CSE 373

OCTOBER 23RD – MEMORY AND HARDWARE

MEMORY ANALYSIS

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  - Consider the worst case

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  - Rather than counting the number of operations, we count the amount of memory needed
  - During the operation, when does the algorithm need to "keep track" of the most number of things?

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  - When the tree is at its widest – how many nodes is that?
  - **N/2:** half the nodes of a tree are leaves

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  - **AVL Insert?** Yes, we need to keep track of the path from the insertion to the root

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  - This isn't always true!
  - At any given time, some memory might be cheaper and easier to access than others
  - Memory can't always be accessed easily
  - Sometimes the OS lies, and says an object is "in memory" when it's actually on the disk

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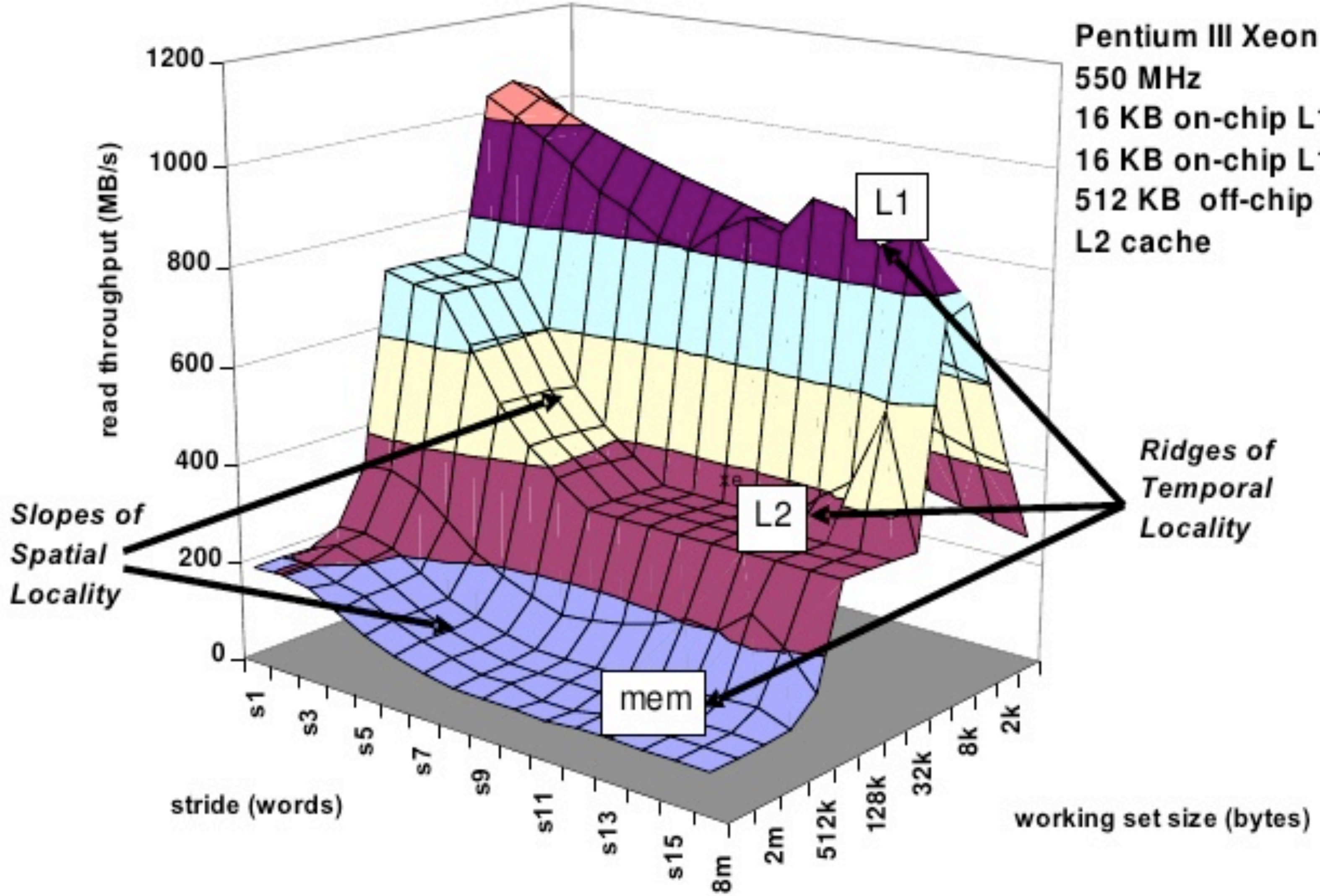
  - Sometimes there isn’t enough available, and so memory that hasn’t been used in a while gets pushed to the disk
- **Memory that is frequently accessed goes to the cache, which is even faster than RAM**

The Memory Mountain



Pentium III Xeon
550 MHz
16 KB on-chip L1 d-cache
16 KB on-chip L1 i-cache
512 KB off-chip unified
L2 cache

LOCALITY AND PAGES

- **So, the OS does two smart things**
  - Spatial locality – if you use memory index Ox371347AB, you are likely to need Ox371347AC – bring both into cache
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  - These are called pages, and they are usually around 4kb
  - All of the processes on your computer have access to pages in memory.

