMatrix> >*
   createMonomial(XMLReader& xml, const string& path)
   {
     return new UnprecTwoFlavorWilsonTypeFermMonomial(
       TwoFlavorWilsonTypeFermMonomialParams(xml, path));
   }

   const std::string name(  TWO_FLAVOR_UNPREC_FERM_MONOMIAL  );

   bool registerAll()
   {
     bool foo = true;
     foo &= WilsonTypeFermActs4DEnv::registerAll();
     foo &= TheMonomialFectory::Instance().registerObject(name,
                                                createMonomial);

   }

      const bool registered = registerAll();
}
```

Code for creation fn

The name, declared as extern in .h

Ensure dependency is registered (see later)

Call to Registration

called at start up

Fly in Ointment - Linkage

- If the registered symbol is not referenced in our program then the compiler may not link xxx_product.o. No linkage means:
  - registerAll() is not called at startup
  - our Monomial does not get registered
  - our temple collapses around our heads
- A solution (aka hack) to this program is to make sure we reference the symbol.
  - linkageHack() function in chroma.cc and hmc.cc

linkageHack and Aggregation

- in linkageHack() we explicitly reference every registered product we need.
- too many products – we want to aggregate
  - xxx_aggregate.h and xxx_aggregate.cc files

```
namespace WilsonTypeFermMonomialAggregrateEnv
{
 bool registerAll()
 {
   bool success = true;
   success &= UnprecTwoFlavorWilsonTypeFermMonomialEnv::registerAll();
   success &=
EvenOddPrecConstDetTwoFlavorWilsonTypeFermMonomialEnv::registerAll()
;
   success &= EvenOddPrecLogDetTwoFlavorWilsonTypeFermMonomialEnv::registeAll();

   // and more ...

   return success;
 }
 const bool registered = registerAll();
}
```

Namespace for Aggregate

Reference individual **registerAll()**-s

Referencing this will pull in ***all*** the individual ones

(chroma/lib/update/molecdyn/monomial/monomial_aggregate_w.cc)

Comments on Linkage Hack and Aggregation

- Using the aggregation our linkageHack function is simplified

```
bool linkageHack(void)
{
  bool foo = true;
  foo &= GaugeMonomialEnv::registerAll();
  foo &= WilsonTypeFermMonomialAggregrateEnv::registerAll();
  foo &= LCMMDIntegratorAggregateEnv::registerAll();
  foo &= ChronoPredictorAggregrateEnv::registerAll();
  foo &= InlineAggregateEnv::registerAll();
  return foo;
}
```

- Still not ideal solution – since now we lose fine control
  - eg: on QCDOC want to omit some individual unused products or we run out of space (.text segment)
- In principle annoyance: Aggregates and Linkage Hack
  - equivalents of big switch statement we didn't want

Summary

- In Chroma, we make use of several design patterns
  - Smart Pointer, Factory Function, Singleton, Factory
  - We use these patterns EVERYWHERE
- We make great use of the LOKI library
- I have shown how these patterns 'look' in the code
- Using patterns allowed us great flexibility and solved many problems
  - eg: using many kinds of fermion without recompilation
- BUT: We are still annoyed by the linkage issue and are looking for a portable solution