Generation Scavenging
A Non-Disruptive High Performance Storage Algorithm

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Organization Of Presentation

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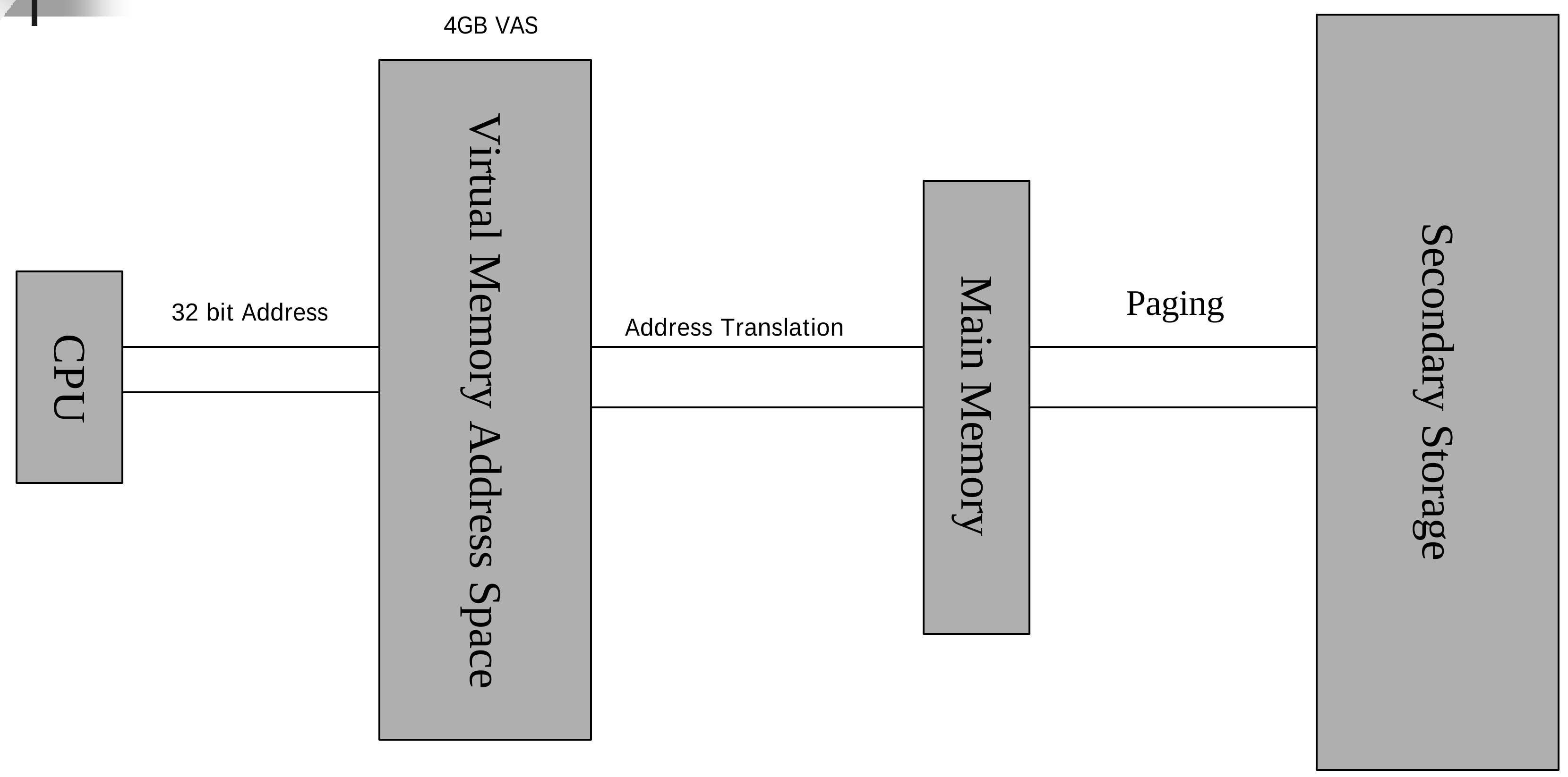
Word Of Caution

- This presentation is going to be my interpretation of Generation Scavenging
- This paper was published in 1984. To appreciate ideas presented in this paper we should read it with right mind set.

