Dynamic Memory Management

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VI) Benchmarks

Motivation

Why do we have to care about memory management ?

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Answer:

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$\mathcal{H}$-matrix Multiplication, constant rank			
p	**SUN**	**PTmalloc**	**rmalloc**
1	98.6 s (82 MB)	98.4 s (81 MB)	99.5 s (84 MB)
16	47.3 s (100 MB)	7.3 s (94 MB)	7.2 s (109 MB)

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- should handle large memory footprint (> 64GB)
- minimal memory allocation, low *fragmentation*

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Options:

- *Splitting*: split larger block and put remainder back into allocator
- *Coalescing*: if free chunks are adjacent in memory, join them

Basic Techniques

Sequential Fits

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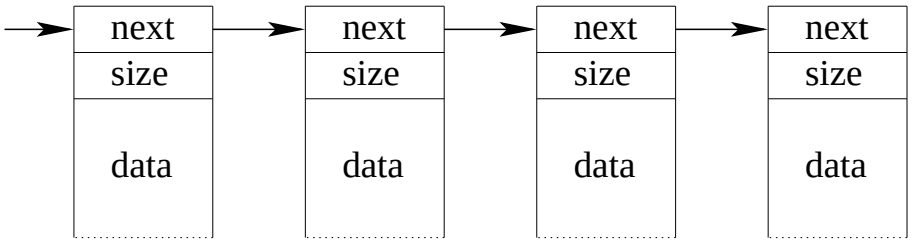
Single list of free blocks:



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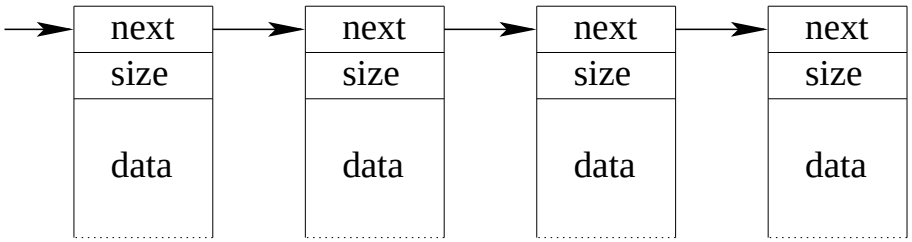

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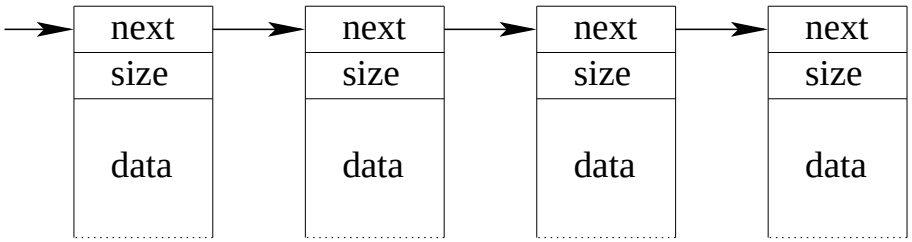

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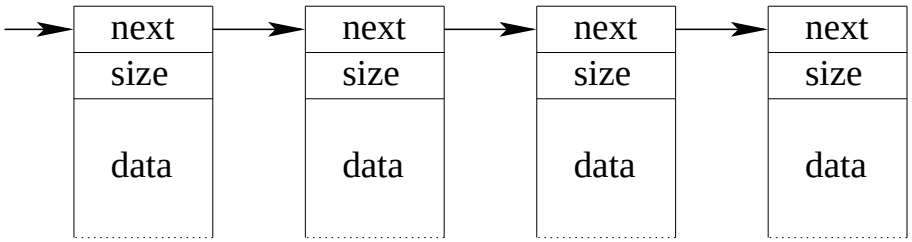

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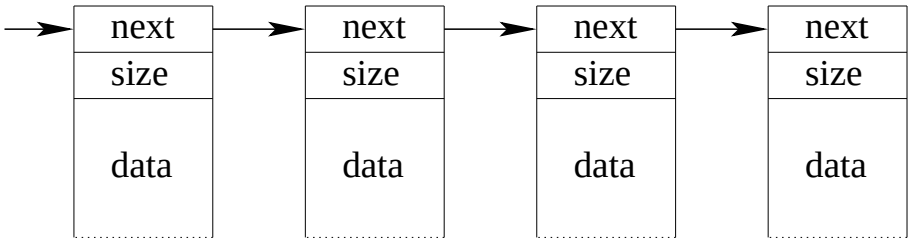

