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MAM: A Memory Allocation Manager for GPUs

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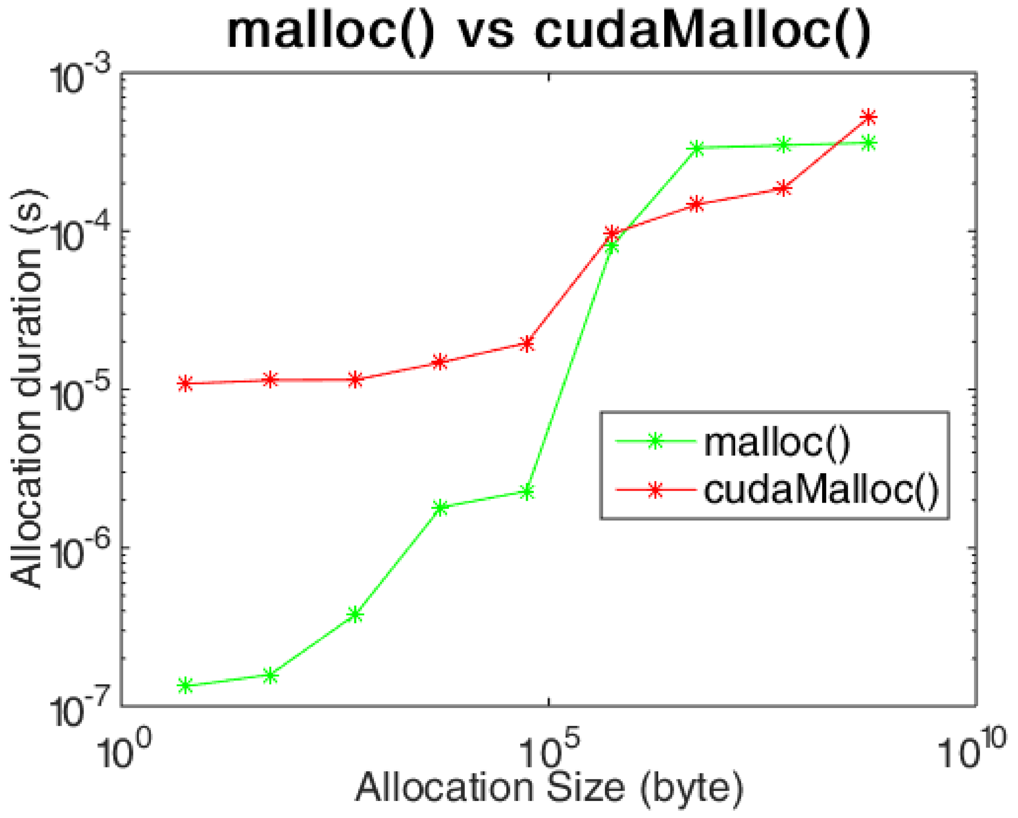
Motivation

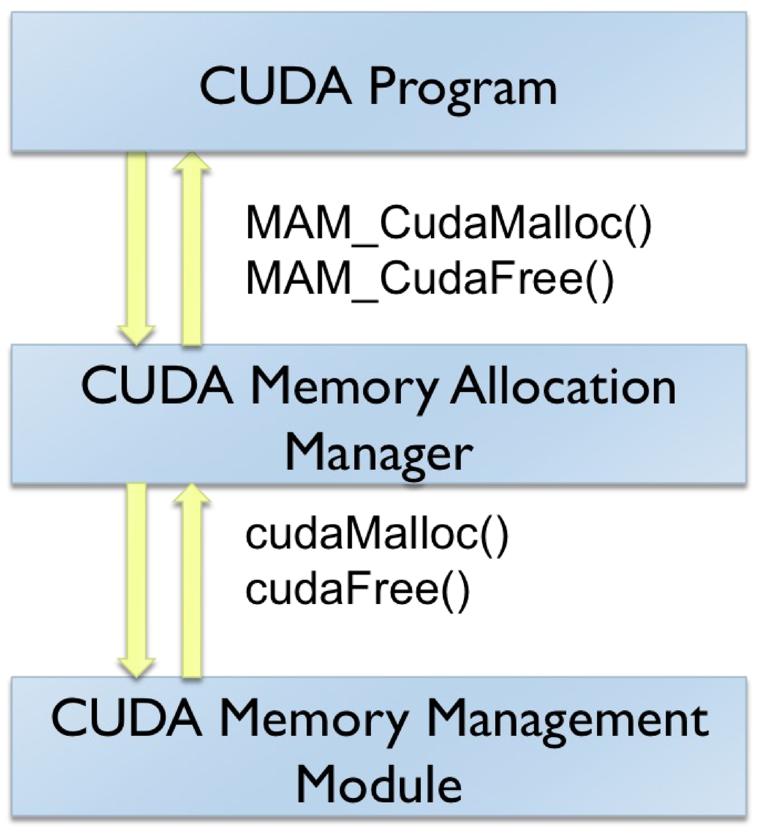


`cudaMalloc()` is slow especially when allocation size is large.

