RAII

- Resource Acquisition Is Initialization
- The idea: keep a resource is expressed by object lifetime

```
// is this correct?
void f()
{
    char *cp = new char[1024];

    g(cp);
    h(cp);

    delete [] cp;
}
```

RAII

- Resource Acquisition Is Initialization
- The idea: keep a resource is expressed by object lifetime

```
// is this maintainable?
void f()
{
    char *cp = new char[1024];

    try
    {
      g(cp);
      h(cp);
      delete [] cp;
    }
    catch (...)
    {
      delete [] cp;
      throw;
    }
}
```

RAII

- Constructor allocates resource
- Destructor deallocates

```
// RAII
struct Res
{
    Res(int n) { cp = new char[n]; }
    ~Res() { delete [] cp; }
    char *getcp() const { return cp; }
};

void f()
{
    Res res(1024);

    g(res.getcp());
    h(res.getcp());
}
// resources will be free here
```

RAII

- Should be careful when implementing RAII
- Destructor calls only when living object goes out of scope
- Object lives only when constructor has successfully finished

```
// But be care:
struct BadRes
{
    Res(int n) { cp = new char[n]; ... init(); ... }
    ~Res()     { delete [] cp; }
    char *cp;
    void init()
    {
       ... throw XXX;
    }
};
```

Typical RAII solutions

- Smart pointers for memory handling
- Guards for locking
- ifstream, ofstream objects for file-i/o
- std::containers

```
class X
{
public:
    void *non_thread_safe();
private:
    Mutex lock_;
};

void *X::non_thread_safe();
{
    Guard<Mutex> guard(lock_);
    /* critical section */
}
```

Smart pointers

- The deprecated auto pointer
- How smart pointers work?
- Unique_ptr
- Shared_ptr and weak_ptr
- Make_ functions
- Shared pointer from this
- Traps and pitfalls

Auto_ptr

- The only smart pointer in C++98/03
- Cheap, ownership-based
- Not works well with STL containers and algorithms
- Not works with arrays
- Deprecated in C++11 Don't use it!

```
int main()
{
    auto_ptr<int> p(new int(42));
    auto_ptr<int> q;
    // p: 42   q: NULL

    q = p;
    // p: NULL q: 42

    *q += 13;   // change value of the object q owns
    p = q;
    // p: 55   q: NULL
}
```

How inheritance works?

- Raw pointers: assign Derived* to Base* works
- But auto_ptr<Derived> is not inherited from auto_ptr<Base> !
- We need a bit of trick here

```
template<class T>
class auto_ptr
{
private:
  T* ap;    // refers to the actual owned object (if any)
public:
  typedef T element_type;

  explicit auto_ptr (T* ptr = 0) : ap(ptr) { }
  auto_ptr (auto_ptr& rhs) : ap(rhs.release()) { }
  template<class Y> auto_ptr(auto_ptr<Y>& rhs) : ap(rhs.release()){ }

  auto_ptr& operator=(auto_ptr& rhs) { ... }
  template<class Y> auto_ptr& operator= (auto_ptr<Y>& rhs) { ... }
};
```

Unique_ptr

- Single ownership pointer (similar to auto_ptr)
- But carefully designed to work with STL and other language features
- Movable but not copyable
- Deleter type parameter

```
#include <memory>
template< class T, class Deleter = std::default_delete<T>>
class unique_ptr;

template <class T, class Deleter>
class unique_ptr<T[],Deleter>;

void f()
{
  std::unique_ptr<MyClass>   up1(new MyClass());  // * and ->
  std::unique_ptr<MyClass[]> up2(new MyClass[n]); // []
  ...
}  // proper delete called here
```

Unique_ptr

```
#include <memory>

void f()
{
  std::unique_ptr<Foo> up(new Foo());  // up is the only owner
  std::unique_ptr<Foo> up2(up);// syntax error: can't copy unique_ptr

  std::unique_ptr<Foo> up3;    // nullptr: not owner

  up3 = up;                 // syntax error: can't assign unique_ptr
  up3 = std::move(up);   // ownership moved to up3

} // up3 destroyed: Foo object is destructed
  // up  destroyed: nop
```