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- bad scaling w.r.t. processors and memory

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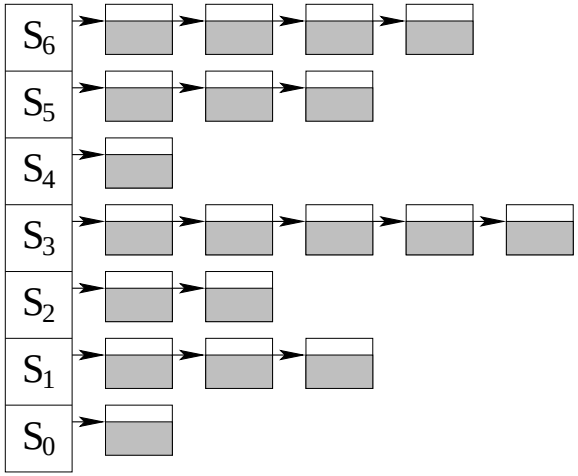
Typical definition: by power series

$$S_i = b^i, \quad b > 1$$

Segregated Free Lists: use array of lists for each size class



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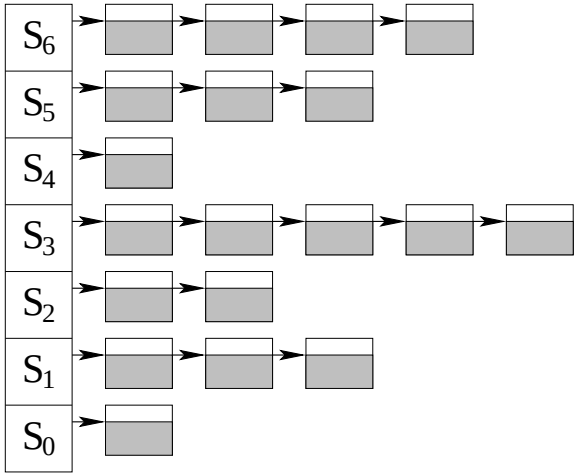

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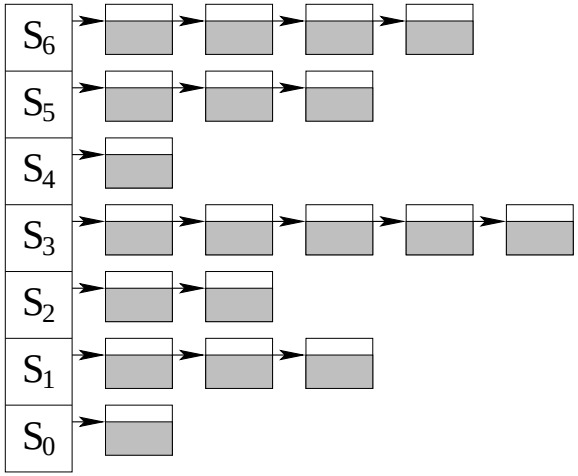

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Option: round up each size to size of class

- $O(1)$ complexity for malloc and free (all blocks in class have same size)
- higher memory consumption, but bounded internal fragmentation

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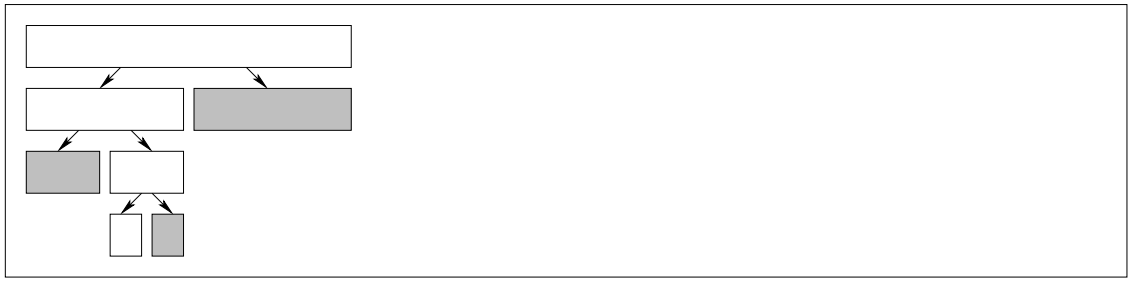

