Reference counting

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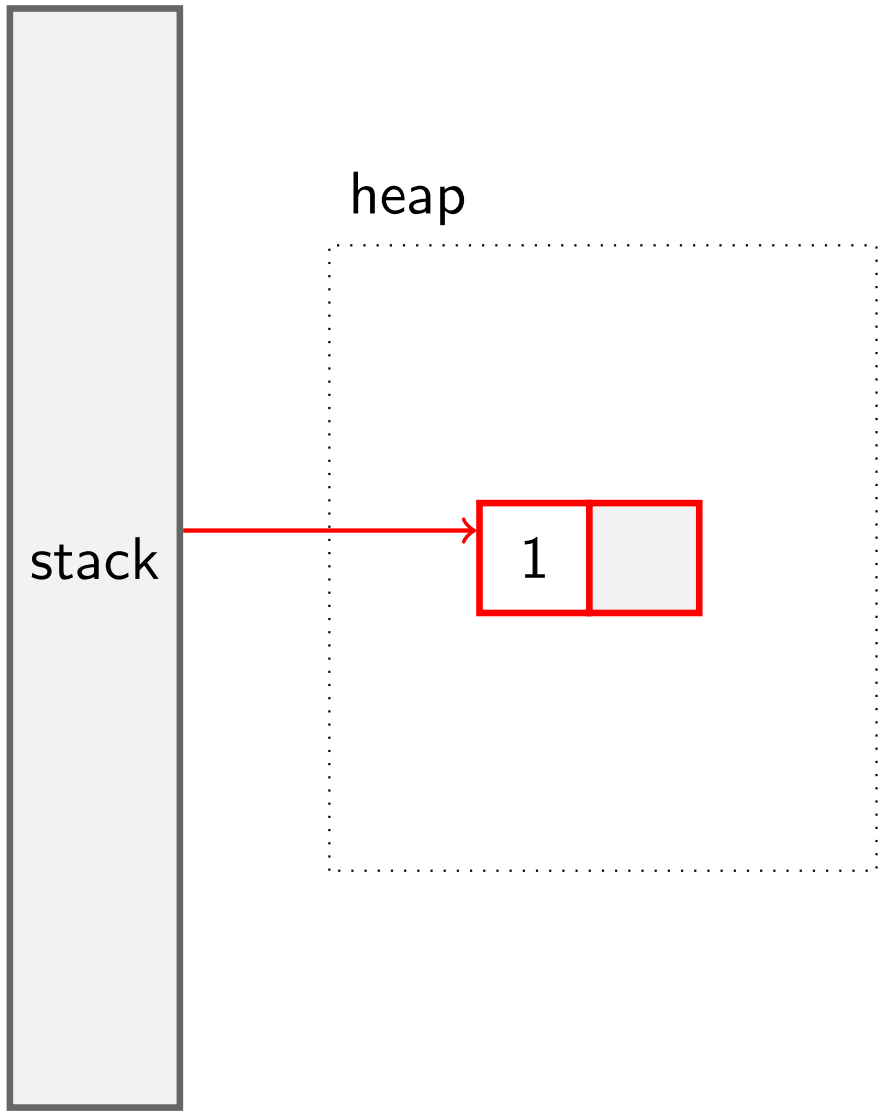
Introduction

Reference counting is an **garbage collection** algorithm. It is based on **recording the number of pointers that points to given chunk of memory**. When the number of pointers drops to zero, the chunk can be declared garbage.

In line with the name ‘reference counting‘, in this presentation pointers will be called ‘references’.