Abstract factory pattern

```
#include <memory>

class Base { ... };
class Derived1 : public Base { ... };
class Derived2 : public Base { ... };


template <typename... Ts>
std::unique_ptr<Base>  makeBase( Ts&&... params)  { ... }

void f() // client code:
{
  auto pBase = makeBase( /* arguments */ );
}
// destroy object
```

Abstract Factory Pattern

```
auto delBase = [](Base *pBase)
               {
                   makeLogEntry(pBase);
                   delete pBase; // delete object
               };

template <typename... Ts>
std::unique_ptr<Base, decltype(delBase)>  makeBase( Ts&&... params)
{
  std::unique_ptr<Base, decltype(delBase)> pBase(nullptr, delBase);

  if ( /* Derived1 */ )
  {
    pBase.reset(new Derived1( std::forward<Ts>(params)...) );
  }
  else if ( /* Derived2 */ )
  {
    pBase.reset(new Derived2( std::forward<Ts>(params)...) );
  }
  return pBase;
}
```

Evaluation

- The sizeof(unique_ptr<>) without deleter is == sizeof(raw pointer)
- If there is deleter with state, the size increases
- If no state, then no size penalty (e.g. lambda with no capture).
- If no state, but function pointer is used as deleter: sizeof(funptr) added
- Prefer unique_ptr when possible
- Can be used in standard containers when polymorphic use needed
- Cheap
- No downcast operation :(

shared_ptr

- Shared ownership pointer with reference counter
- Copy constructible and assignable
- No array specializations (e.g. no shared_ptr<T[ ]>)
- Deleter type parameter

```
#include <memory>
template< class T, class Deleter = std::default_delete<T>>
class shared_ptr;

void f()
{
  std::shared_ptr<MyClass>  sp1(new MyClass());  // * and ->
  std::shared_ptr<MyClass>  sp2(new MyClass[n],  // * and ->
                                    std::default_delete<MyClass[]>());
  ...
}  // proper delete called here
```

shared_ptr

```
void f()
{
  std::shared_ptr<int> p1(new int(5));
  std::shared_ptr<int> p2 = p1; // now both own the memory.

  p1.reset(); // memory still exists, due to p2.
  p2.reset(); // delete the memory, since no one else owns.
}
```

```
T & operator*() const;  // never throws
T * operator->() const; // never throws
T * get() const;        // never throws

bool unique() const;    // never throws
long use_count() const; // never throws
```

weak_ptr

- Not owns the memory
- But part of the “sharing group”
- No direct operation to access the memory
- Can be converted to shared_ptr with lock()

```
long use_count() const;
bool expired() const;     // use_count() == 0

shared_ptr<T> lock() const;
// return expired() ? shared_ptr<T>() : shared_ptr<T>(*this)

void reset();
```

Using lock()

```
void f()
{
    std::shared_ptr<X> ptr1 = std::make_shared<X>();
    std::shared_ptr<X> ptr2 = ptr1;

    std::weak_ptr<X>   wptr = ptr2;

    if ( auto sp = wptr1.lock() )
       // use sp
    else
       // expired
} // destructors are called here
```

Using lock()

```
int main ()
{
  std::shared_ptr<int> sp1,sp2;
  std::weak_ptr<int>   wp;
                                       // sharing group:
                                       // ---------------
  sp1 = std::make_shared<int> (20);    // sp1
  wp = sp1;                            // sp1, wp

  sp2 = wp.lock();                     // sp1, wp, sp2
  sp1.reset();                         //      wp, sp2

  sp1 = wp.lock();                     // sp1, wp, sp2
}
```

Make functions

```
// For unique_ptr
// default constructor of T
std::unique_ptr<T> v1 = std::make_unique<T>();
// constructor with params
std::unique_ptr<T> v2 = std::make_unique<T>(x,y,z);
// array of 5 elements
std::unique_ptr<T[]> v3 = std::make_unique<T[]>(5);

// For shared_ptr
void f()
{
    std::unique_ptr<Foo> up(new Foo());  // up is the only owner

    if ( up )  // owner or not
    {
        *up = ...;   // use the object
    }
}
```

Enable shared from this

```
#include <memory>
#include <cassert>

class Y : public std::enable_shared_from_this<Y>
{
public:

    std::shared_ptr<Y> f()
    {
        return shared_from_this();
    }
};

int main()
{
    std::shared_ptr<Y> p(new Y);
    std::shared_ptr<Y> q = p->f();
    assert(p == q);
    assert(!(p < q || q < p)); // p and q must share ownership
}
```