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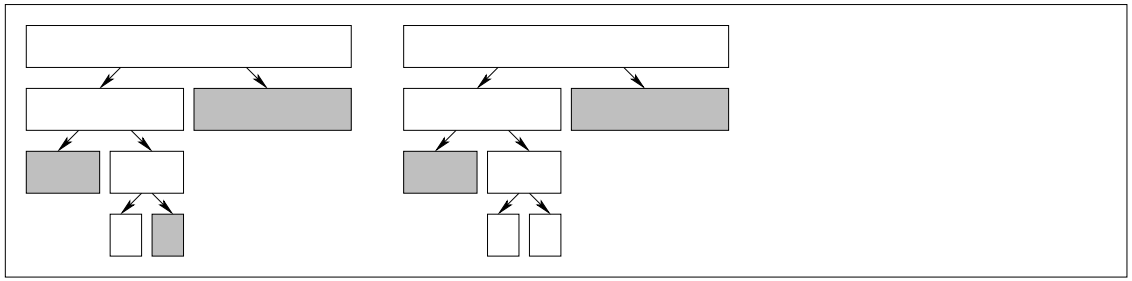

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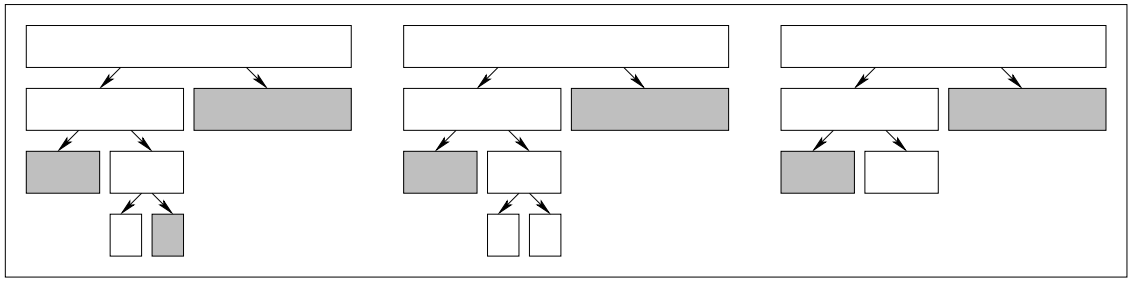

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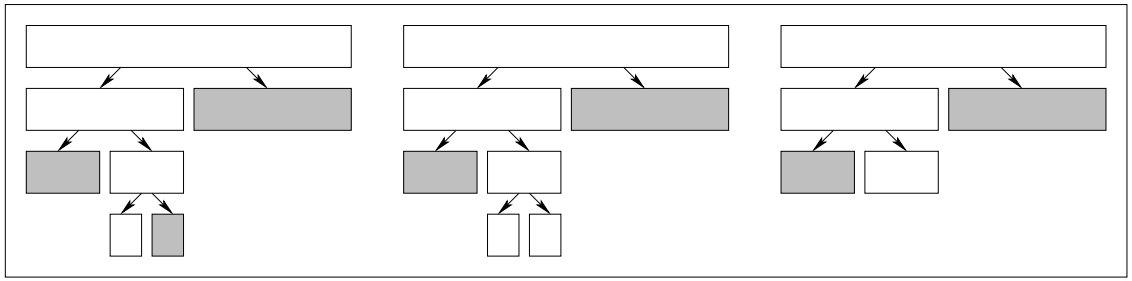

- *Fibonacci buddies*: uses Fibonacci series for splitting

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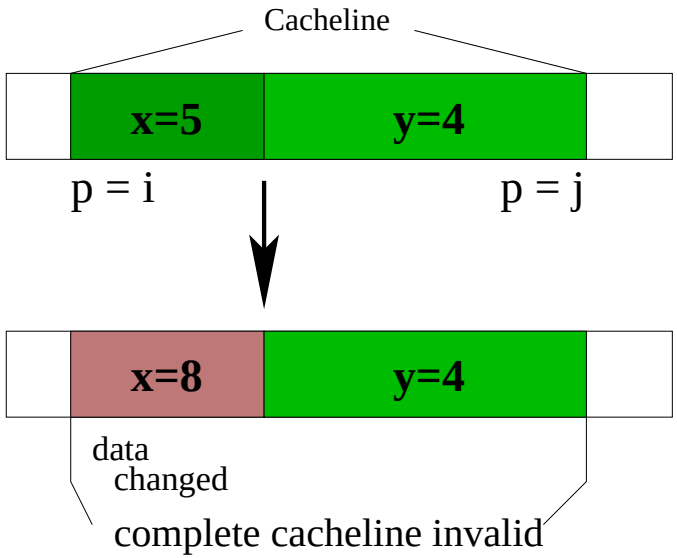
- writing data on one processor leads to memory access on other processor



