A slab-allocator for similar objects

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Abstract

A pool is a slab allocator parameterized to one type, offering packed random-access insertion and deletion. Pointers to valid items in the pool are stable, but not generally in any order. When removal is ongoing and uniformly sampled while reaching a steady-state size, it will eventually settle in one contiguous region.

1 MOTIVATION

In many applications, we would like a stream of one type of many objects address' to be stable throughout each of their lifetimes. We can not tell, *a priori* how many objects at one time will be needed. We would like to cache these objects for re-use instead of allocating and freeing them every time. Dynamic arrays are not suited for this because, in order there to be a contiguity guarantee, the pointers are not guaranteed to be stable. C^{++}'s `std::deqeue` is close, but it only allows deletion from the ends. The pool, therefore, must not be contiguous, but we want blocks of data to be in one section of memory for fast cached-access and low storage-overhead.

2 DETAILS

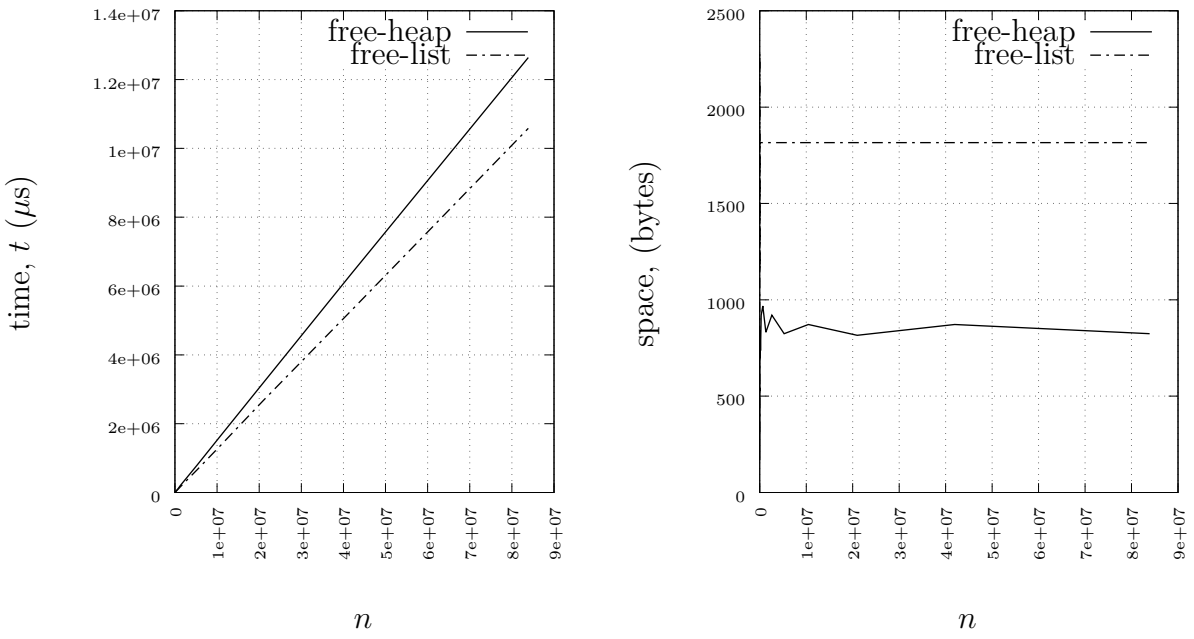
We only need to worry about one parametrized type and size, simplifying matters greatly. This suggests an an array of slabs[1], where each slab is a fixed size array. When any slab gets full, another, exponentially bigger, slab is created.

To reach the ideal contiguous slab of memory, we only allocate memory to an item from the slab of largest capacity, active slab_0. When data is deleted from a secondary slab, it is unused until all the data is gone. When the slab's object count goes to zero, it is freed.

2.1 Marking Entries as Deleted

We face a similar problem as garbage collection: in the active chunk_0, we need some way to tell which are deleted. The first choice is a free-list. When adding an entry, check if the free-list is not empty, and if it is not, we recycle deleted entries by shifting the list. Alternately, popping the free-list works, too, but on average, shifting yields lower, more compact addresses.

