# Testing with Axioms in C++ 2011

Ali Alnajjar
Supervisor : Magne Haveraaen

# Intro  TDD

Test-Driven Development (TDD):

- Writing test before implementing.
- The tests provide a specification of the behaviour.
- Check the implementation throughout development and refactoring.

# Intro

Less extreme methods:

- Call for tests for all program units.
- ward off the reappearance of known bugs.

All rely on the programmer to:

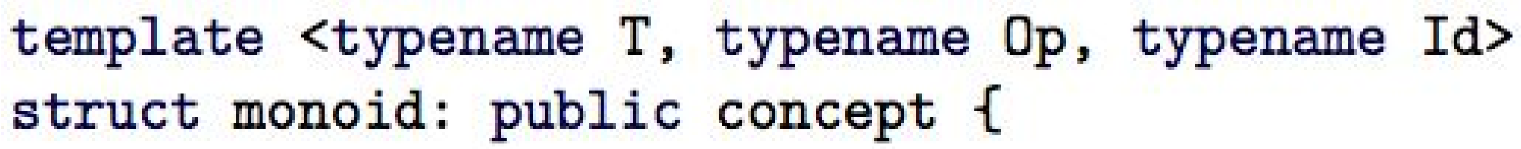
- invent good test cases
- Guarantee that the tests exercise the full expected feature set

# Testing with Concepts and Axioms

- Axioms specify expected behaviour.
- Axioms are integrated with concepts.
- Axiom-based testing provides reusable tests for all models.

# Concepts

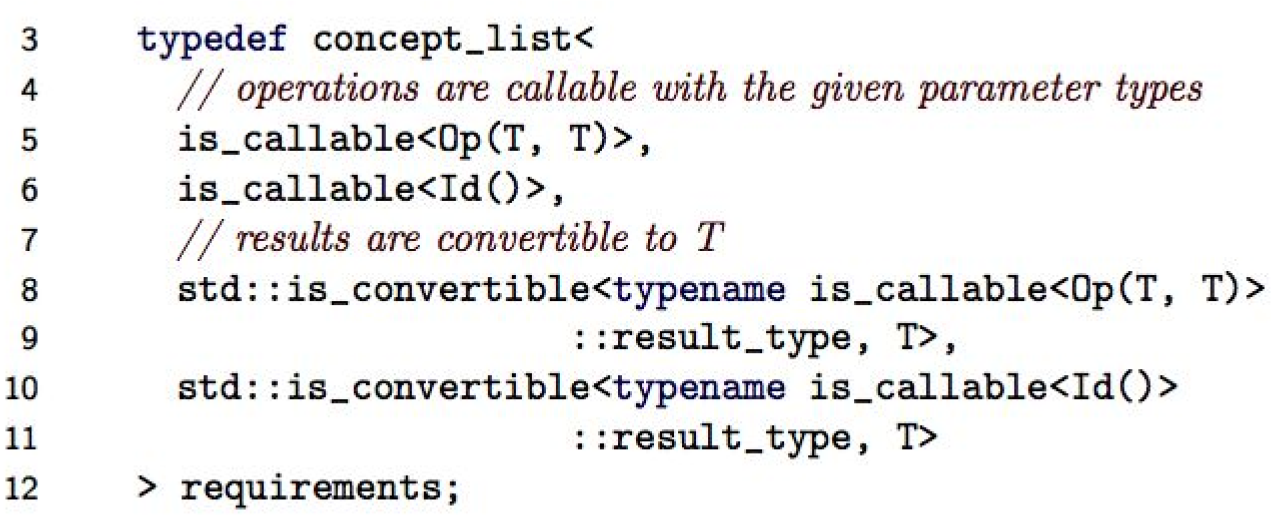
- $C\langle p_1, p_2, \ldots, p_n \rangle = (R, \Phi)$
- A set of parameters, a set of requirements, and a set of axioms.
- Parameters can be TYPES or OPERATIONS.



```
template <typename T, typename Op, typename Id>
struct monoid: public concept {
```