Applications requiring repetitive allocations may reduce the performance.

We develop a memory management library primarily for GPUs.

What is MAM ?



- MAM is a C library that provides an abstraction layer between the programmer and the memory management module of CUDA environment.
- MAM removes the overhead of memory allocation and deallocation.

How to use MAM ?

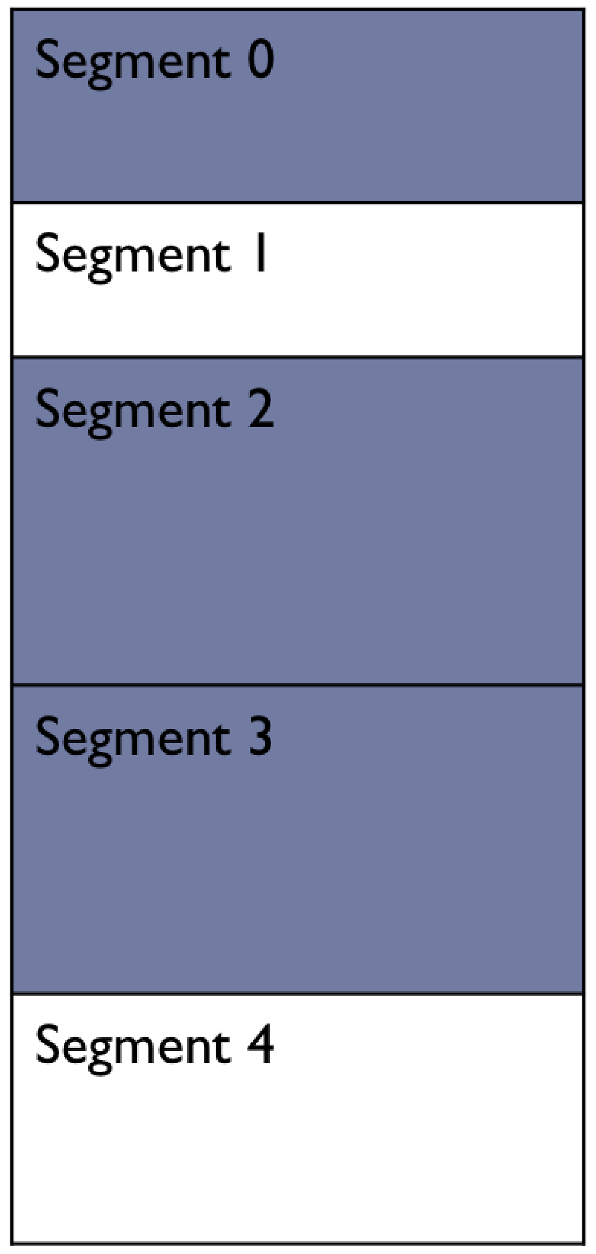
WITHOUT MAM

```
cudaMalloc(&ptr, size);
...
cudaFree(ptr);
```

WITH MAM

```
MAM_Create();
MAM_CudaMalloc(&ptr, size);
...
MAM_CudaFree(ptr);
MAM_Destroy();
```

How MAM Works ?



Blue: Segments being used
White: Empty segments

- When `MAM_Create()` is called, a large continuous *chunk* of memory is allocated on the device.
- The size of the *chunk* is expected to be greater than the total size of the memory that will be allocated by the CUDA program at a time instance.
- During allocation and deallocation, MAM manipulates *segments* of the *chunk* by creating and destroying them.
- Each *segment* is nothing but a small sized structure stored in the host memory.

```
struct segment {
  void *basePtr;
  size_t size;
  char isEmpty;
  /* data related to data
  structures */
};
```

Data Structures in MAM

The Pointer Tree

- Stores empty segments sorted according to their sizes.
- Red-Black Tree is used.

The Size Tree-Dictionary

- Stores empty segments sorted according to their sizes
- Red-Black Tree is used.

Allocation Algorithm

```
procedure ALLOCATE
  Find a best-fitting empty segment from the tree-
dictionary O(log n)
  Mark the segment as filled O(1)
  if The segment perfectly fits O(1) then
    Remove segment from tree-dictionary O(log n)
  else
    Resize it O(1)
    Remove it from tree-dictionary O(log n)
    Create a new empty segment O(1)
    Insert it in pointer-tree & tree-dictionary O(log n)
  end if
  Return the base pointer of filled segment O(1)
end procedure
```