Basic rules (1)

1. When a chunk is allocated from the heap, its reference count is initialized to **one**.
2. Whenever a reference to the chunk is **duplicated**, its reference count is **increased by one** (incremented).
3. Whenever a reference to the chunk is **deleted**, its reference count is **decreased by one** (decremented).
4. If the reference count **drops to 0**, the chunk **can be freed** because it is no longer reachable



Basic rules (2)

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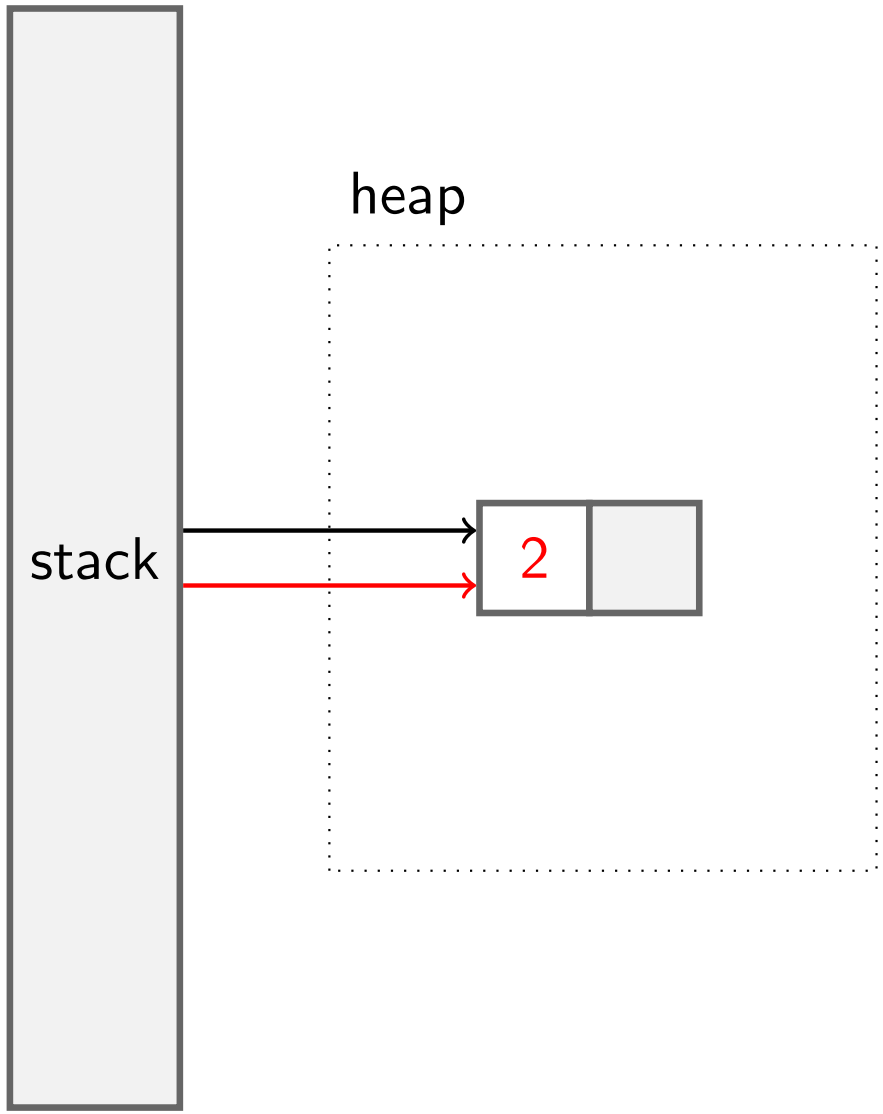

Basic rules (3)