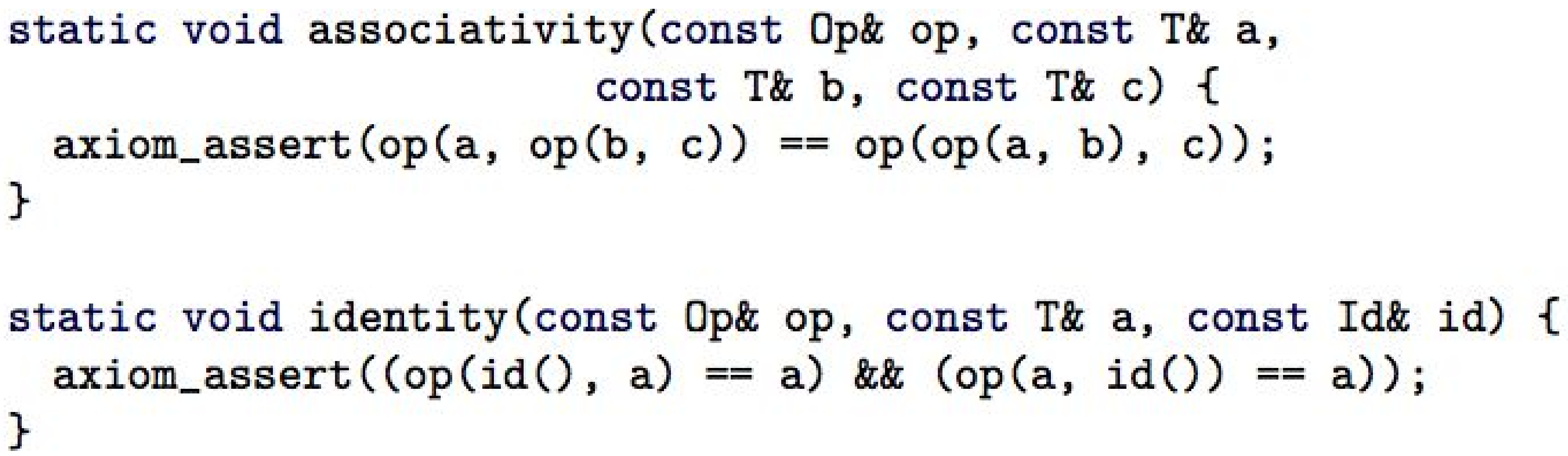
# Requirements

- A predicate
- Another concept.



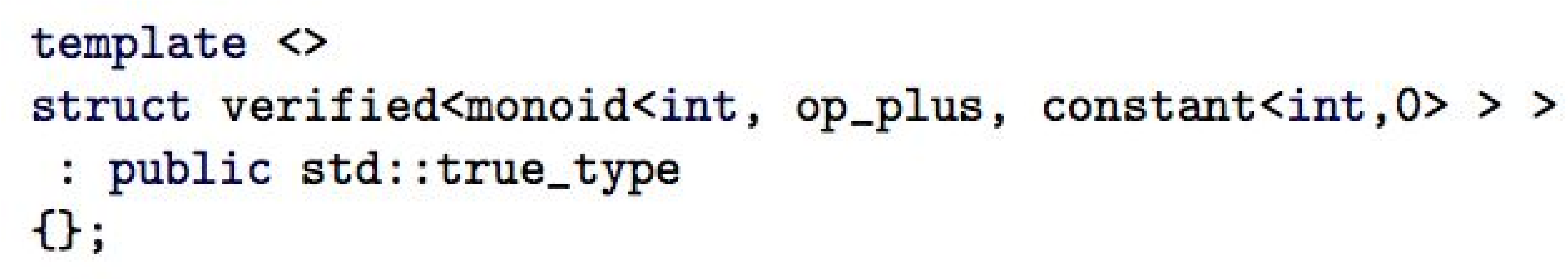
```
typedef concept_list<
  // operations are callable with the given parameter types
  is_callable<Op(T, T)>,
  is_callable<Id()>,
  // results are convertible to T
  std::is_convertible<typename is_callable<Op(T, T)>
                               ::result_type, T>,
  std::is_convertible<typename is_callable<Id()>
                               ::result_type, T>
> requirements;
```

# Axioms



```
static void associativity(const Op& op, const T& a,
                          const T& b, const T& c) {
  axiom_assert(op(a, op(b, c)) == op(op(a, b), c));
}

static void identity(const Op& op, const T& a, const Id& id) {
  axiom_assert((op(id(), a) == a) && (op(a, id()) == a));
}
```