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  - But you can use that 4kb if you need more

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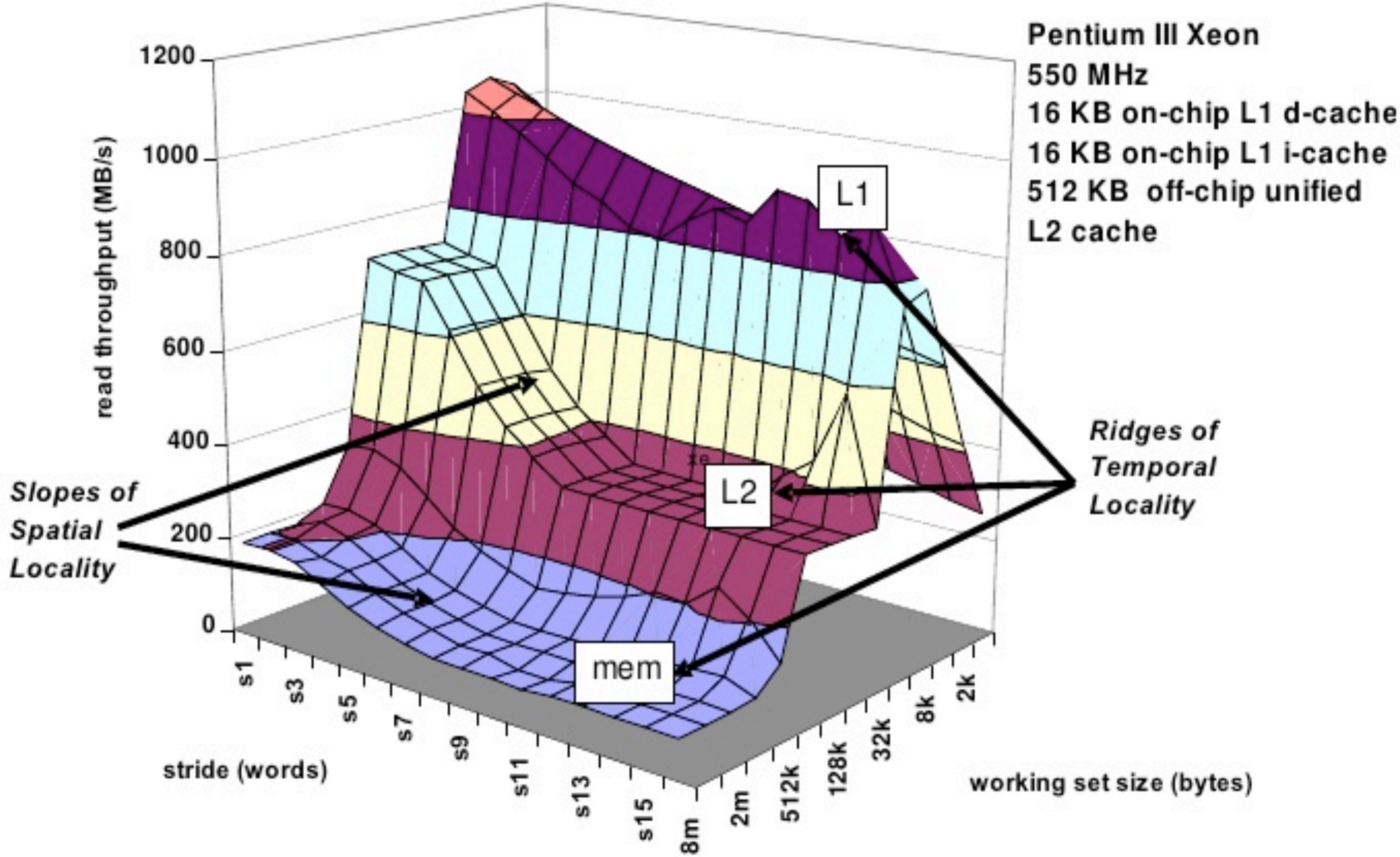

LOCALITY AND PAGES

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  - Memory recently accessed is likely to be accessed again
  - Bring recently used data into faster memory
- **Types of memory (by speed)**
  - Register
  - L1,L2,L3
  - Memory
  - Disk
  - The interwebs (the cloud)

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  - This is why arrays are faster in practice, they are always next to each other in memory
  - Each new node in a tree may not even be in the same page in memory!!
- **Important to consider when designing and explaining design problems.**