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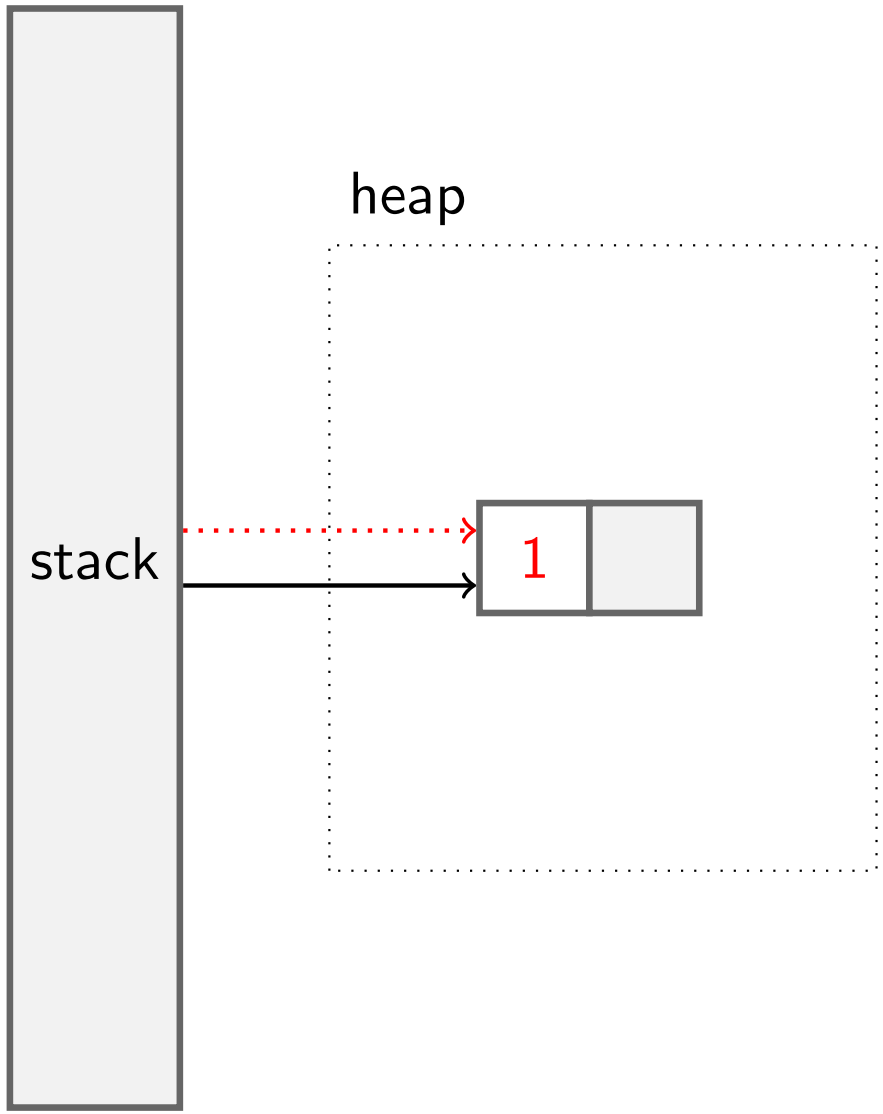

Basic rules (4)