The free-list is $\mathcal{O}(1)$ amortized run-time, but hard $\Theta(\sum_n \text{capacity of chunk}_n)$[2] space requirement. Alternately, we could use an implicit complete binary-tree free-heap[3]. This will negatively affect the run-time, $\mathcal{O}(\log \text{chunk}_0)$, but space requirement is much more reasonable, $\mathcal{O}(\text{chunk}_0)$. A reference count suffices on the secondary chunks.



(a) Run-time. (b) Space.

Figure 1: Time and space to inserting and deleting n random, but linearly stable about 50 items.

Figure 1 compares a hypothetical `struct keyval` with an `int` and a string of 12 `char` both in run-time, Figure 1a, and total space, Figure 1b. It was decided that the space requirement of using a free-list is too great for, what turned out to be, a very modest performance gain in this region.

With a free-list, all the items in a block that are non-deleted have a null pointer attached to them. A free-heap saves initializing and reading the list, and only needs the space for what one has deleted. This is not without a downside: there is no guarantee that one will be able to expand the heap to account for a deletion; it could be that deleting an item fails.

2.2 Which chunk are they in?

Except primary chunk$_0$, we maintain the chunks sorted by memory location. Whenever we allocate a new chunk$_0$ in response to the old chunk$_0$ being full, it requires that we binary search the array of chunks and insert the old, $\mathcal{O}(\log \text{chunks} + \text{chunks}) = \mathcal{O}(\text{chunks})$. Similarly for deleting a chunk. Because the exponential growth of chunks, this happens $\mathcal{O}(\log \text{items})$. Thus, the worst-case time to delete is, $\mathcal{O}(\text{chunks} + \log \text{items in chunk}_0) = \mathcal{O}(\log \text{items})$.

Insertion is amortized $\mathcal{O}(1)$. In the case where chunk$_0$ is full, we allocate a new chunk for at least $(1 + \epsilon)n$ new entries, and each entry bears a transfer of constant time. In practice, we use an approximation to golden ratio for the growth factor.

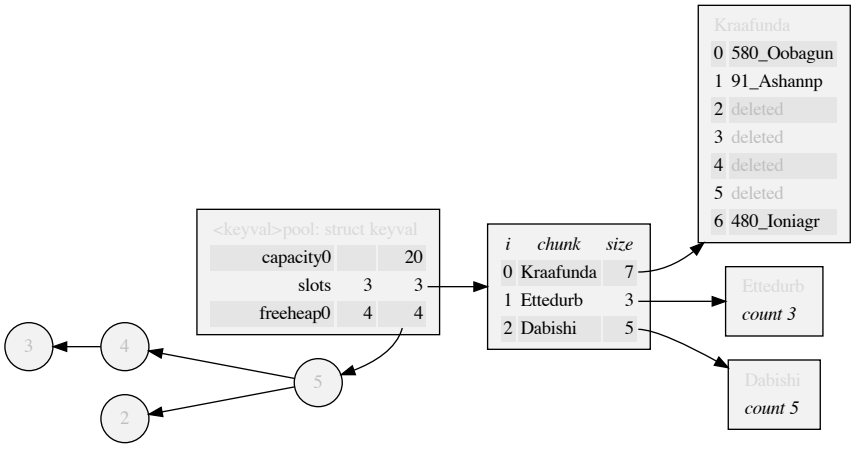


Figure 2: A pool consists of several chunks of packed data managed by an array, and a free-heap for chunk_0.

In the case where the free-heap is empty, just return $\text{chunk}_0[\text{size}_0]$. If there's any addresses in the maximum free-heap, just pop an address from the array of which the heap is made and return it; we know that it is lower in the binary-tree heap than those higher up. We prefer to have low-numbers, but any number would do.

Figure 2 shows a diagram of a pool. This is the *free-heap* design from Figure 1.

2.3 Heap implementation

This implements an invariant that the end of the list is never deleted. A maximum-heap with which we can compare the data in the maximum position in chunk_0 on deletion. If it matches, we decrement the max value and pop from the stack until top $< \text{address}_{\text{end}}$. The procedure is amortized. For example, in Figure 2, if we deleted the data at chunk_0, index 6, `480_Ioniagr`, then it would result in successive amortized deletions of all the heap; the *size* would be 2.

3 CONCLUSION

Solely focusing on one object only, we can make a simple memory pool. To ensure random-access deletion, we use a free-maximum-heap to ensure that the end is never deleted.

REFERENCES

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