# - Examples

Let's have a look at some examples of expression templates.

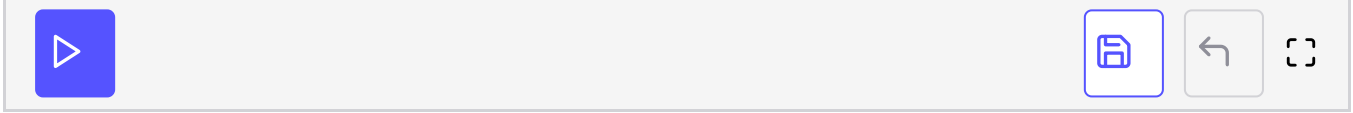
WE'LL COVER THE FOLLOWING



## Example 1: Vector Arithmetic Based on Object-Orientation #

```
// vectorArithmeticOperatorOverloading.cpp

#include <iostream>
#include <vector>

template<typename T>
class MyVector{
  std::vector<T> cont;

public:
  // MyVector with initial size
  explicit MyVector(const std::size_t n) : cont(n){}

  // MyVector with initial size and value
  MyVector(const std::size_t n, const double initialValue) : cont(n, initialValue){}

  // size of underlying container
  std::size_t size() const{
    return cont.size();
  }

  // index operators
  T operator[](const std::size_t i) const{
    return cont[i];
  }

  T& operator[](const std::size_t i){
    return cont[i];
  }
```

```
};


// function template for the + operator
template<typename T>
MyVector<T> operator+ (const MyVector<T>& a, const MyVector<T>& b){
  MyVector<T> result(a.size());
  for (std::size_t s= 0; s <= a.size(); ++s){
    result[s]= a[s]+b[s];
  }
  return result;
}

// function template for the * operator
template<typename T>
MyVector<T> operator* (const MyVector<T>& a, const MyVector<T>& b){
  MyVector<T> result(a.size());
  for (std::size_t s= 0; s <= a.size(); ++s){
    result[s]= a[s]*b[s];
  }
  return result;
}

// function template for << operator
template<typename T>
std::ostream& operator<<(std::ostream& os, const MyVector<T>& cont){
  os << std::endl;
  for (std::size_t i=0; i<cont.size(); ++i) {
    os << cont[i] << ' ';
  }
  return os;
}

int main(){

  MyVector<double> x(10,5.4);
  MyVector<double> y(10,10.3);

  MyVector<double> result(10);

  result= x+x + y*y;

  std::cout << result << std::endl;

}
```



## Explanation #

`MyVector` is a simple wrapper for an `std::vector<T>`. The wrapper class has two constructors (line 12 and 15), we have a `size` function which returns its size (line 18 - 20), and the reading index operator (line 23 - 25) and writing index access (line 27 - 29).

Thanks to the overloaded `+` operator (line 34 - 41), the overloaded `*` operator

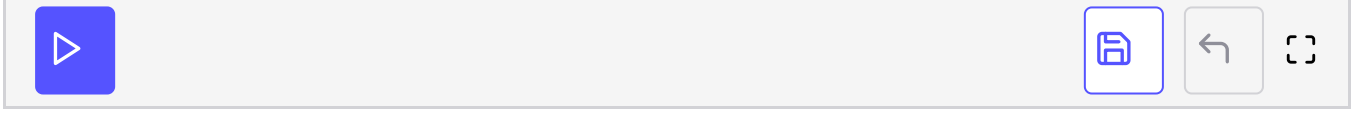
Thanks to the overloaded `+` operator (line 34 - 41), the overloaded `*` operator (line 44 - 51) and the overloaded `output` operator (line 54 - 61), the objects `x`, `y`, and `result` feel like numbers on lines 70 and 72.

## Example 2: Vector Arithmetic Based on Expression Templates #

```
// vectorArithmeticExpressionTemplates.cpp

#include <cassert>
#include <iostream>
#include <vector>

template<typename T, typename Cont= std::vector<T> >
class MyVector{
  Cont cont;

public:
  // MyVector with initial size
  MyVector(const std::size_t n) : cont(n){}

  // MyVector with initial size and value
  MyVector(const std::size_t n, const double initialValue) : cont(n, initialValue){}

  // Constructor for underlying container
  MyVector(const Cont& other) : cont(other){}

  // assignment operator for MyVector of different type
  template<typename T2, typename R2>
  MyVector& operator=(const MyVector<T2, R2>& other){
    assert(size() == other.size());
    for (std::size_t i = 0; i < cont.size(); ++i) cont[i] = other[i];
    return *this;
  }

  // size of underlying container
  std::size_t size() const{
    return cont.size();
  }

  // index operators
  T operator[](const std::size_t i) const{
    return cont[i];
  }

  T& operator[](const std::size_t i){
    return cont[i];
  }

  // returns the underlying data
  const Cont& data() const{
    return cont;
  }

  Cont& data(){
    return cont;
  }
```

```
};

// MyVector + MyVector
template<typename T, typename Op1 , typename Op2>
class MyVectorAdd{
  const Op1& op1;
  const Op2& op2;

public:
  MyVectorAdd(const Op1& a, const Op2& b): op1(a), op2(b){}

  T operator[](const std::size_t i) const{
    return op1[i] + op2[i];
  }

  std::size_t size() const{
    return op1.size();
  }
};

// elementwise MyVector * MyVector
template< typename T, typename Op1 , typename Op2 >
class MyVectorMul {
  const Op1& op1;
  const Op2& op2;

public:
  MyVectorMul(const Op1& a, const Op2& b ): op1(a), op2(b){}

  T operator[](const std::size_t i) const{
    return op1[i] * op2[i];
  }

  std::size_t size() const{
    return op1.size();
  }
};

// function template for the + operator
template<typename T, typename R1, typename R2>
MyVector<T, MyVectorAdd<T, R1, R2> >
operator+ (const MyVector<T, R1>& a, const MyVector<T, R2>& b){
  return MyVector<T, MyVectorAdd<T, R1, R2> >(MyVectorAdd<T, R1, R2 >(a.data(), b.data()));
}

// function template for the * operator
template<typename T, typename R1, typename R2>
MyVector<T, MyVectorMul< T, R1, R2> >
operator* (const MyVector<T, R1>& a, const MyVector<T, R2>& b){
  return MyVector<T, MyVectorMul<T, R1, R2> >(MyVectorMul<T, R1, R2 >(a.data(), b.data()));
}

// function template for << operator
template<typename T>
std::ostream& operator<<(std::ostream& os, const MyVector<T>& cont){
  std::cout << std::endl;
  for (int i=0; i<cont.size(); ++i) {
    os << cont[i] << ' ';
  }
  os << std::endl;
  return os;
}
```

```
int main(){

  MyVector<double> x(10,5.4);
  MyVector<double> y(10,10.3);

  MyVector<double> result(10);

  result= x+x + y*y;

  std::cout << result << std::endl;

}
```



## Explanation #

The key difference between the first naive implementation and this implementation with expression templates is that the overloaded `+` and `*` operators return in case of the expression tree proxy objects. These proxies represent the expression tree (lines 91 and 98). The expression tree is only created but not evaluated. Lazy, of course. The assignment operator (lines 22 - 27) triggers the evaluation of the expression tree that needs no temporary objects.

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In the next lesson, we'll solve a few exercises for expression templates.