

r-value references

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“Object oriented programming and C++” course

“l-value” and “r-value” early definition

C

- “l-value”: an expression that may appear on the left (or on the right) hand side of an assignment
- “r-value”: an expression that may appear only on the right hand side of an assignment

```
int a=12; // "a": lvalue, "12": rvalue
int b=a;  // "a": lvalue,
           //          may appear on the right
int c=a*b; // "a*b": rvalue (on the right)
c*b=15;    // WRONG! "c*b": rvalue,
           //          cannot appear on the left
```

C++: new situations

References introduce some complication:

- The call of a function returning by value gives a r-value
- The call of a function returning by reference gives a l-value

```
int  vFunc(); // return by value
int& rFunc(); // return by reference
...
int a=vFunc(); // vFunc(): rvalue
rFunc()=43;    // rFunc(): lvalue
vFunc()=57;    // WRONG! vFunc(): rvalue,
                // cannot appear on the left
```

“l-value” and “r-value” redefinition

C++98/03

- “l-value”: an expression that refers to a memory location so that the address of that memory location can be taken via the & operator
- “r-value”: an expression that’s not a l-value

```
int  vFunc(); // return by value
int& rFunc(); // return by reference
...
int* p=&rFunc(); // rFunc(): lvalue,
                // address can be taken
int* q=&vFunc(); // WRONG! vFunc(): rvalue,
                // address cannot be taken
int& r= vFunc(); // WRONG! vFunc(): rvalue,
                // reference cannot be taken
```

l-value references

Reference binding to values

- l-value reference:
 - can bind to l-values
 - cannot bind to r-values
- l-value reference to const can bind to l-values and r-values

```
void f(      int& i); // called with non-const
                // lvalues only
void g(const int& i); // called with
                // lvalues or rvalues

int a=12;
f(a); // OK      "a": lvalue
f(12); // WRONG! "12": rvalue
g(a); // OK      "a": lvalue
g(12); // OK     "12": rvalue
```

r-value references

C++11 only

r-value references give a solution to two issues:

- move semantics
- perfect forwarding

r-values references can be declared with a `&&`

```
void f(      X&  x); // called with non-const
                    // lvalues only
void f(const X&  x); // called with
                    // lvalues or rvalues
void f(      X&& x); // called with rvalues
```

r-value references are r-values?

r-value references without a name are r-values,
otherwise they're l-values.

```
void g(X&& x) {  
    f(x);    // argument of f has a name  
}           // -> l-value -> call f(X& x)
```

```
X&& g();  
...  
f(g());    // argument of f has no name  
           // -> r-value -> call f(X&& x)
```

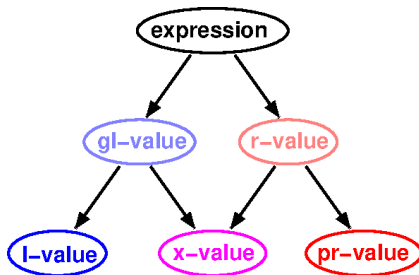
Moving objects

An object is “moved” when the resources it owns are simply taken by another object, or swapped, without being copied.

Move semantics allow performance gain in several situations:

- moving from objects just before their end-of-life:
 - temporary objects
 - objects in `std::vector` to reallocate
- object swap (e.g. in sorting)

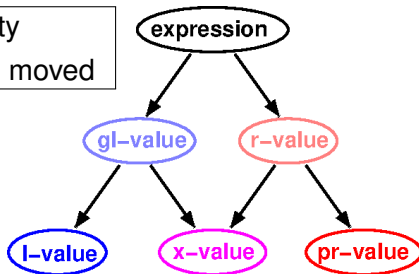
Expressions classification



- l-value: an expression that refers to a memory location
- x-value: an object near the end of its lifetime (“eXpiring”)
- gl-value: an l-value or an x-value (“Generalized”)
- r-value: an x-value or a value that is not associated with an object
- pr-value: an r-value that is not an x-value (“Pure”)

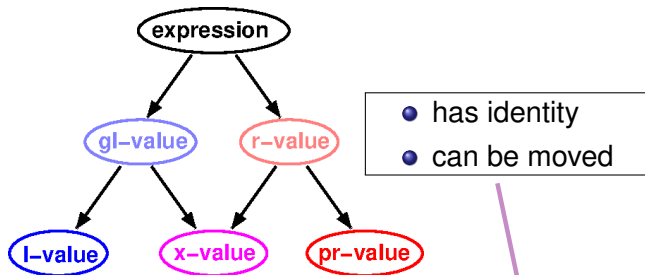
Expressions classification

- has identity
- cannot be moved



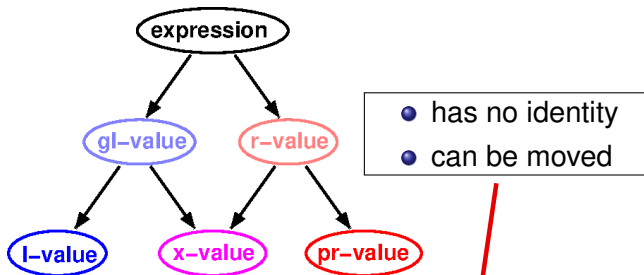
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Move semantics

“move” constructor and assignment:
constructor and assignment operators
with a r-value reference argument

```
class X {  
    ...  
    X(X&& x) noexcept;  
    const X& operator=(X&& x) noexcept;  
    ...  
};
```

Object lifetime

The objects owned by `x` are not deleted until the instance of `X` move-created or move-assigned from `x` is deleted:
be careful with destructor side effects!

Move constructor and assignment are used in STL containers
only when declared `noexcept`.

Force move semantics

Object swap

Object swap is usually done by round-copying objects through a temporary; usual assignment involves l-values. Move assignment can be forced transforming l-values to r-values by `std::move (in <utility>)`.

```
template<class T>
void swap(T& l, T& r) {
    T tmp(std::move(l));
    l = std::move(r);
    r = std::move(tmp);
}
```

Simply declaring the arguments as r-value reference
`template<class T> void swap(T&& l, T&& r)`
is not sufficient.

Forwarding (a.k.a. “universal”) references

Template/`auto` types

Variables or parameters with type `T&&` where `T` is a deduced type are called “forwarding references”. They were originally called “universal references” by S.Meyers. The actual type depends on a set of rules.

Type deduction for template parameters being universal references:

- l-values of type `T` are deduced to be of type `T&`.
- r-values of type `T` are deduced to be of type `T`.

Reference-collapsing rules:

- A rv-reference to a rv-reference becomes a rv-reference.
- Any other reference to reference becomes a lv-reference.

Perfect forwarding

Function parameters forwarding

Function call inside another function,
passing as parameters (part of) the parameters
of the enclosing function, with exactly the same meaning

```
template<class T>
void wrap( T&& x ) {
    ...
    func( std::forward<T>( x ) );
    ...
    return;
}
```