Deallocation Algorithm

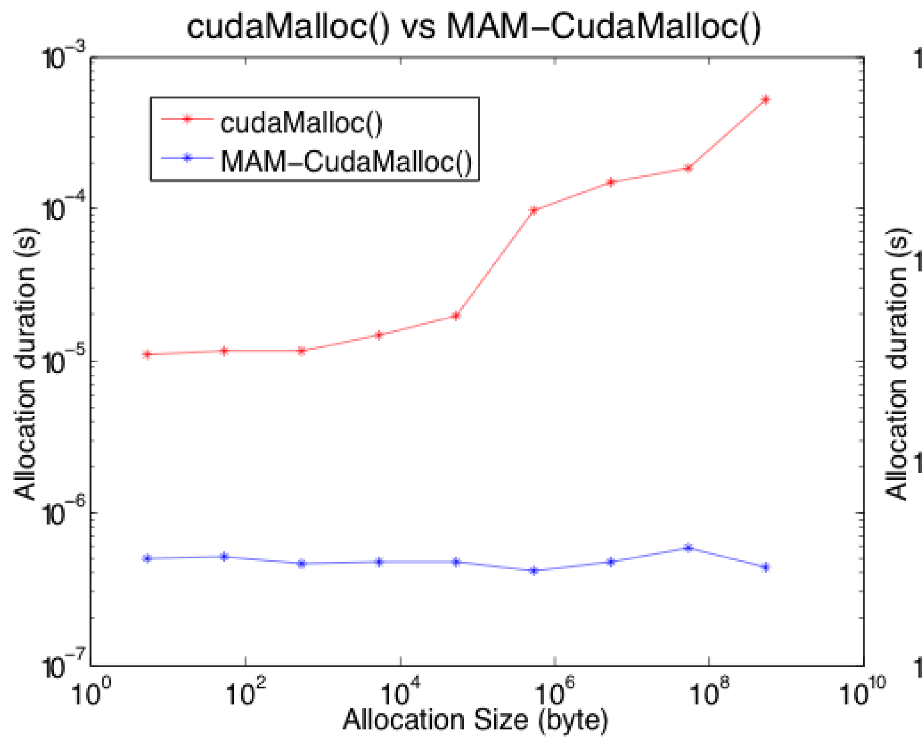
```
procedure DEALLOCATE
  Find the segment in the pointer-tree O(log n)
  Mark the segment as empty O(1)
  Get previous and next segments O(log n)
  if the previous segment is empty O(1) then
    Remove the segment being newly emptied from pointer-tree and
tree-dictionary O(log n)
    Destroy the segment being newly emptied O(1)
    Resize previous segment O(1)
    Replace it in tree-dictionary O(log n)
    Assign it to the variable stored the destroyed segment O(log n)
  end if
  // repeat the similar procedure for next segment.
end procedure
```

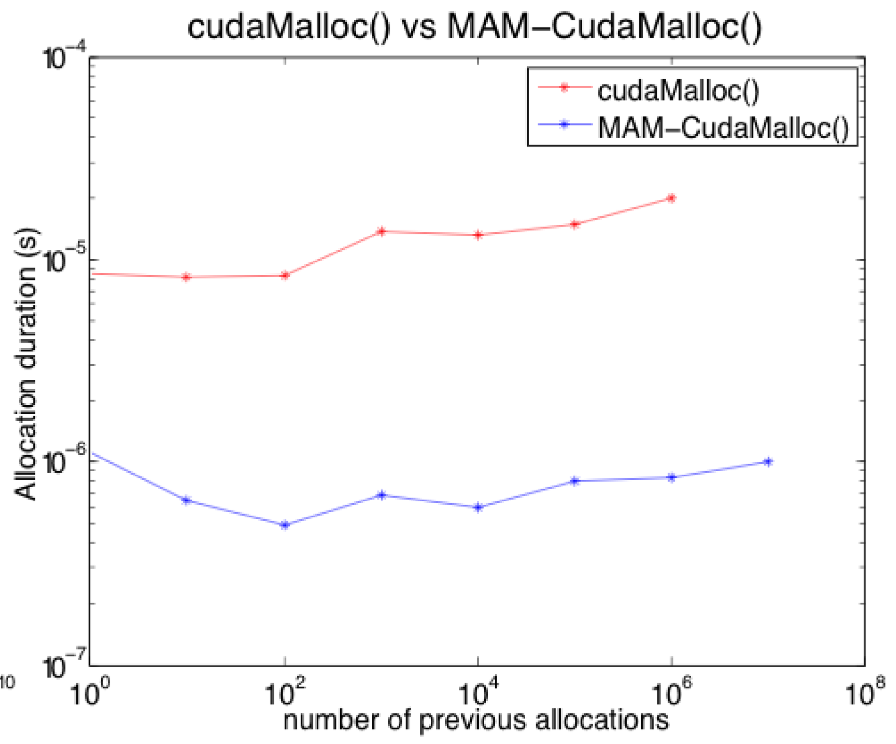
For both algorithms,

- Time complexity: O(log n)
- Space complexity: O(n)

where n = number of segments

Performance Results





- MAM performs better in the mesurement which is according to the allocation size. While the allocation duration of `cudaMalloc()` increases linearly, the duration of `MAM_CudaMalloc()` stays constant.
- MAM performs better also in the measurement which is according to the number of previously allocated segments.