Java Reference Objects

or

How I Learned to Stop Worrying and Love OutOfMemoryError

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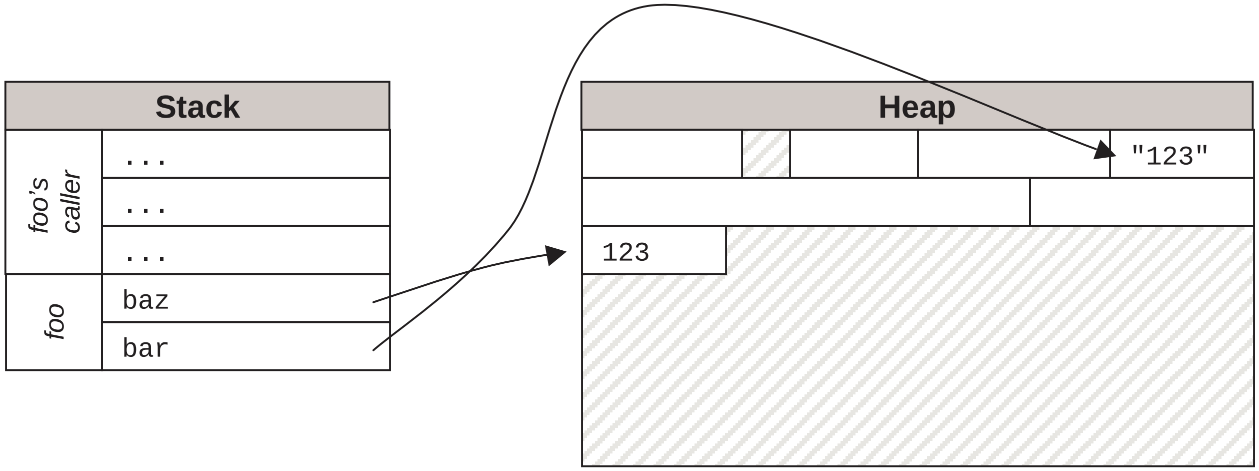
Role of Stack and Heap

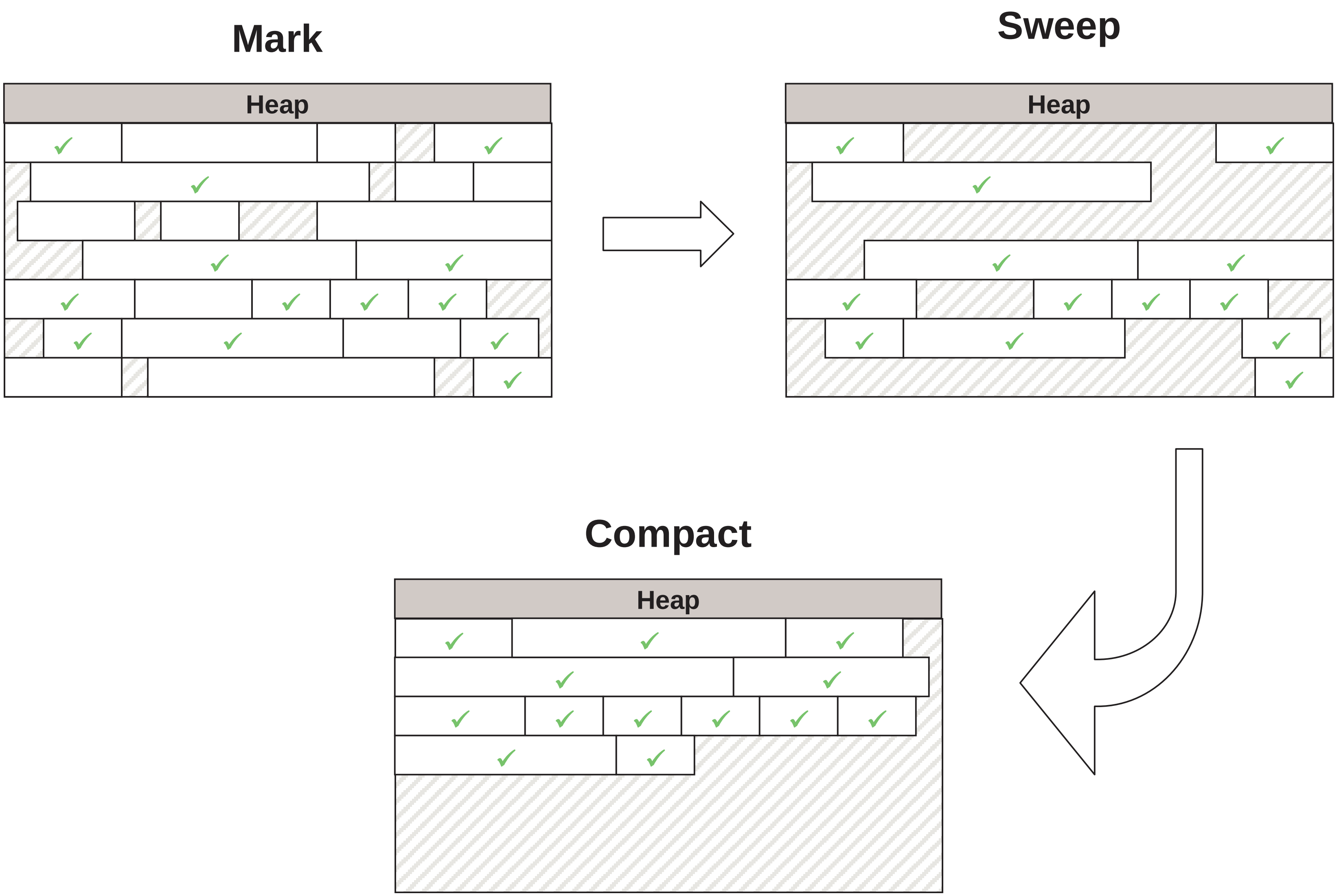
Stack holds all local variables, including method parameters and object references