# Models

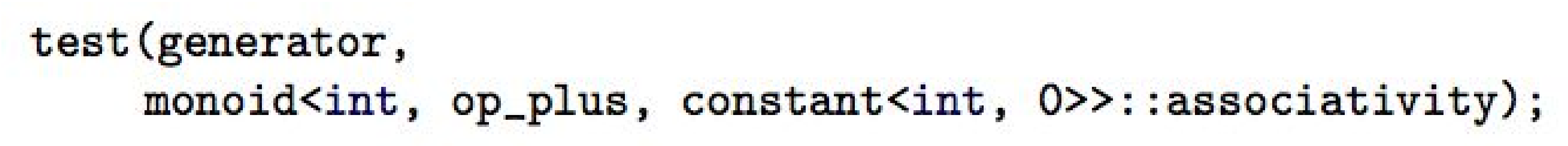


```
template <>
struct verified<monoid<int, op_plus, constant<int,0> > >
 : public std::true_type
{};
```

# Testing Axioms

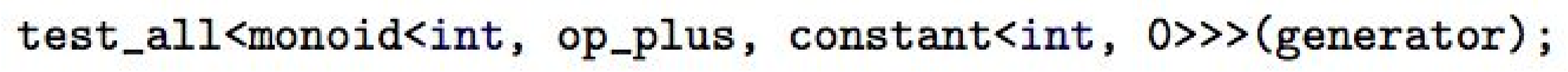
Axiom = Function that calls a macro (**`axiom_assert`**)

Testing a single axiom:



```
test(generator,
     monoid<int, op_plus, constant<int, 0>>::associativity);
```

# Testing Concept



```
test_all<monoid<int, op_plus, constant<int, 0>>>(generator);
```

1. **`test_all`** obtains a list of all axioms in a concept from the **`get_axioms`** function.

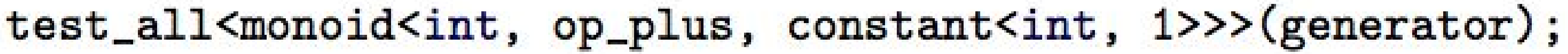
2. Testing each axiom using **`test`** function.

3. Test all the concept requirements.

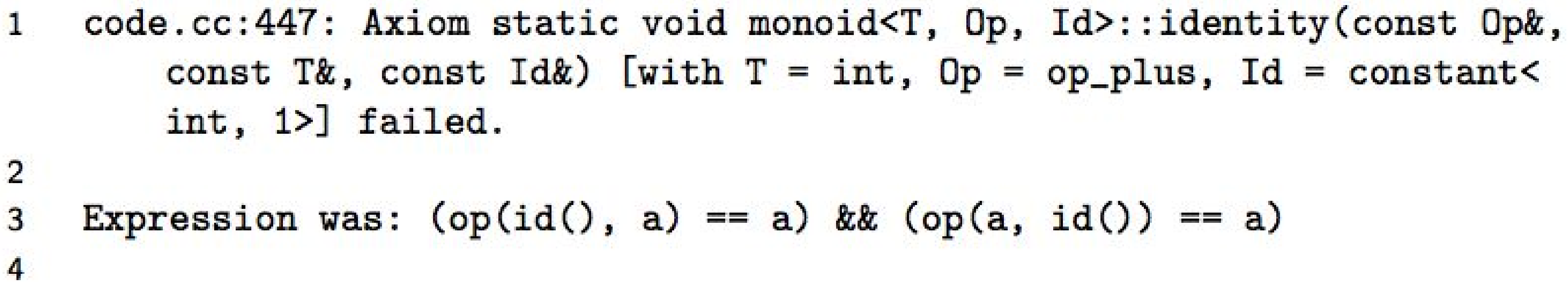
# Testing Reports

**Passed**.

OR: is $\langle \mathbb{Z}, +, 1 \rangle$ monoid ?

