A Real-Time Garbage Collector Based on the Lifetimes of Objects

Henry Lieberman and Carl Hewitt
(CACM, June 1983)

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CS395T: Memory Management Hierarchies
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Lifetime Observation

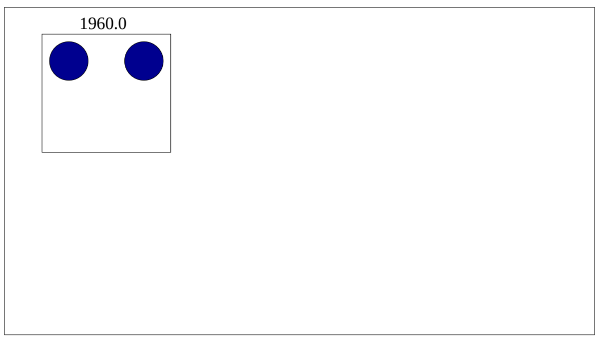
- Programs have two types of objects
  - “thinking objects” $\Longrightarrow$ short-lived
  - “decision objects” $\Longrightarrow$ long-lived
- Improve performance of Baker’s Algorithm
  - optimize for scavenging short-lived objects
  - scavenge long-lived objects less frequently
- **Rental cost**
  - storage management cost for an object is proportional to the time during which the object is used

Modify Baker’s Algorithm

- address space broken up into **generations**
  - small (relative to address space) set of pages
- Baker’s algorithm used per region
  - flip $\Longrightarrow$ condemning a region
  - fromspace $\Longrightarrow$ obsolete areas
  - tospace $\Longrightarrow$ non-obsolete areas
  - evacuate objects in the same way

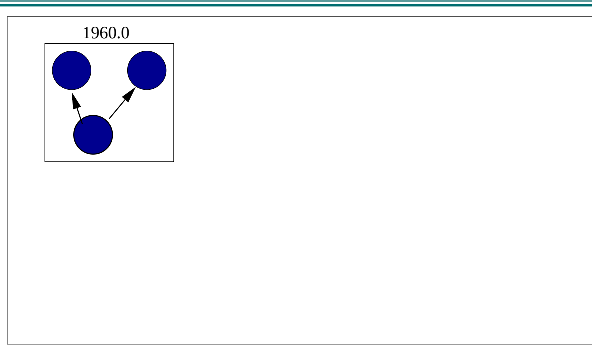
Regions are tagged with generation and version number