Heap holds object data

```
public static void foo(String bar)
{
    Integer baz = new Integer(bar);
}
```



Garbage Collection Process



Mark

Heap

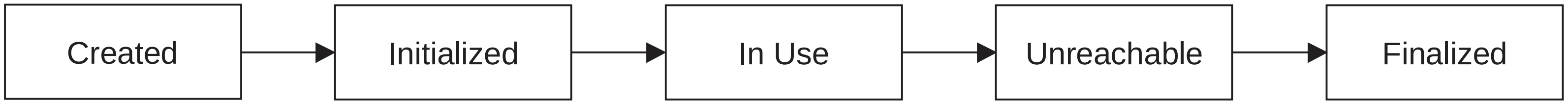
Sweep

Heap

Compact

Heap

Object Life Cycle pre Reference Objects


Created → Initialized → In Use → Unreachable → Finalized

`new` operator creates the object, constructor initializes it

- These are separate steps!

In-use (reachable) when program can access it

- Chain of references from static member variable, local method variable, or in-process expression

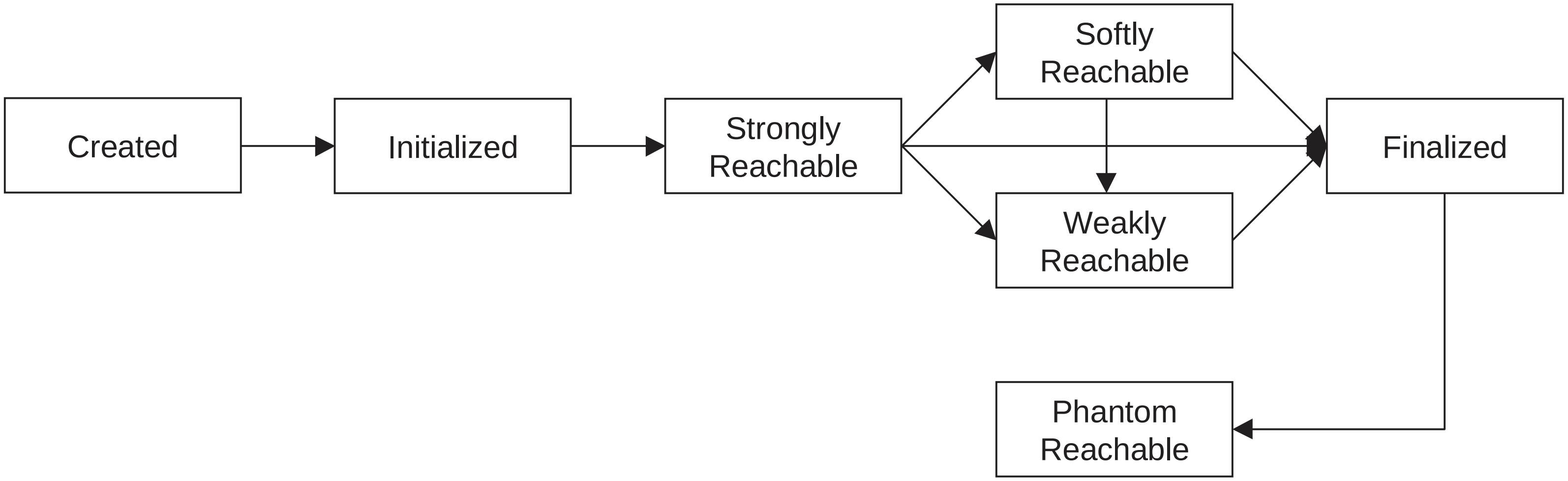
Unreachable when nothing points to it

- But the garbage collector only runs when JVM needs memory
- May never happen!