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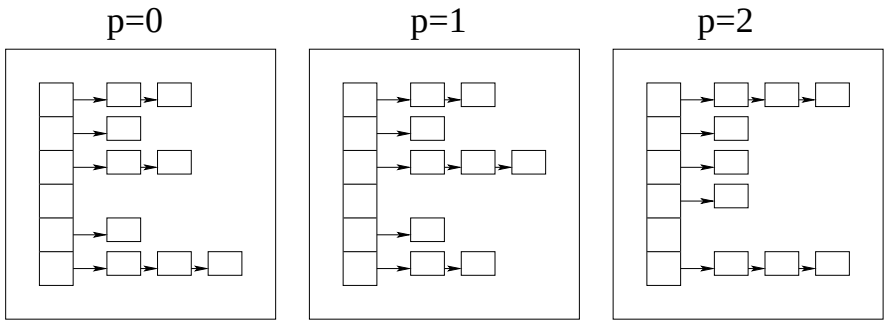

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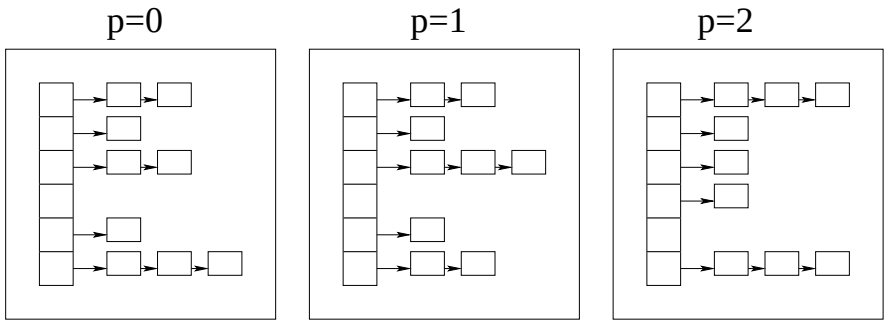

  - data on different processors is allocated from different areas
  - important: freed chunks must be returned to their heaps
  - memory management is completely independent on different processors
  - but: memory consumption grows linearly in p (higher external fragmentation)

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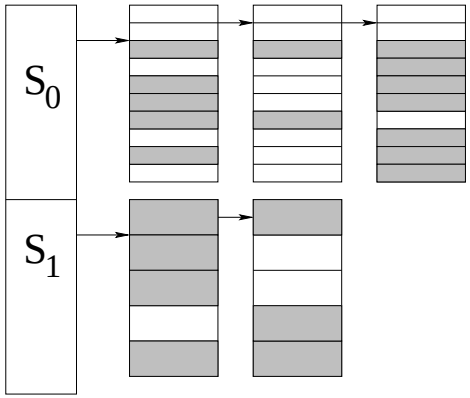

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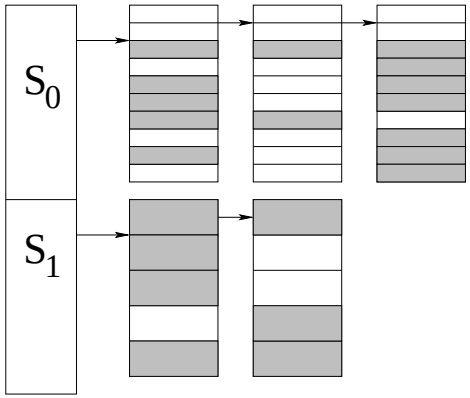

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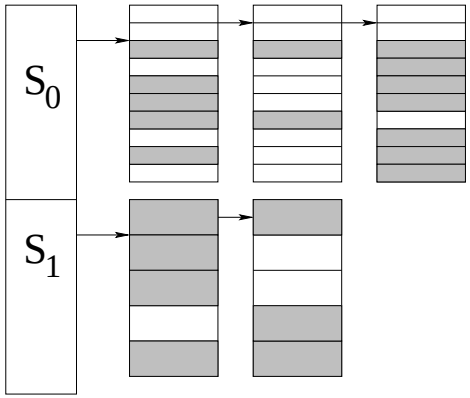