COST OF MEMORY ACCESSES

- Registers (128B): Instantaneous access
- L2 Cache (128KB): 0.5 nanoseconds
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PROCESS MEMORY

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- **Many different demands**
  - Global variables
  - Call stack
  - Allocated variables
  - Process code

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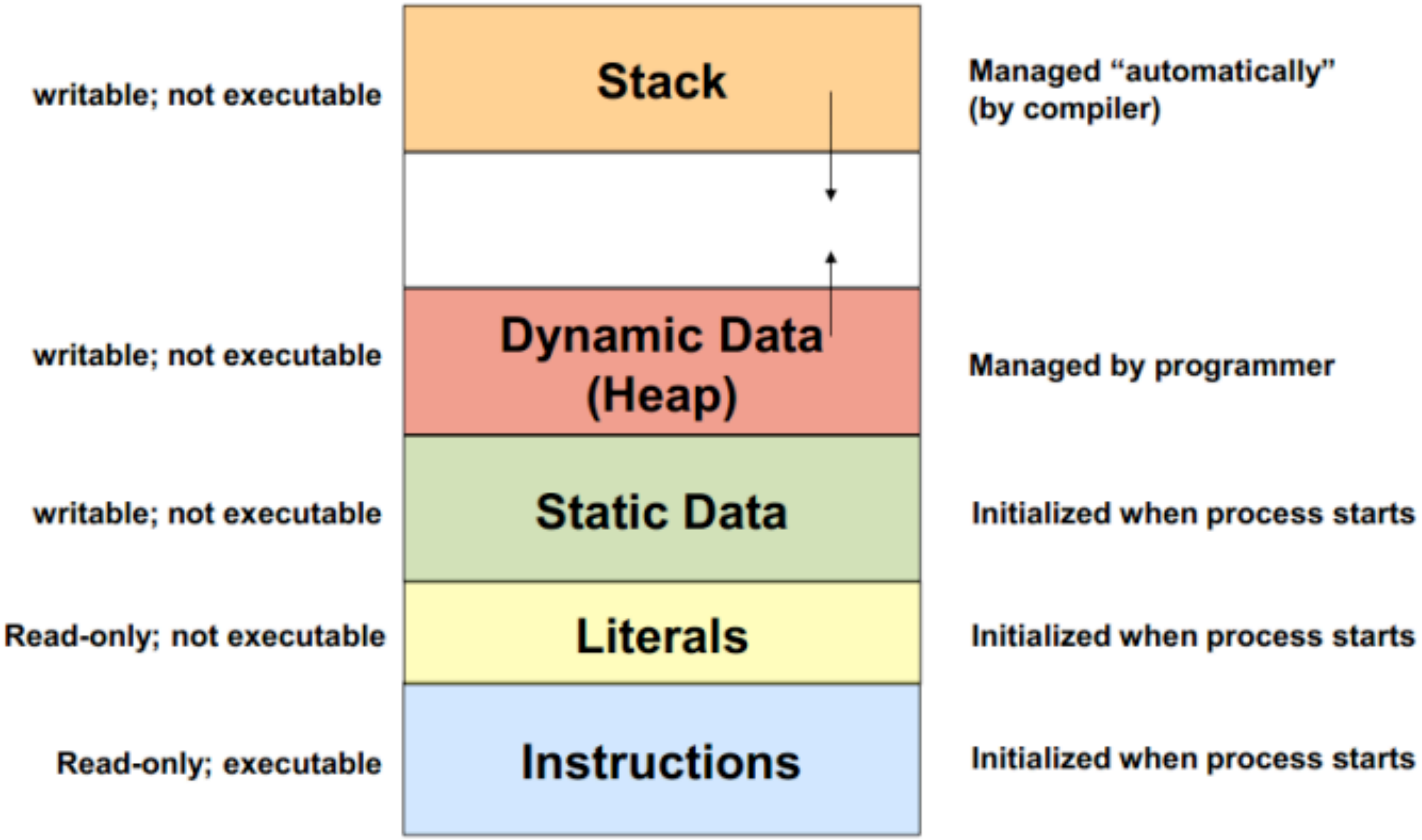

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- **These different demands are not next to each other in memory—little locality benefit**
- **Each call to new allocates wherever there is space in the heap (memory allocator)**
  - Even if two elements are created one after another, there is no guarantee that they'll both be in the same page
  - This is especially true for java
  - How important is caching?

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  - *This is much, much worse*

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  - If lots data is stored on the disk, O(log n) finds don’t happen in practice

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  - Each call of **`new`** may not place objects next to each other
  - Has large height, for the number of elements?

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  - Have a higher branching factor so that data you want is at a lower depth
  - Take advantage of page sizes