Trap: exception safety

```
int f(); // may throw exception

// possible memory leak
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::unique<MyClass>(new MyClass()), f());
}
```

Trap: exception safety

```
int f(); // may throw exception

// possible memory leak
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::unique<MyClass>(new MyClass()), f());
}
```

```
1. Runs new MyClass
2. Runs f() and throw exception
3. std::unique_ptr constructor is not called
```

Trap: exception safety

```
int f(); // may throw exception

// possible memory leak
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::unique<MyClass>(new MyClass()), f());
}


int f(); // may throw exception

// safe
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::make_unique<MyClass>(), f());
}
```

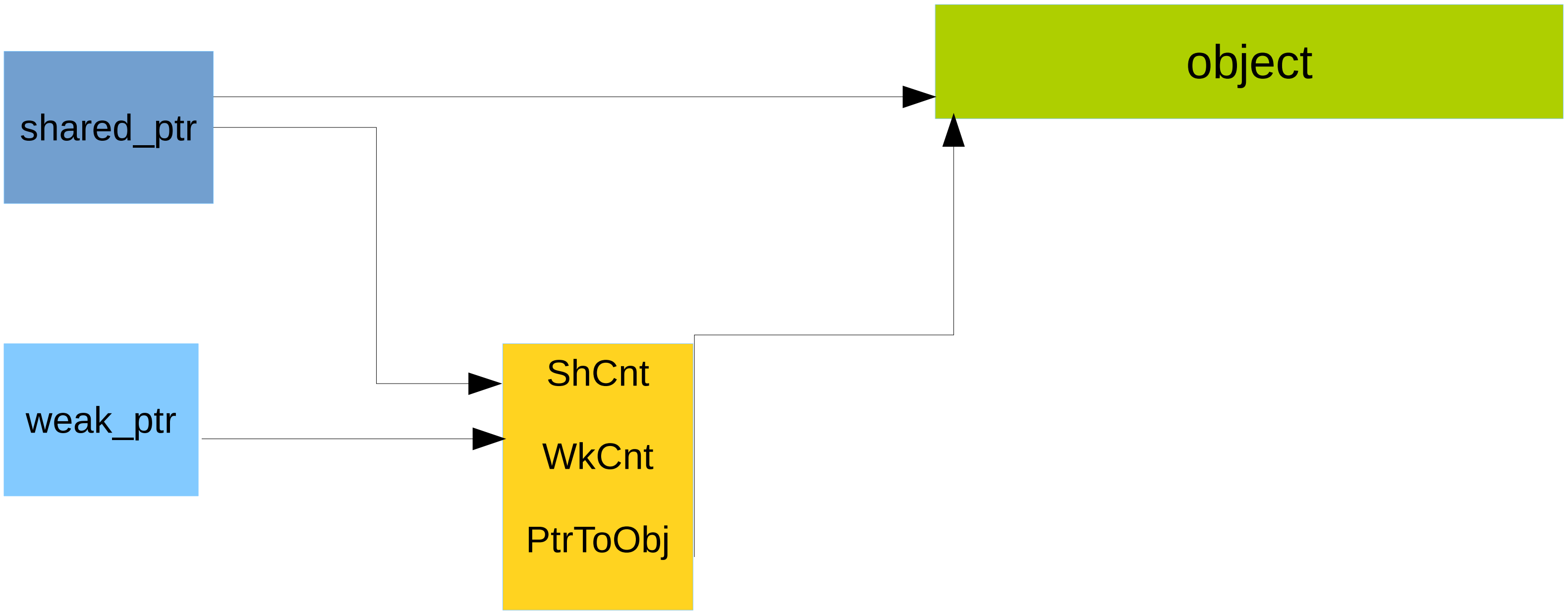
Trap: exception safety

```
int f(); // may throw exception

// possible memory leak
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::unique<MyClass>(new MyClass()), f());
}
```