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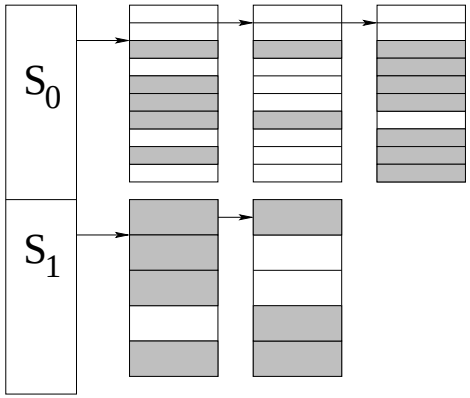

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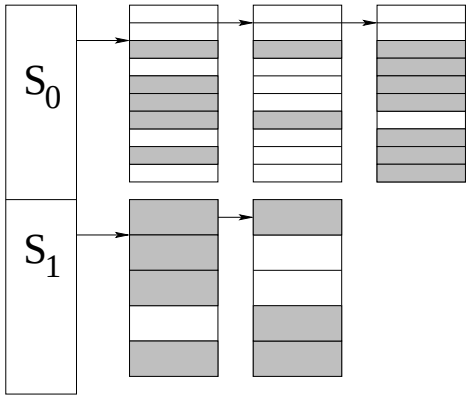

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- but: maximal managed size defined by size of superblock

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  - Middle sized chunks ($256\mathrm{B} < s < 260\mathrm{MB}$):
    - segregated free lists with immediate coalescing and splitting
  - Small chunks ($\leq 256\mathrm{B}$):
    - stored in *containers* (superblocks) of a fixed size ($8\mathrm{kB}$)
    - unused containers are cached and can be reused by different size classes
    - avoids splitting/coalescing for small blocks, reduces external fragmentation

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- size of preallocated area dependent on current memory usage

Benchmarks

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$\mathcal{H}$-building, fixed precision					
malloc	**4096**	**16384**	**65536**	**262144**	**memory**
SUN	1.2 s	5.3 s	24.9 s	147.8 s	592 MB

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SUN	56.7 s	539.2 s	4065.3 s	1399 MB
PT	56.3 s	571.7 s	5174.5 s	1373 MB
RM	56.1 s	510.7 s	3683.0 s	1399 MB

$\mathcal{H}$-matrix Multiplication, fixed rank						
malloc	$t(1)$	$t(4)$	$t(8)$	$t(12)$	$t(16)$	**memory**
SUN	98.6 s	34.9 s	39.4 s	45.6 s	47.3 s	100 MB
PT	98.4 s	26.8 s	13.7 s	9.3 s	7.3 s	94 MB
MT	99.3 s	26.1 s	13.3 s	9.1 s	7.2 s	144 MB

$\mathcal{H}$-inversion, fixed precision				
malloc	**4096**	**16384**	**65536**	**memory**
SUN	56.7 s	539.2 s	4065.3 s	1399 MB
PT	56.3 s	571.7 s	5174.5 s	1373 MB
RM	56.1 s	510.7 s	3683.0 s	1399 MB

$\mathcal{H}$-matrix Multiplication, fixed rank						
malloc	$t(1)$	$t(4)$	$t(8)$	$t(12)$	$t(16)$	**memory**
SUN	98.6 s	34.9 s	39.4 s	45.6 s	47.3 s	100 MB
PT	98.4 s	26.8 s	13.7 s	9.3 s	7.3 s	94 MB
MT	99.3 s	26.1 s	13.3 s	9.1 s	7.2 s	144 MB
RM	99.5 s	26.2 s	13.3 s	9.0 s	7.2 s	109 MB

libBEM, building PC operator				
malloc	**4098**	**16386**	**65538**	**memory**
SUN	48.6 s	290.6 s	1477.2 s	8609 MB

libBEM, building PC operator				
malloc	**4098**	**16386**	**65538**	**memory**
SUN	48.6 s	290.6 s	1477.2 s	8609 MB
PT	46.4 s	223.3 s	838.4 s	8176 MB

libBEM, building PC operator				
malloc	**4098**	**16386**	**65538**	**memory**
SUN	48.6 s	290.6 s	1477.2 s	8609 MB
PT	46.4 s	223.3 s	838.4 s	8176 MB
RM	45.6 s	219.2 s	811.2 s	8395 MB