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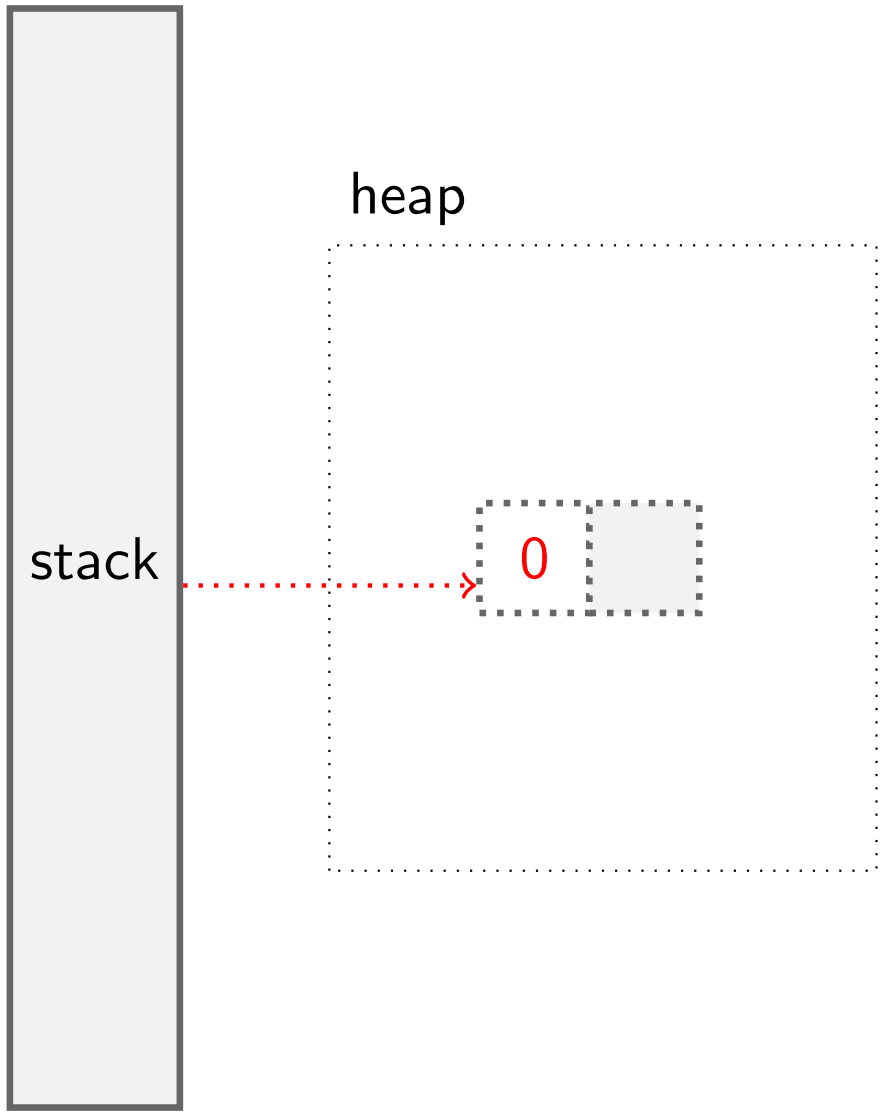

On-the-fly

Reference counting is **on-the-fly** type of garbage collector (also called incremental): some actions are performed at each call of `malloc` and/or `free`. These actions make some local modifications to the chunk structure to increase the probability of finding a free chunk when needed.

Main implementation challenges

1. keeping track of all reference manipulations
2. recursively freeing chunks with zero reference count

Reference manipulations

The compiler **inserts special code for all reference manipulations** and at each call of `malloc` and/or `free` - incrementing the reference count when a reference to a chunk is duplicated and decrementing it when such a reference is deleted.

Besides assignment statements, the compiler also has to add reference increasing code to **parameter transfers**, since a reference that is passed as a parameter is effectively assigned to a local variable of the called routine. Note that not all references in the running program are references to chunks on the heap; many of them point to blocks in the program data area, and all reference counting code must make sure it does not follow such references.

p := q additional reference manipulations pseudocode

```
if Points into the heap (q):
    Increment q.referenceCount;
if Points into the heap (p):
    Decrement p.referenceCount;
    if p.referenceCount = 0:
        FreeRecursively (p);
```

recursively freeing chunks pseudocode

```
procedure FreeRecursively(Pointer);
    if not IsPointerIntoHeap (Pointer): return;
    if Pointer.referenceCount != 0: return;
    for each i in 1 .. Pointer.numberOfPointers:
        if IsPointerIntoHeap (Pointer.pointer [i]):
            Decrement Pointer.pointer [i].referenceCount;
            FreeRecursively(Pointer.pointer [i]);
    FreeChunk(Pointer);
```

Recursively freeing cons

Cons

Recursion is, however, an unwelcome feature in a garbage collector since it requires an **unpredictable amount of stack space**.

Having a garbage collector fail for lack of memory is kind of embarrassing, though, and several techniques have been invented to avoid the problem. The best solution is using **pointer reversal**.