Introduction To Generation Scavenging Algorithm

- Computing systems provide automatic storage facilities
- Price to be paid :
  - CPU Time
  - Main Memory
  - Unexpected pauses cause distraction and reduction of productivity
- Proposed Generation Scavenging Algorithm (GSA)
  - Limits pause times to a fraction of a second
  - Requires no hardware support
  - Meshes well with virtual memory
  - Reclaims circular structures, and
  - Uses less than 2% of CPU time on Smalltalk system
- GSA has been implemented on Berkeley Smalltalk (BS)

Relationship : Virtual Memory and Storage Reclamation



Bandwidth Issues With Storage Allocator

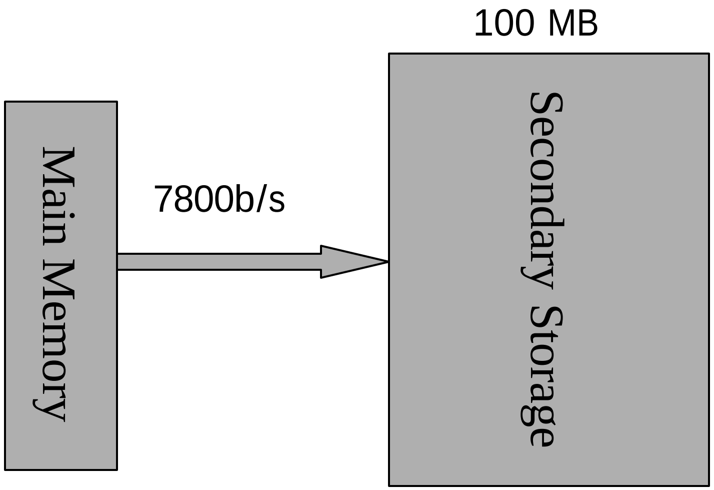
- Bandwidth is the reclamation rate for system to be in equilibrium.
- Smalltalk-80 system allocates a new object every 80 instructions.
- Mean dynamic object size is about 70 bytes.
- If system runs at 9000 bytecodes per second :–
- Storage Allocator Bandwidth =

  70bytes/1object * 1object/80instruction * 9000bytescodes/second = 7800b/s

- What does this mean ?

Bandwidth Issues With Storage Allocator

- Flush out data from main memory to secondary storage at 7800b/s



T = 100 MB/7800BpS
= 3.5 Hrs

- Recycle data from Main Memory (GC)

Various Garbage Collection Algorithms

- Reference Counting (1960) :

  Maintain a count of number of pointers that reference each object

  - Immediate RC :
    - Adjust reference count on every store instruction
    - Counting references takes time. Around 15% of CPU time
    - Additional 5% for decrementing counts when object is released
    - Advantages : least amount of memory for dynamic objects
    - Fails to reclaim circular structure
  - Deferred RC :
    - Ignore references from local variables
    - Preclude reclamation during program execution
    - System has to periodically stop to free dead objects
    - Requires 25 KB more space as compared to Immediate RC
    - 30 ms pause every 500 ms
    - Saves 90% of reference count manipulation
    - 3% CPU Time + 3% periodic reconciliation + 5% for recursive freeing

Various Garbage Collection Algorithms

- Marking Storage Reclamation Algorithms (1960) :