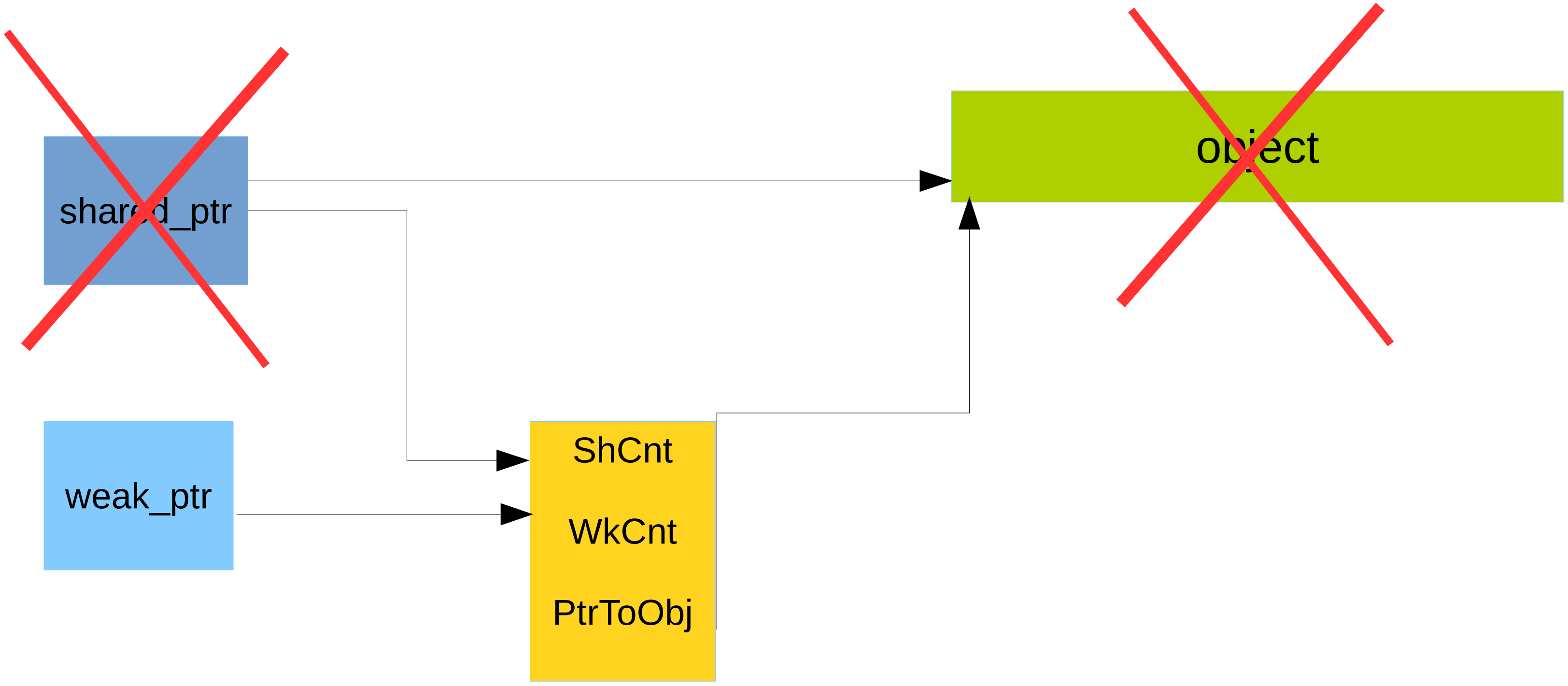
```
int f(); // may throw exception

// safe
std::pair<std::unique_ptr<MyClass>,int> foo()
{
  return std::make_pair(std::make_unique<MyClass>(), f());
}
```

No news – good news!

