What is rvalue reference?

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Season 1, Episode 2

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lvalue and rvalue definition in C

- lvalue can appear in the left and right side of the assignment
- rvalue always appear in the right side of the assignment

```
int a= 42; // a is lvalue but 42 is rvalue
a = b; // a and b are both lvalue
int c = a * b; // a*b is rvalue and c is lvalue
```

lvalue and rvalue definition in C++

- lvalue refers to a memory location and allows us to take the address via & operator
- rvalue is the opposite

```
int i = 42;
int * p = &i; // i is an lvalue
int & foo() {return i;}
foo() = 43;
int * p1 = &foo(); // foo() is an lvalue because you can get its address
```

```
int foobar();
int j = foobar(); // foobar is an rvalue
j = 42; // 42 is an lvalue
//foobar() = 43; //ERROR
```

Why returning lvalue in a function?

- The ability of C++ to return lvalues from functions is important for implementing some overloaded operators.
- Example: Overloading the brackets operator []
  - std::map<int, float> mymap;
  - mymap[10] = 5.6;

Conversion between lvalue and rvalue

- lvalue to rvalue:
  - int c = a + b; //a and b are both lvalue but the operatior “+” returns “a + b” which is an rvalue.
- rvalue to lvalue:
  - int arr[] = {1, 2};
  - int* p = &arr[0];
  - *(p + 1) = 10; // “p + 1” is an rvalue but operator “*” makes it lvalue

rvalue reference by example (1)

- Consider the following class

```
class Intvec {
public:
        Intvec(size_t num = 0) :
                        m_size(num),
        m_data(new int[m_size]) {
                log("constructor");
        }
        ~Intvec() {
                log("destructor");
                if (m_data) {
                        delete[] m_data;
                        m_data = 0;
                }
         }
        Intvec(const Intvec& other) :
                m_size(other.m_size), m_data(new int[m_size])
{
                log("copy constructor");
                for (size_t i = 0; i < m_size; ++i)
                        m_data[i] = other.m_data[i];
        }
        Intvec& operator=(const Intvec& other) {
                log("copy assignment operator");
                Intvec tmp(other);
                std::swap(m_size, tmp.m_size);
                std::swap(m_data, tmp.m_data);
                return *this;
        }
private:
        void log(const char* msg) {
        cout << "[" << this << "] "
                << msg << "\n"; }
        size_t m_size; int* m_data;
};
```

rvalue reference by example (2)

- Now suppose the following assignment is taking place.

```
Intvec v1(20);
Intvec v2;
cout << "assigning lvalue...\n";
v2 = v1;
cout << "ended assigning lvalue...\n";
```

- How many functions from class Intvec are called?

rvalue reference by example (3)

- copy assignment operator
- copy constructor
- destructor

```
Intvec& operator=(const Intvec& other) {
    log("copy assignment operator");
    Intvec tmp(other);
    std::swap(m_size, tmp.m_size);
    std::swap(m_data, tmp.m_data);
    return *this;
}
```

rvalue reference by example (4)

- Now suppose the following assignment is taking place.

```
Intvec v2;
cout << "assigning lvalue...\n";
v2 = Intvec(20);
cout << "ended assigning lvalue...\n";
```

- How many functions from class Intvec are called?

rvalue reference by example (5)

- constructor : **Intvec(20);**
- copy assignment operator
- copy constructor : **Intvec tmp(other);**
- destructor
- destructor : **temporary object**

```
Intvec& operator=(const Intvec& other) {
    log("copy assignment operator");
    Intvec tmp(other);
    std::swap(m_size, tmp.m_size);
    std::swap(m_data, tmp.m_data);
    return *this;
}
```

rvalue reference by example (5)

- What if in assignment we knew that the parameter is temporary?

```
Intvec& operator=(<tell me compiler if other is an lvalue or an rvalue>
other) {

    // if other is an rvalue then i don't need to create tmp
    //because other itself is temporary
    //Intvec tmp(other);
    //std::swap(m_size, tmp.m_size);
    //std::swap(m_data, tmp.m_data);

    std::swap(m_size, other.m_size);
    std::swap(m_data, other.m_data);

    return *this;
}
```

rvalue reference by example (6)

- And this is why rvalue reference is invented!

```
Intvec& operator=(Intvec && other) {
        log("move assignment operator");
        std::swap(m_size, other.m_size);
        std::swap(m_data, other.m_data);

        return *this;
}
```

rvalue reference by example (7)

- Now suppose the following assignment is taking place.

```
Intvec v2;
cout << "assigning lvalue...\n";
v2 = Intvec(20);
cout << "ended assigning lvalue...\n";
```

- How many functions from class Intvec are called?

rvalue reference by example (8)

- constructor : **Intvec(20);**
- move assignment operator
- destructor : **temporary object**

```
Intvec& operator=(Intvec && other) {
    log("move assignment operator");
    std::swap(m_size, other.m_size);
    std::swap(m_data, other.m_data);

    return *this;
}
```

std::move

- std::move transforms an lvalue to rvalue.

```
void rval(int && m) {
    m = m + 1;
    cout << "rval: " << m << endl;
}
rval(5); //it works because 5 is a rvalue
int t = 42;
rval(t); //it does not work because t is a lvalue
rvalue(move(t)); //it work because move transforms t to rvalue

cout << "t=" << t << endl; // now t has changed to 43!
```

Example of move constructor

```
class ArrayWrapper
{
public:
    // default constructor produces
    // a moderately sized array
    ArrayWrapper ()
        : _p_vals( new int[ 64 ] )
        , _metadata( 64, "ArrayWrapper" )
    {}

    ArrayWrapper (int n)
        : _p_vals( new int[ n ] )
        , _metadata( n, "ArrayWrapper" )
    {}

    // move constructor
    ArrayWrapper (ArrayWrapper&& other)
        : _p_vals( other._p_vals  )
        , _metadata( move(other._metadata))
    {
        other._p_vals = NULL;
        other._size = 0;
    }

    // copy constructor
    ArrayWrapper (const ArrayWrapper& other)
        : _p_vals( new
int[ other._metadata.getSize()  ] )
        , _metadata( other._metadata )
    {
        for ( int i = 0; i < _metadata.getSize(); +
+i )
        {
            _p_vals[ i ] = other._p_vals[ i ];
        }
    }
    ~ArrayWrapper ()
    {
        delete [] _p_vals;
    }

public:
    int *_p_vals;
    Metadata _metadata;
};
```

Sources

[1] http://eli.thegreenplace.net/2011/12/15/understanding-lvalues-and-rvalues-in-c-and-c
[2] http://www.cprogramming.com/c++11/rvalue-references-and-move-semantics-in-c++11.html