Finalizer is run after object is selected for collection

- Memory becomes available only after finalizer runs — if it exists

Object Life Cycle post Reference Objects

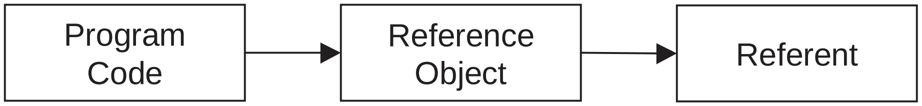


Unreachable objects are still eligible for collection

But there are different levels of unreachability

- Garbage collector is more/less aggressive
- Docs indicate strict hierarchy, that's misleading: reachability depends on the reference objects *you* use

How Reference Objects Work



Adds a layer of indirection

- Call `get()` on the reference object to access referent
- `get()` returns null when referent is collected (reference is “cleared”)

Program must hold a strong reference to the reference object itself

- Otherwise it will be collected

Program must hold strong reference to referent while accessing it

- Otherwise it might be reclaimed between two statements

Phantom references are … different

Types of Reference Objects

`SoftReference`

- Doesn’t prevent garbage collector from reclaiming referent, but asks nicely that it be left alone
- “Official” use: memory-sensitive cache
- Better use: circuit breaker

`WeakReference`

- Garbage collector will reclaim referent at the drop of a hat
- Useful when you want to attach data to an object with limited lifetime
- Or for a canonicalizing map

`PhantomReference`

- Lets program know when garbage collector has already marked referent for collection, allowing program-controlled cleanup
- Can’t be used to access referent directly — `get()` returns null

Reference Queues

Reference objects may be associated with a `ReferenceQueue` when created, will be added to that queue when cleared

- Program can poll `ReferenceQueue` to find cleared objects
- Must still hold a strong reference to the reference object, or it will be collected — queue doesn't hold strong reference

The only way to work with Phantom references

Also useful for cleaning up

- Can poll with a background thread
- Or just check the queue when creating new objects

Soft References as Circuit Breaker

Technique

- Hold large object via `SoftReference` while performing memory-intensive operations
- Switch to strong reference to update the large object
- If reference is cleared, operation fails

Rationale

- Memory consumption tends to be localized
- Failing single operation is better than throwing `OutOfMemoryError`

Not a silver bullet

- Always a window where `OutOfMemoryError` is possible
- Sometimes you can't control this (*eg*, DOM tree)

Code in need of a circuit breaker

```
public static List<List<Object>> processResults(ResultSet rslt)
throws SQLException
{
    try {
        List<List<Object>> results = new LinkedList<List<Object>>();
        ResultSetMetaData meta = rslt.getMetaData();
        int colCount = meta.getColumnCount();
        while (rslt.next())
        {
            List<Object> row = new ArrayList<Object>(colCount);
            for (int ii = 1 ; ii <= colCount ; ii++)
                row.add(rslt.getObject(ii));

            results.add(row);
        }
        return results;
    }
    finally {
        closeQuietly(rslt);
    }
}
```

Adding Soft References

```
SoftReference<List<List<Object>>> ref
    = new SoftReference<List<List<Object>>>(
        new LinkedList<List<Object>>());

while (rslt.next())
{
    List<Object> row = new ArrayList<Object>(colCount);
    for (int ii = 1 ; ii <= colCount ; ii++)
        row.add(rslt.getObject(ii));

    List<List<Object>> results = ref.get();
    if (results == null)
        throw new ResultsTooLargeException();
    else
        results.add(row);
    results = null;
}
```

Weak References for auto-clear cache

Often useful to attach data to an object via Map

- Particularly if you can't extend / decorate the original object
- However, a normal Map can turn into a memory leak, as it always holds a strong reference to the base object

If the map uses a weak reference, once the program is done with the object the associated data goes as well

- Example: `ThreadLocal`
- Should be used by `ObjectOutputStream`, but isn't

JDK provides `WeakHashMap`

- Keys are held by weak references, values by strong references
- When the weak references are cleared, map entry is removed

Canonicalizing Maps

Always returns the same value for a given key

- Think `String.intern()`

Useful when processing data with duplicates

- Pass raw data through map, replace duplicated objects with canonical object
- If there isn't a strong reference to the object, no need to hold it in the map — replace it next time through

Both key and value must be held via weak reference

- `WeakHashMap` isn't sufficient on its own
- But it provides a good starting point