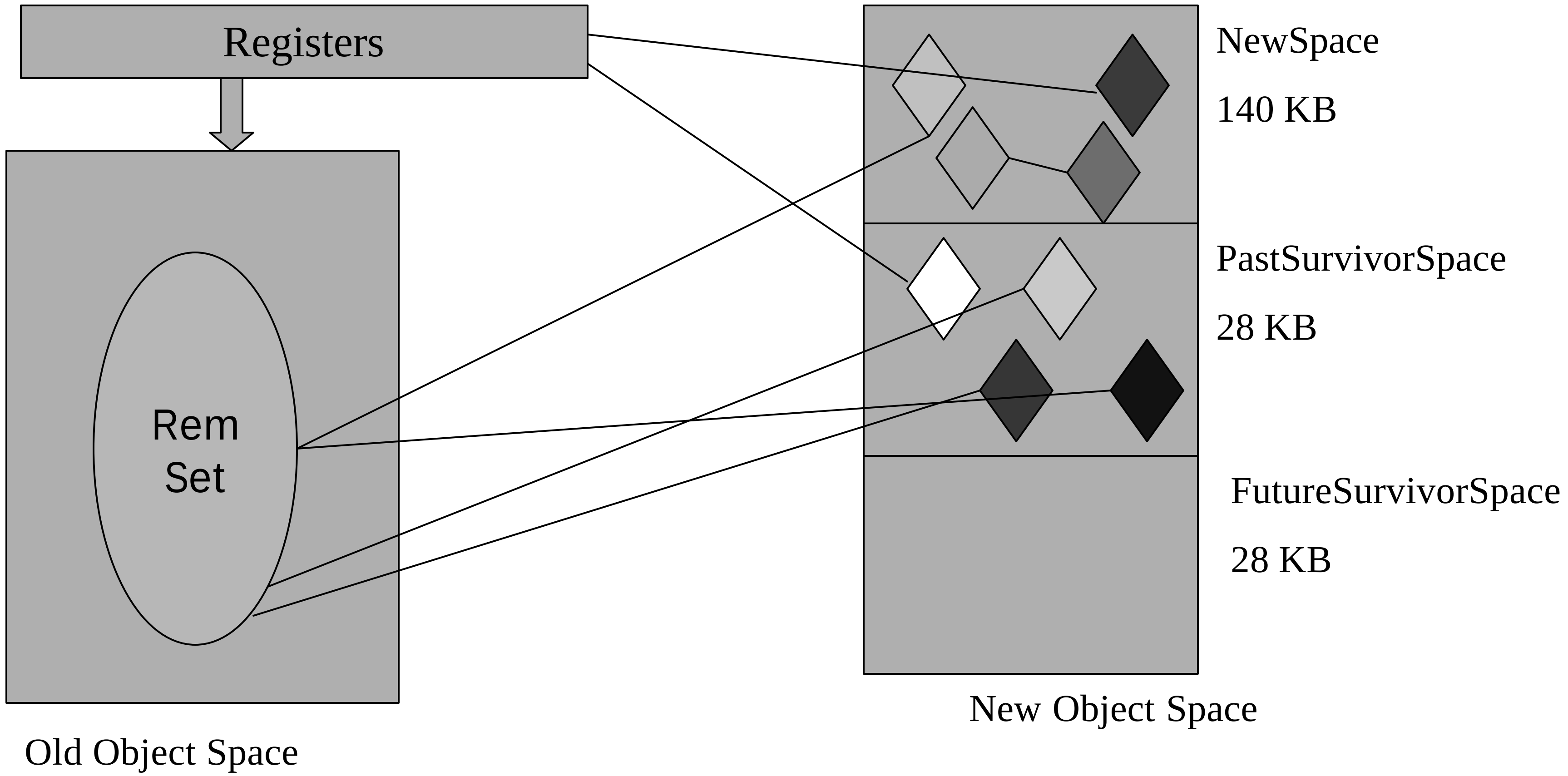
  First traverse and mark reachable objects and then reclaim the space filled by unmarked ones

  - Mark and Sweep
    - Marking phase identifies all live objects
    - Reclaims one object at a time.
    - Inefficient, because this algorithm requires object space to be traversed twice.
    - CPU Time : 25%-40%
    - 4.5 second pause every 79 seconds
  - Scavenging Live Objects
    - Costly sweep phase can be eliminated by moving live objects to a new area
    - After scavenging former area is free and new objects can be allocated from its base
    - Forwarding pointers are required
    - CPU Time : 7%
    - Next improvement is to divide objects into generations and do GC more often for younger ones.