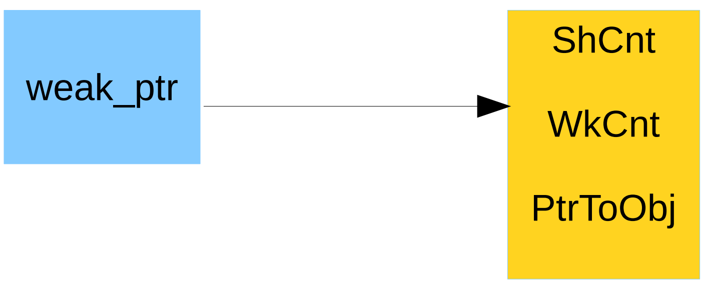
Trap: overuse of memory



Trap: overuse of memory



Trap: overuse of memory



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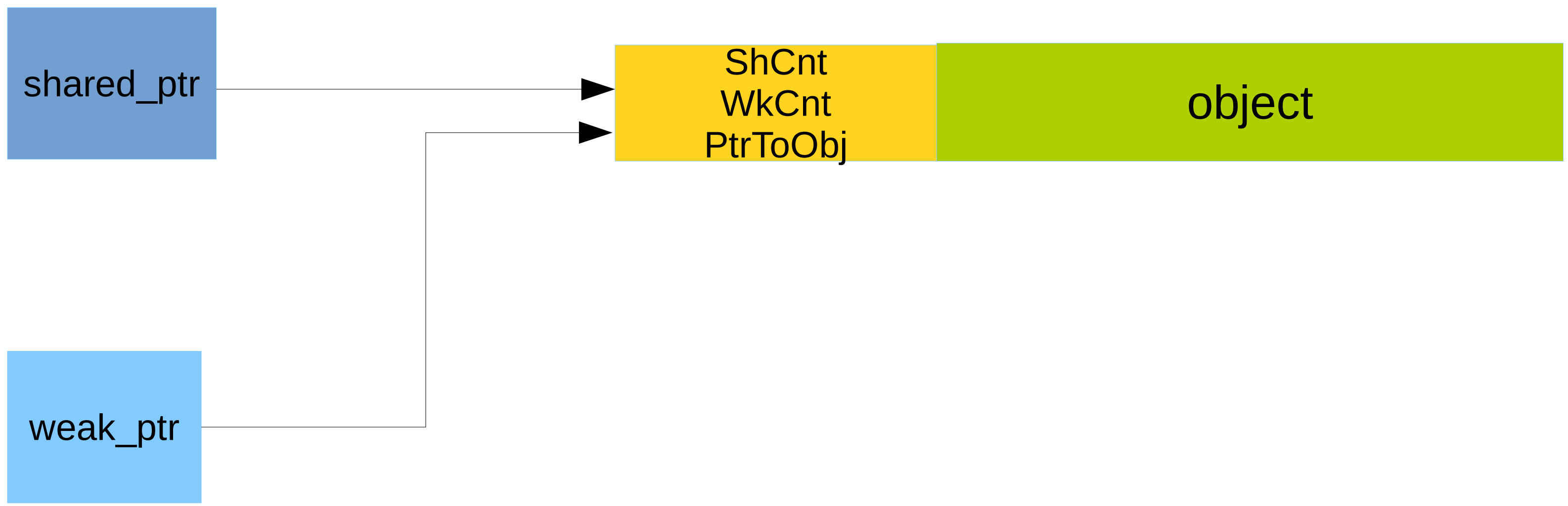