Interning strings via Weak References

```
private Map<String,WeakReference<String>> _map
        = new WeakHashMap<String,WeakReference<String>>();


public static synchronized String intern(String str)
{
    WeakReference<String> ref = _map.get(str);
    String s2 = (ref != null) ? ref.get() : null;
    if (s2 != null)
        return s2;
    _map.put(str, new WeakReference(str));
    return str;
}
```

The Trouble with Finalizers

Finalizers introduce a break between identifying a dead object and reclaiming its memory

- Dead objects go into finalization queue
- If every dead object has a finalizer, you'll get OOM

Finalization takes place on a separate thread

- In practice, just one thread
- A slow finalizer can leave the heap full of uncollected objects

Finalizer may never run

- Only run when when GC identifies object as dead — if GC doesn't run, finalizer isn't executed
- This applies to phantom references as well, but your program can iterate over the references manually

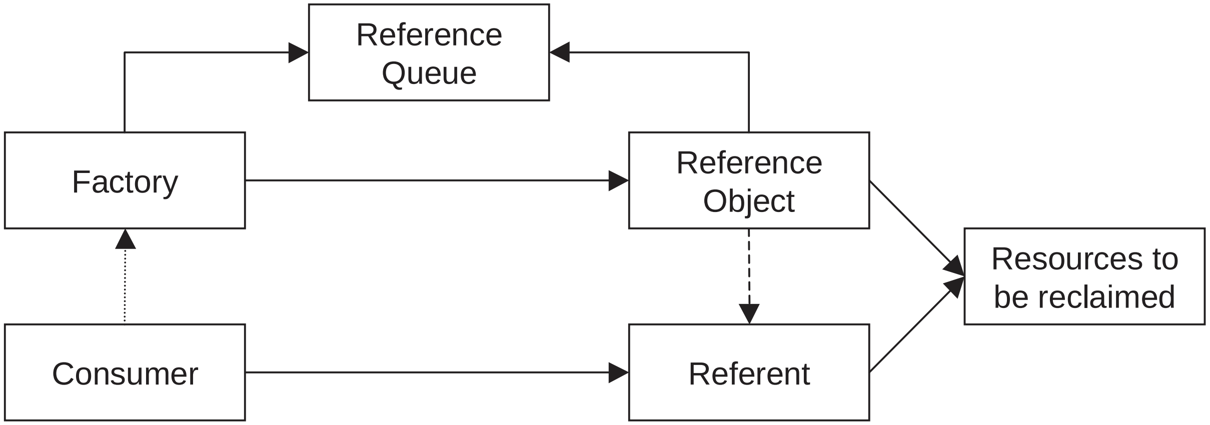
Using Phantom References

The phantom reference must be associated with a `ReferenceQueue`

- The reference is enqueued when its referent is marked for collection
- The memory is not freed until the reference is dequeued!

Program accesses the referent directly, lets it go out of scope

- Must keep a separate (strong) reference to the resources



Phantom Reference Example

Database connection pool

- Wraps actual connection, returns wrapper
- Connection returns to pool via `close()` or wrapper collection

```
private ReferenceQueue<Object> _refQueue = // ...
private IdentityHashMap<Object,Connection> _ref2Cxt = // ...
private IdentityHashMap<Connection,Object> _cxt2Ref = // ...

// ...

private Connection wrapConnection(Connection cxt)
{
    Connection wrapped = new PooledConnection(this, cxt);
    PhantomReference<Connection> ref =
            new PhantomReference<Connection>(wrapped, _refQueue);
    _cxt2Ref.put(wrapped, ref);
    _ref2Cxt.put(ref, wrapped);
    return wrapped;
}
```

Unit Testing and Reference Objects

It isn’t easy

- Running out of memory is harder than it looks
- System.gc() is just a hint
- Make sure that you don’t hold strong references to the referent

But you have to do it

- Reference objects become useful when living on the edge — too easy to fall off if you don’t test

Build task-specific scaffolding

- Example: `ResultSet` implementation that returns large `byte[]`s on every call to `getObject()`

Write development-only tests

- Sometimes Hotspot gets in the way

Additional Reading

The “companion volume” to this presentation.

- `http://www.kdgregory.com/index.php?page=java.refobj`

Sun’s current whitepaper on tuning the garbage collector, which provides some good background information on how the collector works (Sun JVM only).

- `http://java.sun.com/docs/hotspot/gc5.0/gc_tuning_5.html`

An article from Brian Goetz, about using Weak references to associate objects with limited lifetimes. I don’t often use this technique, so only touched on it lightly in this presentation. I recommend reading his entire series of articles.

- `http://www.ibm.com/developerworks/java/library/j-jtp11225/index.html?S_TACT=105AGX02&S_CMP=EDU`