Identification techniques

figures that will illustrate this algorithm

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Algorithm issues

Cons

1. efficiency
2. memory fragmentation
3. failes to reclaim a cyclic data structure

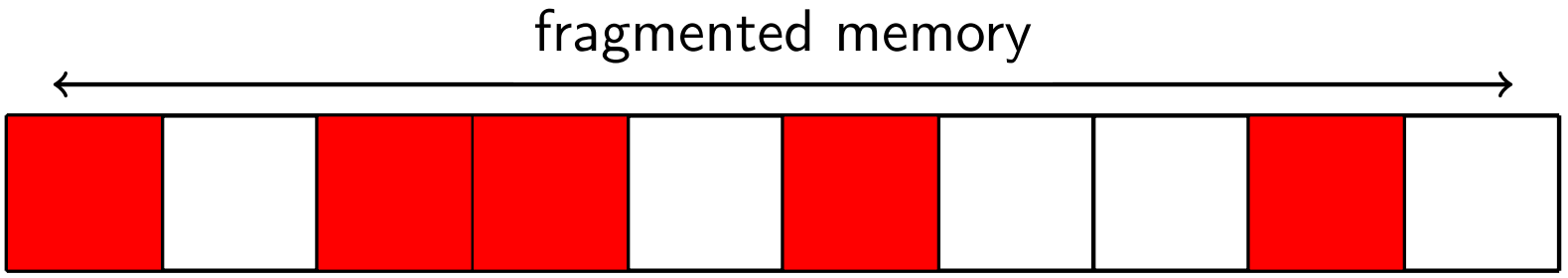
Efficiency

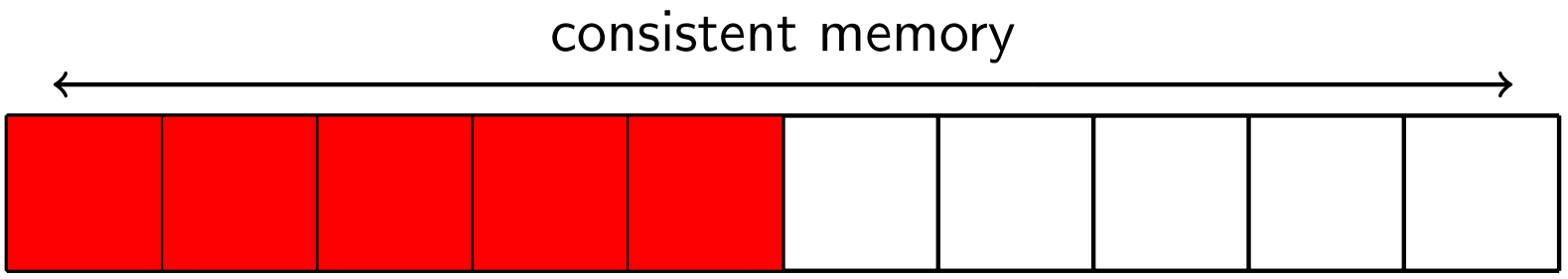
The compiled code has to monitor **all reference manipulations** and each and every reference manipulation requires the adjustment of the associated reference counts.

This is a considerable **overhead** in comparison to other garbage collection techniques that do not monitor any pointer action and reclaim garbage chunks only when needed.

Memory fragmentation

The free list is augmented with the reclaimed chunks, but it remains **fragmented**. In principle doing a compaction phase during a reference counting allocation request is possible, but few reference counting garbage collectors go to such lengths.





Cycles

The problem with reference counting is that it takes its decisions by considering **only one node** in the graph at a time and *in order to reclaim a cyclic data structure all nodes in the data structure should be considered as garbage together*.

Once reference counting has failed to reclaim a cyclic data structure, the chunks involved **will never be reclaimed**. This has the unfortunate effect that free space leaks away, which might even cause the program to run out of free space when other garbage collectors would be able to reclaim the cyclic structures and allow the program to continue.