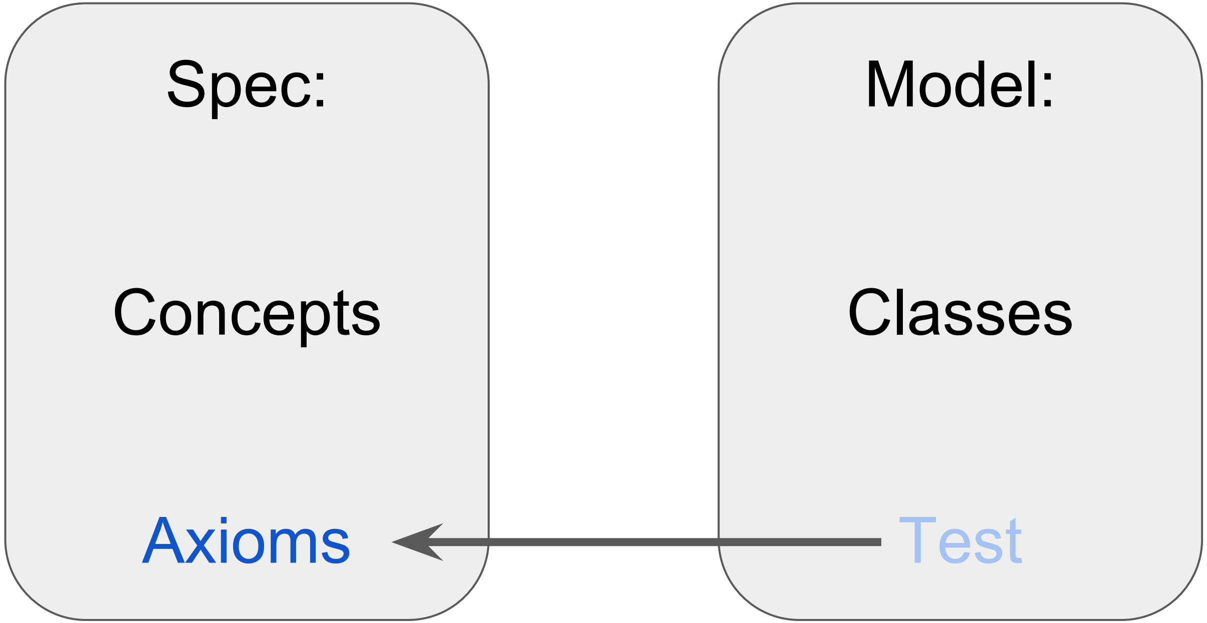


```
test_all<monoid<int, op_plus, constant<int, 1>>>(generator);
```



```
code.cc:447: Axiom static void monoid<T, Op, Id>::identity(const Op&,
    const T&, const Id&) [with T = int, Op = op_plus, Id = constant<
    int, 1>] failed.

Expression was: (op(id(), a) == a) && (op(a, id()) == a)

```

# Reusable Tests



Spec:

Concepts

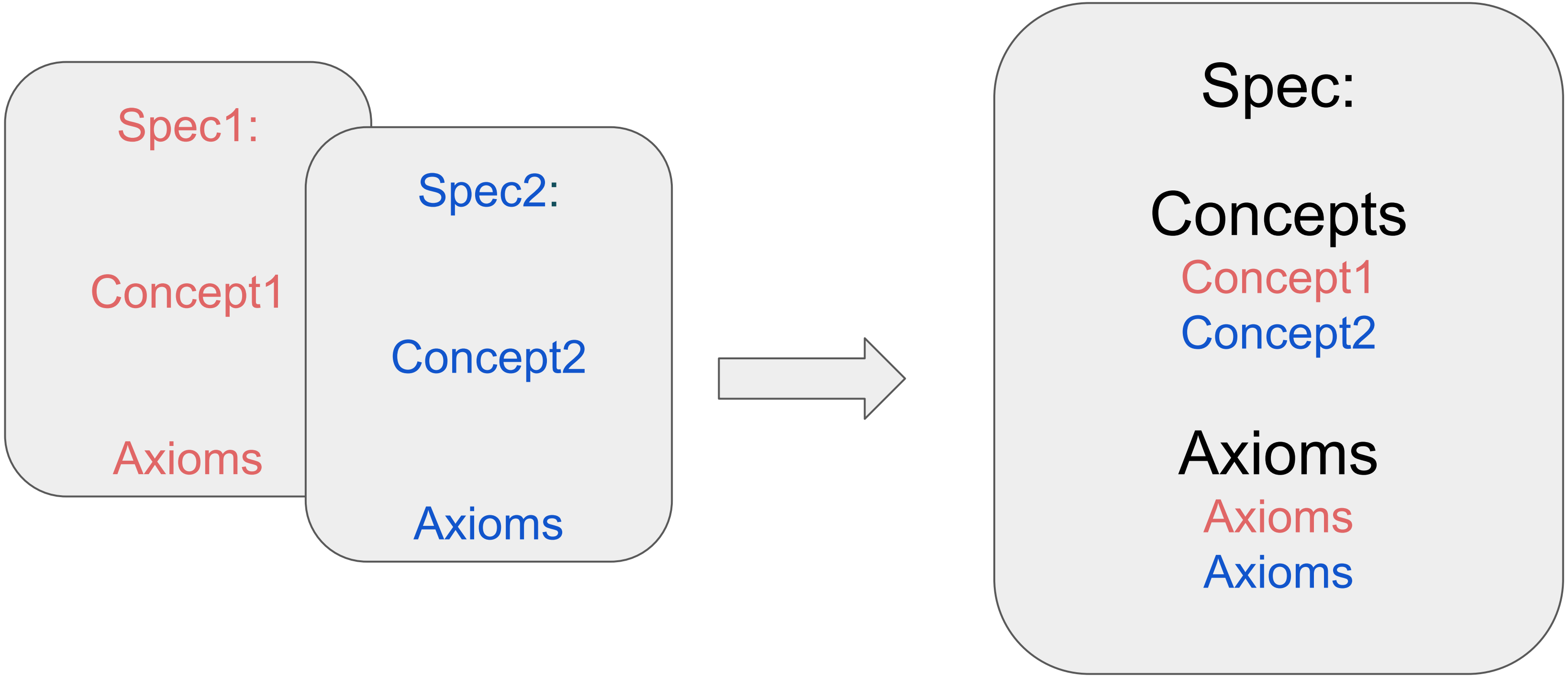
Axioms

Model:

Classes

Test

# Reusable Tests



Spec1:

Concept1

Axioms

Spec2:

Concept2

Axioms

Spec:

Concepts

Concept1

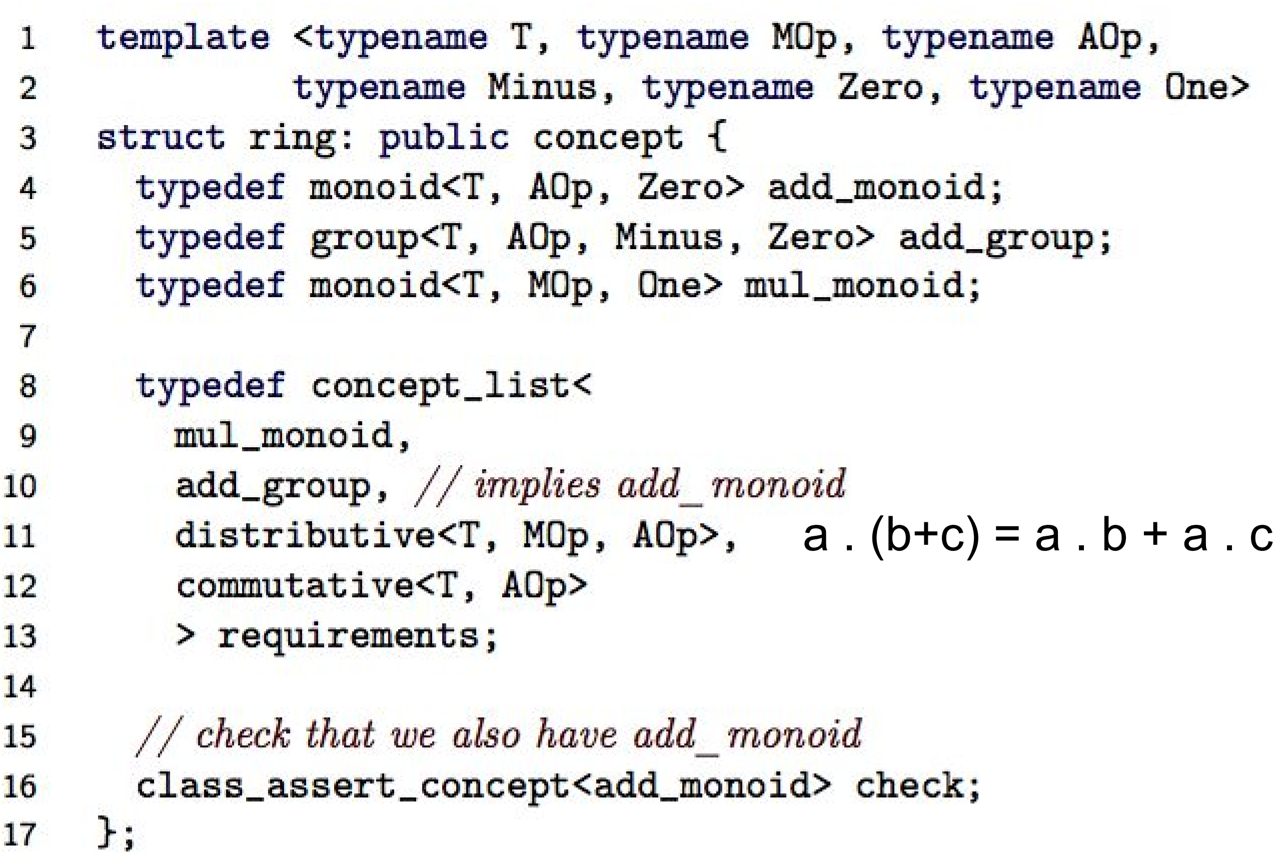
Concept2

Axioms

Axioms

Axioms

# Reusable Tests



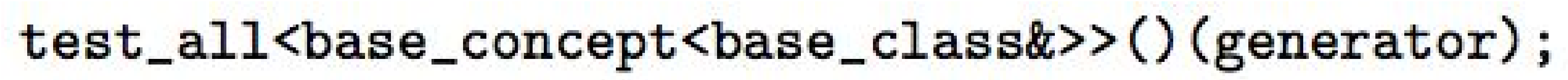
```
template <typename T, typename MOp, typename AOp,
          typename Minus, typename Zero, typename One>
struct ring: public concept {
  typedef monoid<T, AOp, Zero> add_monoid;
  typedef group<T, AOp, Minus, Zero> add_group;
  typedef monoid<T, MOp, One> mul_monoid;

  typedef concept_list<
    mul_monoid,
    add_group, // implies add_ monoid
    distributive<T, MOp, AOp>,
    commutative<T, AOp>
    > requirements;

  // check that we also have add_ monoid
  class_assert_concept<add_monoid> check;
};
```

a . (b+c) = a . b + a . c

# Inheritance

-Subclass must satisfy the behaviour specification of the **base class.**

-Test on references instead of values:



```
test_all<base_concept<base_class&>>()(generator);
```

# Data Coverage.

-all the axioms have been tested.

-a wide and diverse data points tested.

# Data Generation.

1. user selected data sets.

2. randomly chosen generator **terms**.

3. randomly chosen data structure **values**

4. data values **harvested** from an application.

# Data Generation: user selected data sets

Analyse the behaviour of the function.

Select data depending on behaviour.

Select data on the boundaries.

**`list_data_generator<T...>`**

# Data Generation: random terms generation

Generate random expressions and use their values.

All data values can be generated by some sequence of the available operations

```
term_generator<T...>
```

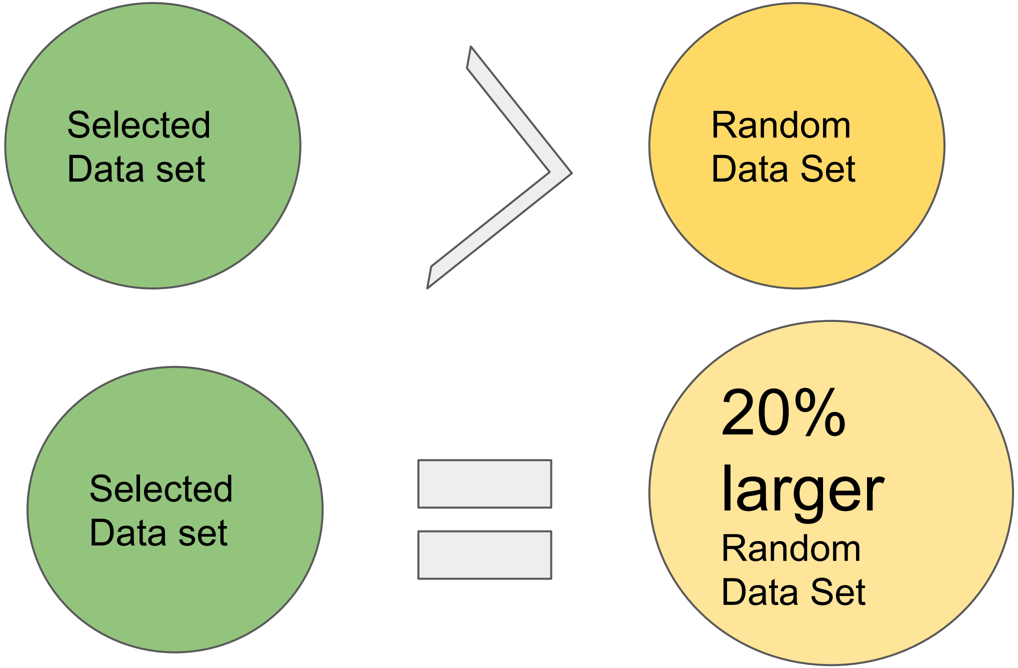
# Data Generation: Random field value generation

There is often a particular relationship between the fields of a class.

Implement a specific data generator for **each class**

**`default_generator`**

# Data Generation: testing efficiency



Selected Data set > Random Data Set

Selected Data set = 20% larger Random Data Set