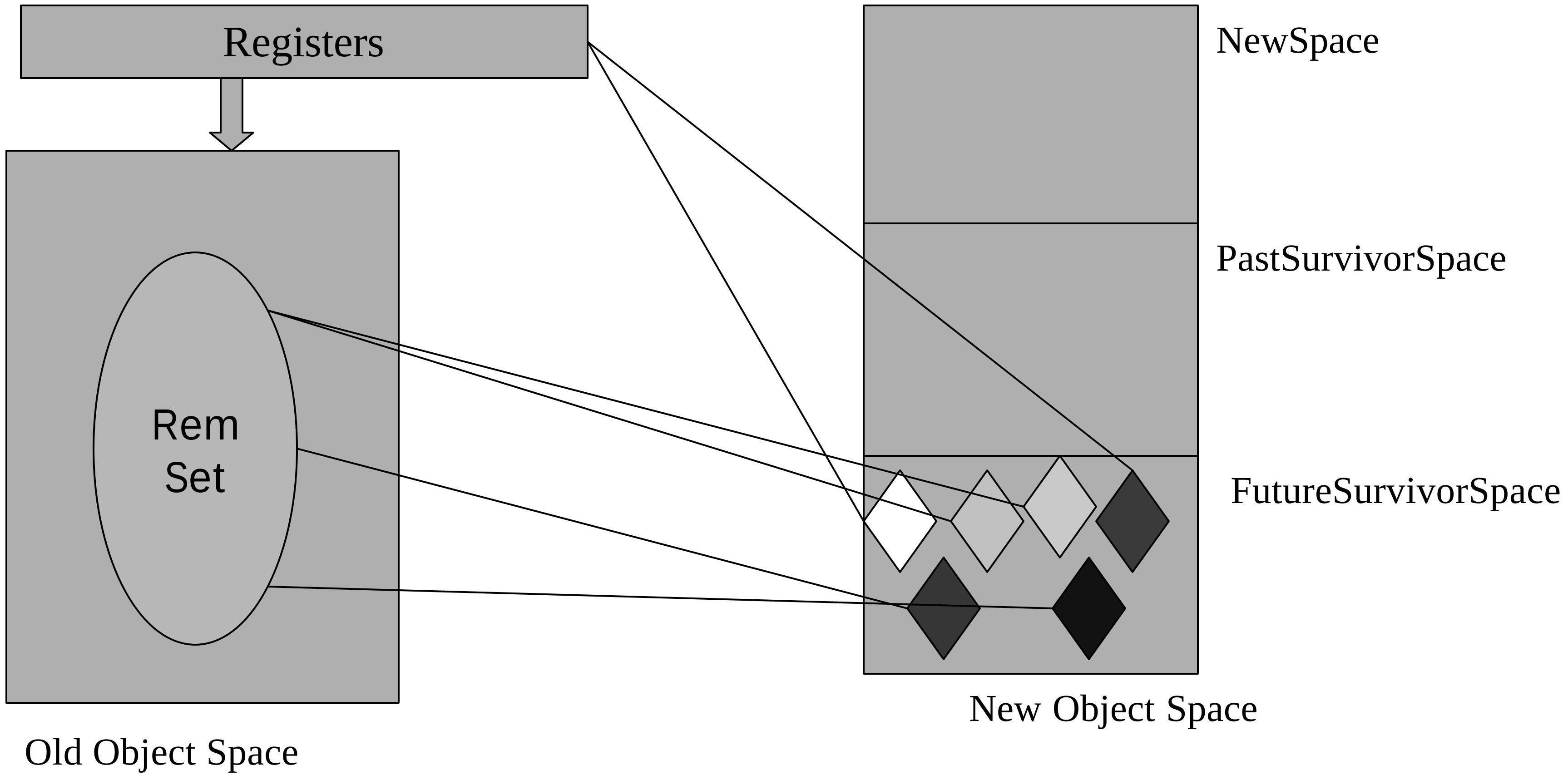
Generation Scavenging Algorithm

- Each object is classified as new or old
- Old objects reside in memory region called old area
- New objects can be found in following places
  - NewSpace
  - PastSurvivorSpace
  - FutureSurvivorSpace
- Remembered Set : Set of old objects having a reference to new object
- All new objects are reachable through Remembered Set objects and roots
- During GC, live objects from NewSpace and PastSurvivorSpace are moved to FutureSurvivorSpace
- Interchange FutureSurvivorSpace with PastSurvivorSpace
- NewSpace can be reused for new objects
- Space cost of only 1bit/object
- Tenuring : promotion from new space to old space