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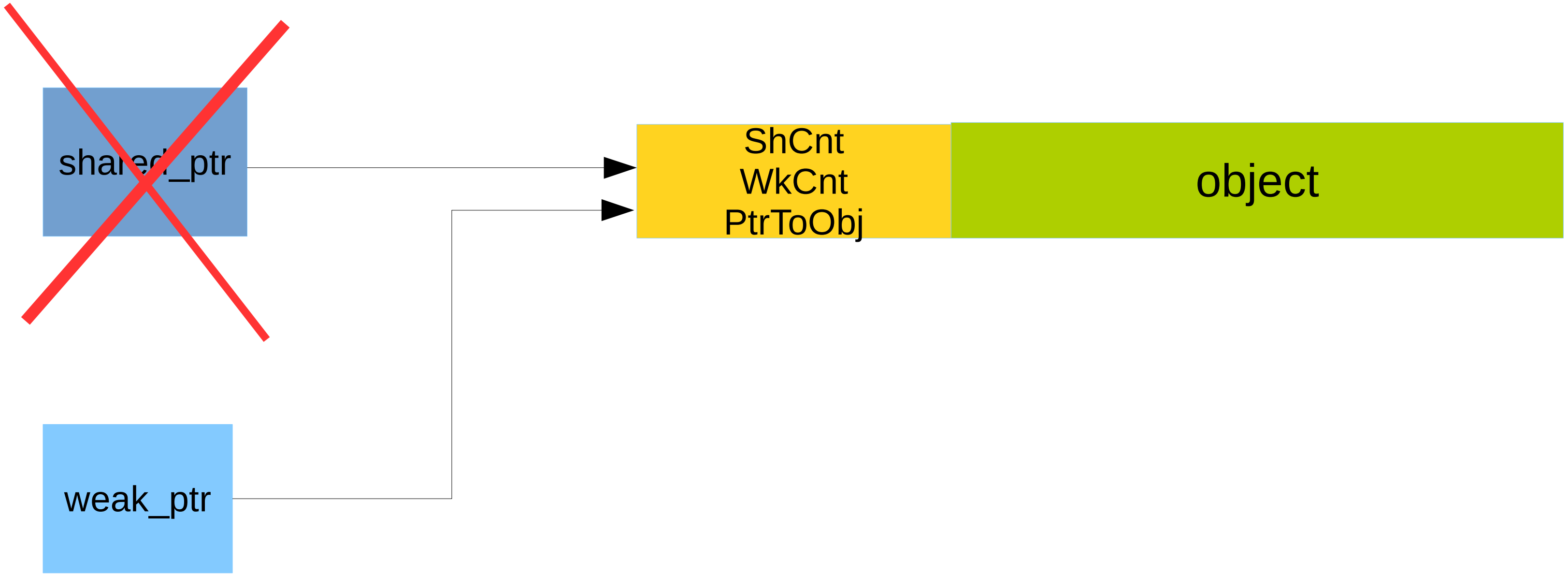

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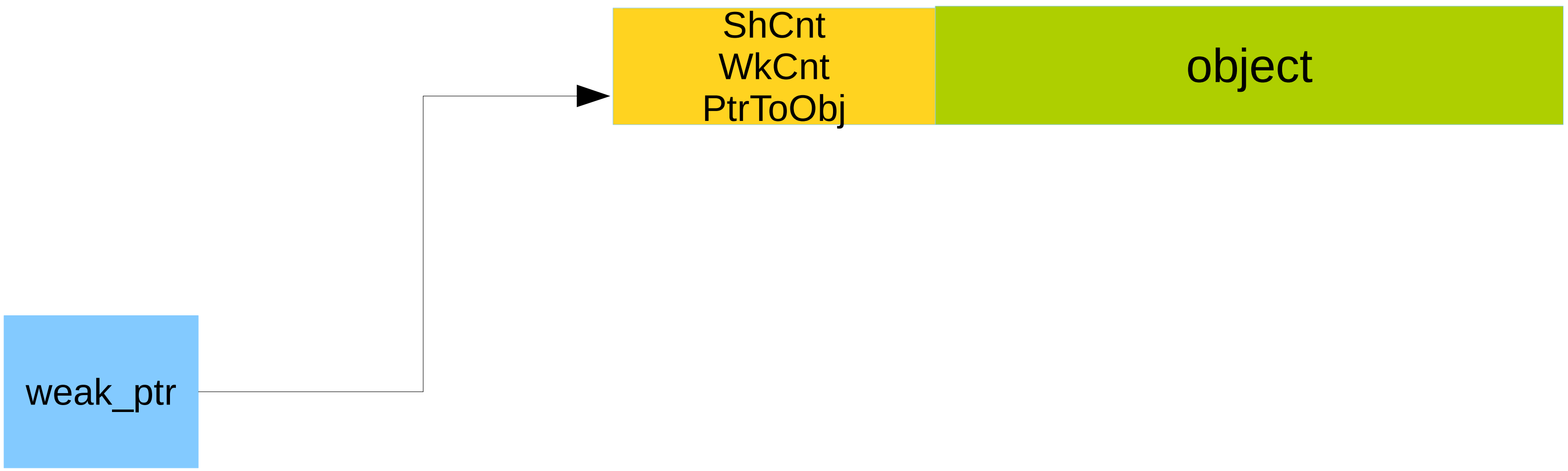

When NOT to use make_*

- Both
  - You need custom deleter
  - You want to use braced initializer
- std::unique_ptr
  - You want custom allocator
- std::shared_ptr
  - Long living weak_ptrs
  - Class-specific new and delete
  - Potential false sharing of the object and the reference counter