Lieberman & Hewitt Algorithm

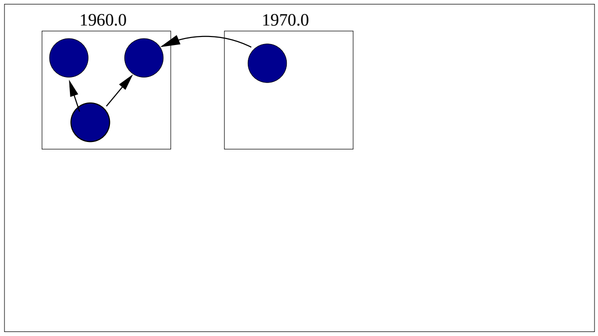


Allocation occurs in **creation region**

Lieberman & Hewitt Algorithm

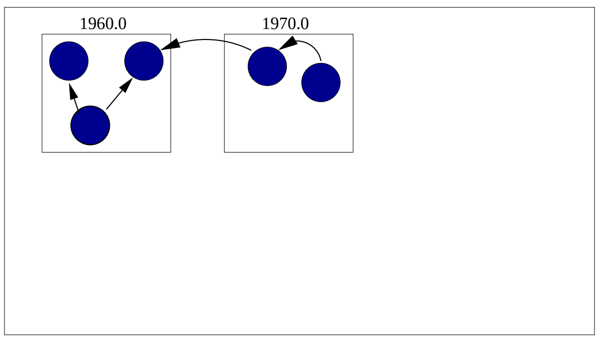


... until the **creation region** is full



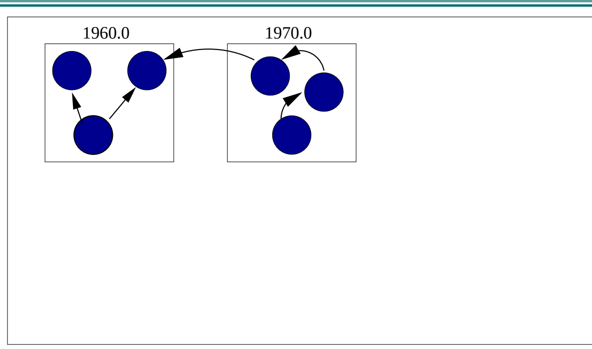
... then new creation region is created

Lieberman & Hewitt Algorithm



... and so on

Lieberman & Hewitt Algorithm



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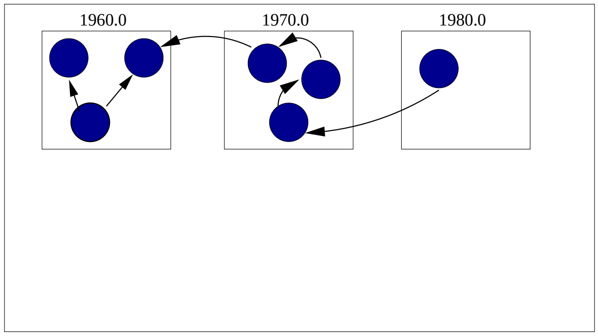

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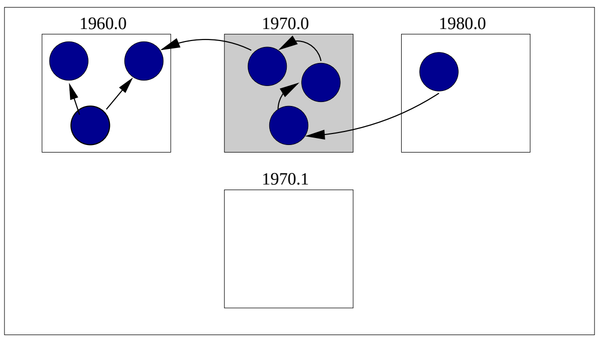
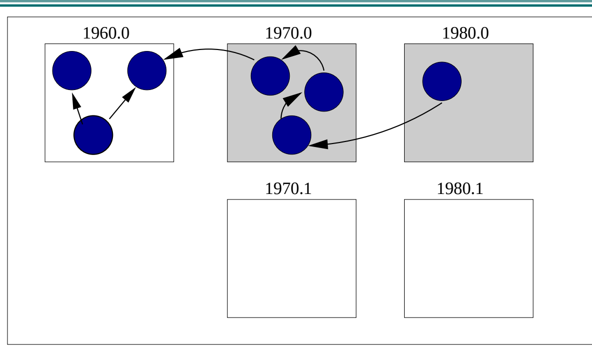
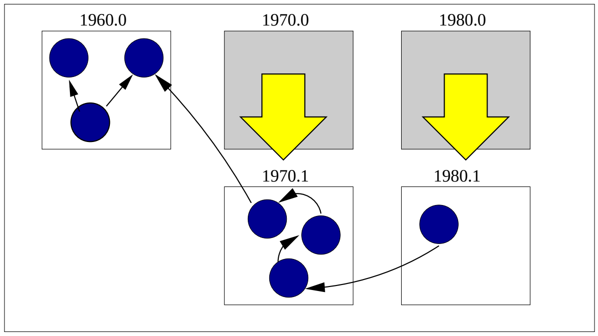


GC is initiated by condemning a region (making it obsolete) and creating an evacuation region

Lieberman & Hewitt Algorithm

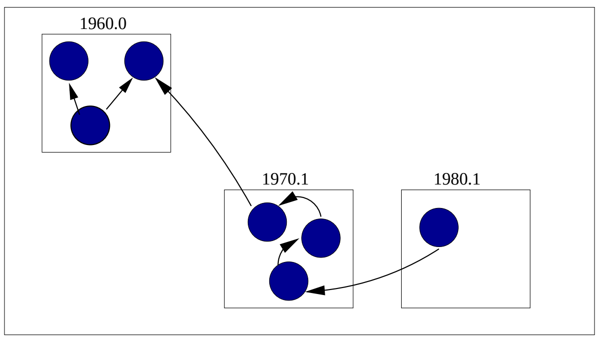


this requires that younger generations also be condemned



accessible objects in condemned region(s) are incrementally evacuated using Baker's Algorithm