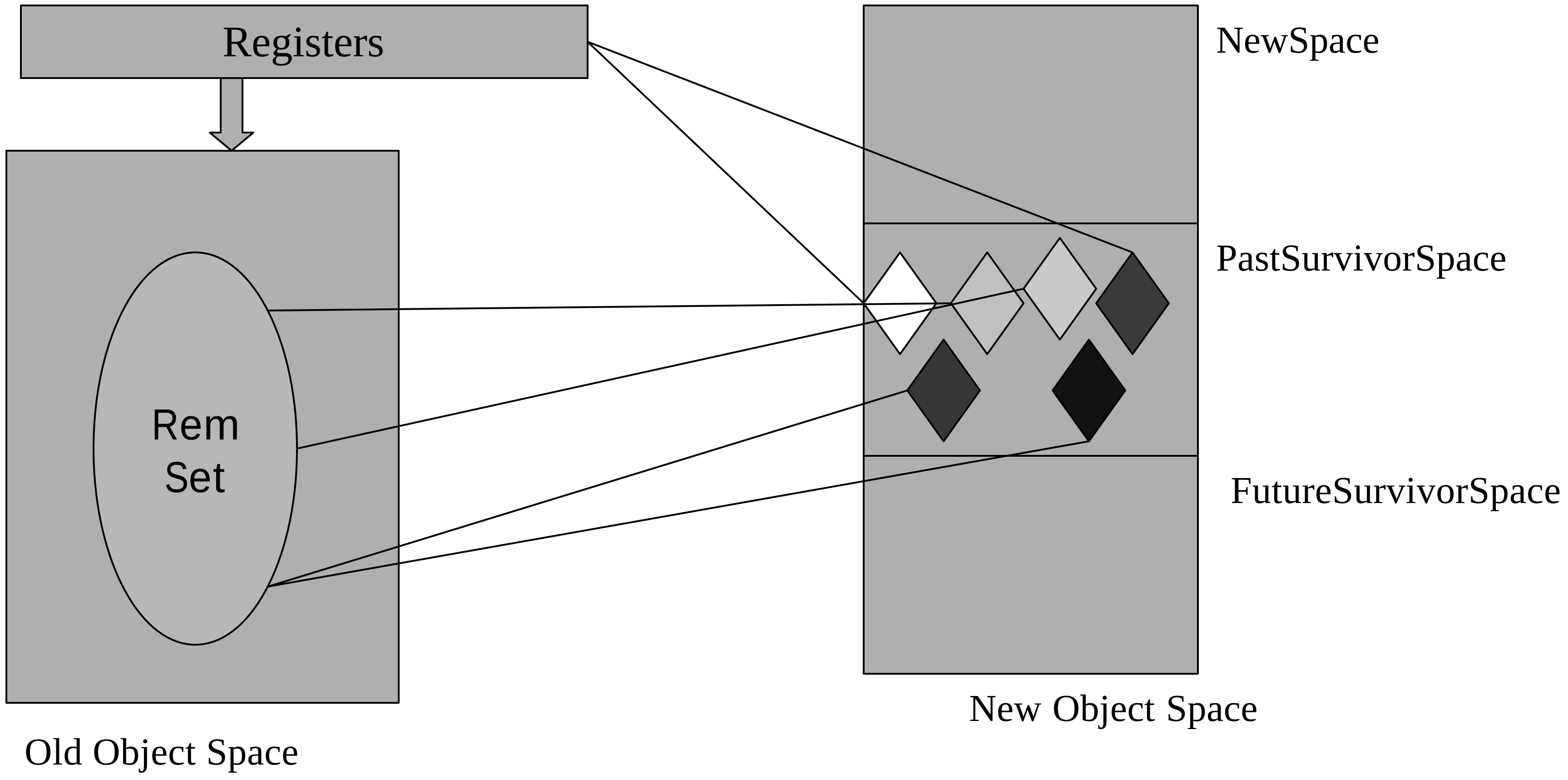
Generation Scavenging Algorithm



Generation Scavenging Algorithm

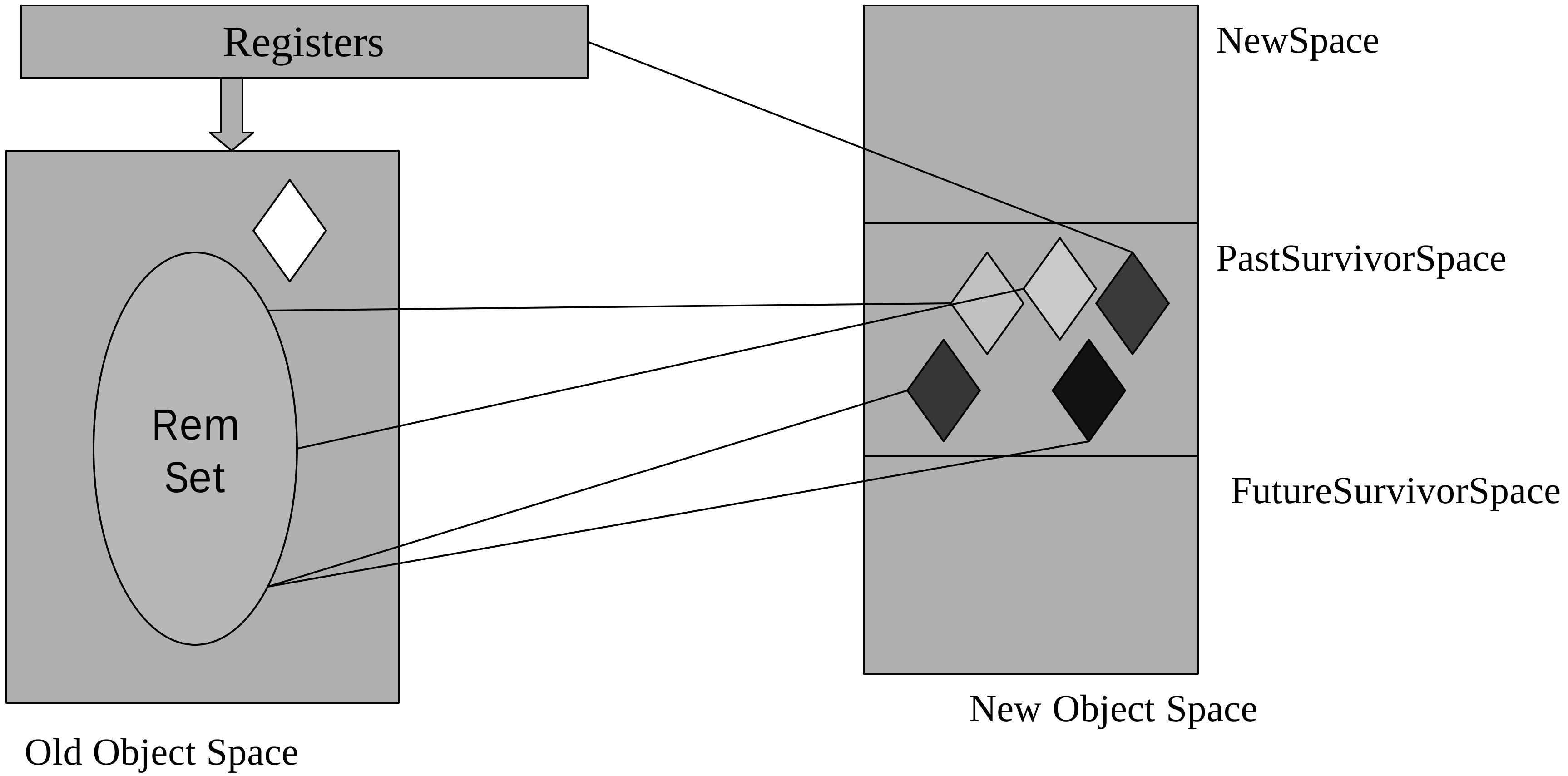


Generation Scavenging Algorithm

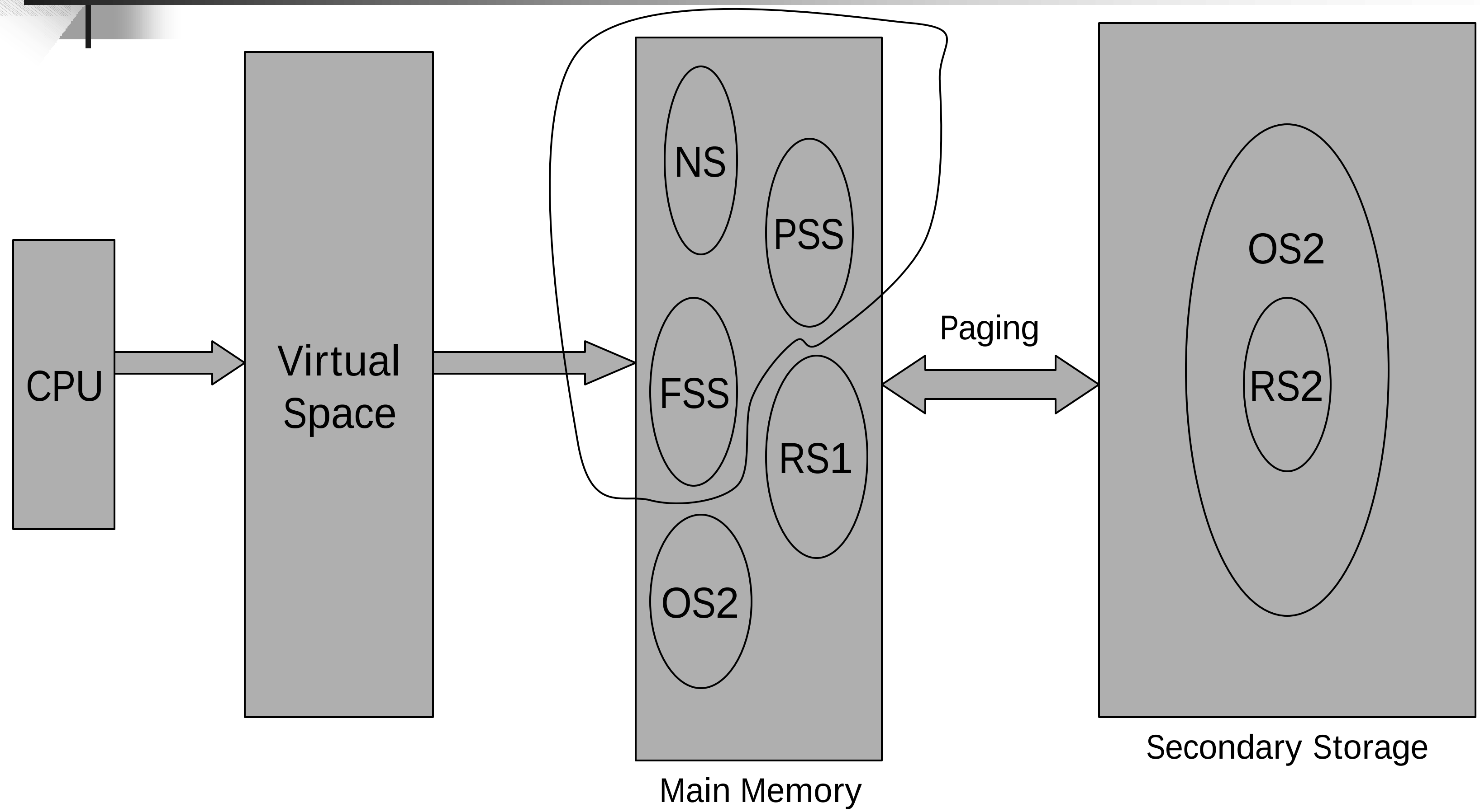


Microsoft Excel Worksheet

Generation Scavenging Algorithm : Tenuring



GSA : Role Of Virtual Memory



Comparison of GSA with other scavenging algorithms

- Similarities
  - It divides objects into young and old generations
  - Copies live objects instead of sweeping dead ones
  - Reorganizes old objects offline

- Differs
  - Conservers memory space by dividing new space into three spaces instead of two
  - Is not incremental. This eliminates the checking needed for load instructions

Evaluation of GSA

- CPU Time :
  - Takes only 1.5% of total user CPU Time
  - This is four times better than its nearest competitor (7%)
- Main Memory Consumption :
  - Takes only 200 KB (140 + 28 + 28) for dynamic objects
  - Around 10% of BS main memory
  - Comparison with Baker Semispace Algorithm: 2 * (140+28) = 360 KB (appx)
- Pauses
  - Pauses were small averaging 150 ms
  - Longest was 330 ms

Microsoft Excel Worksheet

Conclusion

- Combination of generation scavenging and paging provides high performance GC
- Careful consideration of virtual memory is essential for any GC algorithm
- GSA uses these principles to achieve 2% CPU time, 200 KB primary memory, 1.2/s backing store operations and 1/6-1/3 s pause time.

Microsoft Excel Worksheet

Discussion

- Do we have a control over paging ?
- Is it still a good idea to page out old object space to secondary memory ?
- Are the results reliable ? He used only (I guess) smalltalk-80 macro bench marks.