Lieberman & Hewitt Algorithm



... and the memory is recycled

The Good – Varying GC Rates

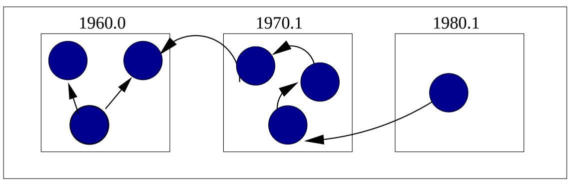
- Vary the rate of GC for each generation
  - younger generations contain high percentages of garbage and are collected frequently
  - older generations contain relatively permanent data and are collected seldomly
- Focus scavange time where the highest proportion of inaccessible objects
- Minimizes the amount of scavenging needed per inaccessible object

- Fragmentation results from partially-filled regions
  - choose a region size to minimize fragmentation
  - coalesce older regions reducing the amount of wasted space

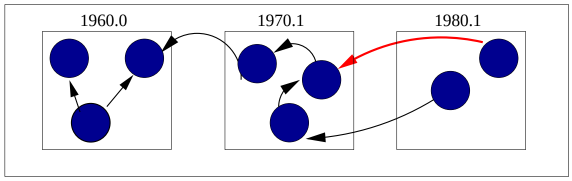
The Ugly – Scavenge Time

- Whole heap scavenge required to ensure no pointers point into condemned region(s)
- Scavenging is a lot of work
- Scavenging is good because it
  - reuses the address space
  - compacts the address space
- Want to reduce the scavenging time by using **forward pointers**

Forward Pointers



Forward Pointers



- CONS composes existing components into objects
  - creates a **backward pointer**

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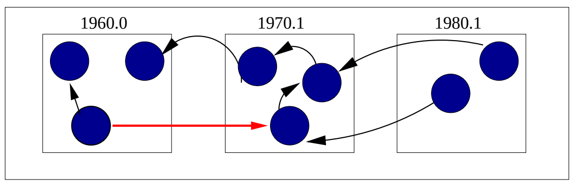
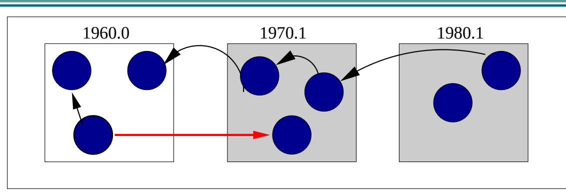
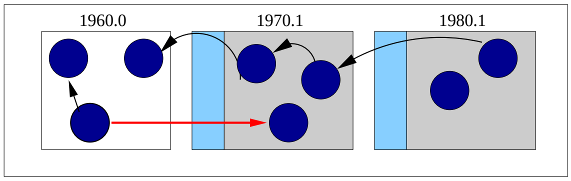


- CONS composes existing components into objects
  - creates a **backward pointer**
- RPLACA can assign a new pointer as a component to an older object
  - creates a **forward pointer**

Entry Tables



- Problem occurs after heap is manipulated further



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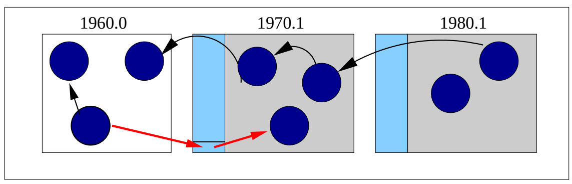

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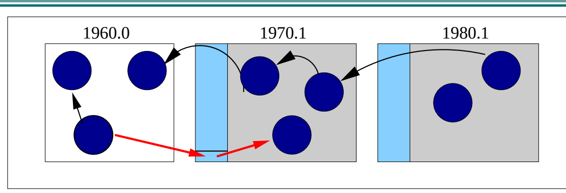

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- Adds a level of indirection for some pointers
- GC uses **entry table** entries as roots to the region

Conclusions

- Different objects have different lifetimes
- Performance benefit from varying the collection of rates of objects with different lifetimes
- Introduced concept of different generations within a copying collector
- Introduced use of entry table to avoid scanning entire heap

Sidebar 1: Weak Pointers

Pointers in the program which do not protect an object from being collected

- not followed during GC
- small in number
- forward weak pointers use the entry table

Sidebar 2: Value Cells & Stacks

Represent roots of scavenging

- What is the advantage of considering them the “oldest” generation?
- What is the advantage of considering them the “youngest” generation?
  - no entry tables pointers needed

Providing different allocators for different regions

- Can sophisticated users direct the flavor of allocation?
- Can compiler analysis accurately change the flavor of allocation?
- Can runtime information accurately change the flavor of allocation?

Aspects of Program Behavior

- Rate of object creation
- Average lifetimes of objects
- Proportion of forward vs. backward pointers
- Average “length” of pointers

The End