Comparison of Compacting Algorithms for Garbage Collection

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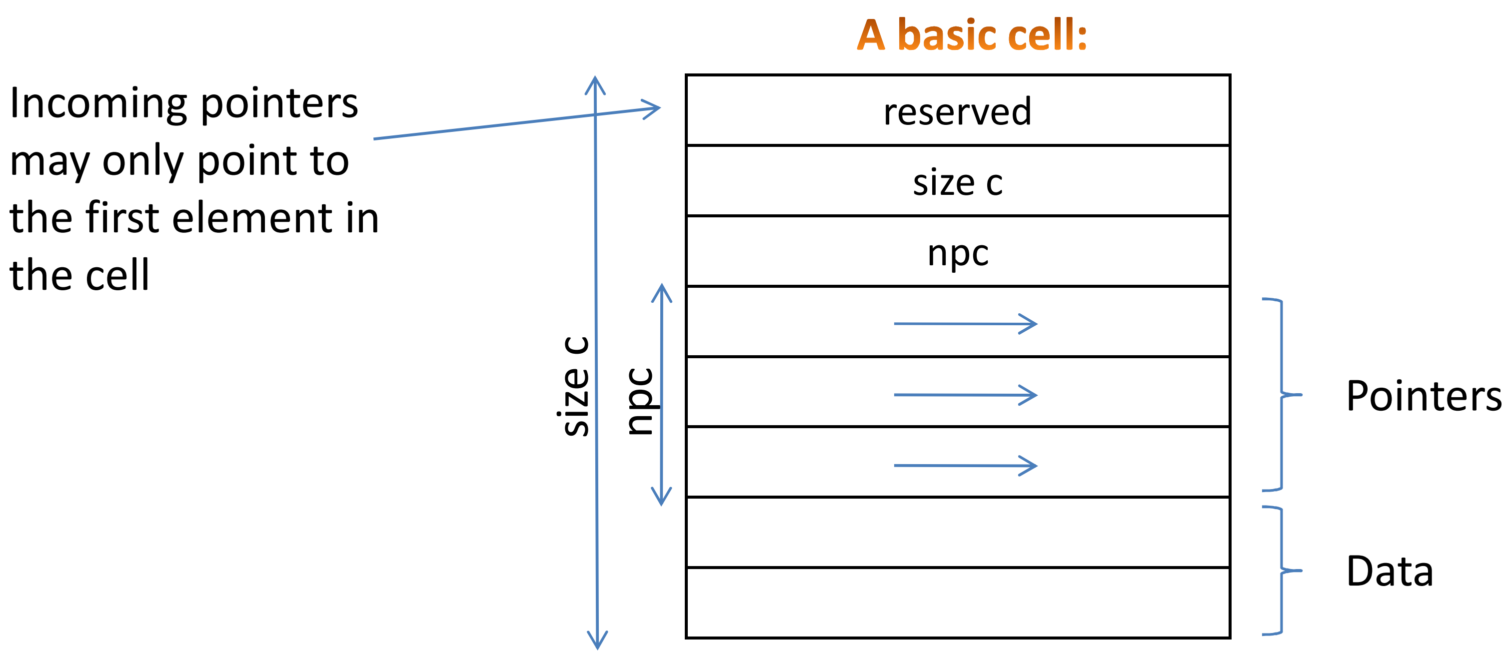
Presented by Sam Harwell

Mark/Sweep/Compact Collection

- Garbage collection is performed in two stages
  - Identify objects in memory that are live (*mark*)
  - Make dead-object memory locations available to the allocator by *compacting* live objects
- We are focusing on the compaction algorithm

Allocator Fundamentals

- Memory is allocated for *cells*:
  - Variable sized
  - Each may hold pointers and/or data



Algorithms

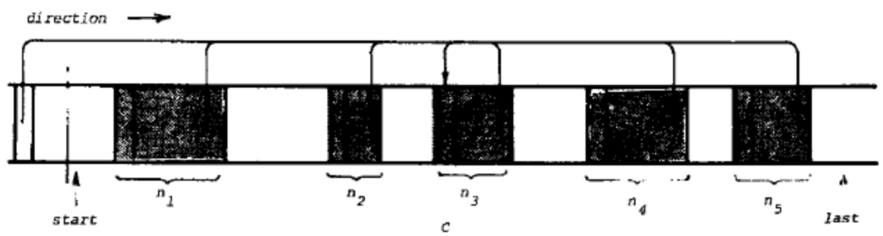
- Classical
  - Lisp 2
    - D.E. Knuth, 1973
  - Table Compactor
    - Modified algorithm based on Waite and Haddon, 1967
- Modern (at the time)
  - Morris’ algorithm, 1978
  - Jonkers’ algorithm, 1979

Lisp 2

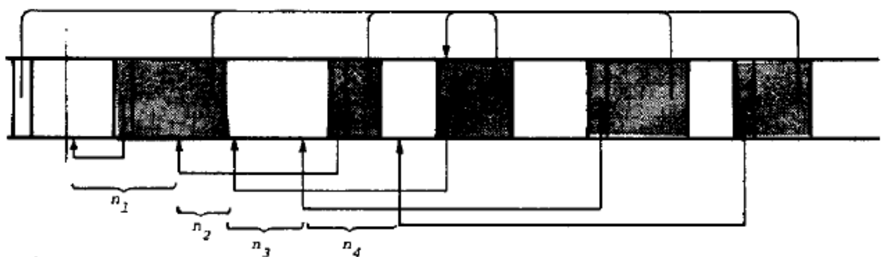
- Requires additional space in each cell for a pointer
- Three passes:
  - Compute new address of each active cell
  - Update pointer fields of each active cell
  - Relocate active cells

Lisp 2 Compactor

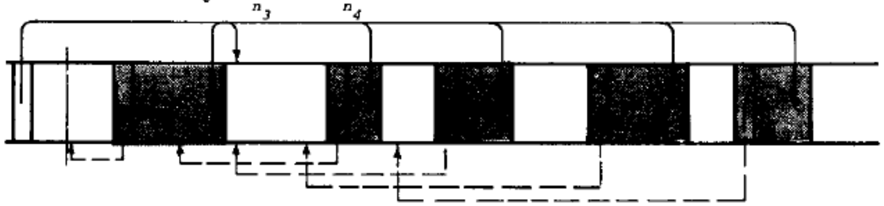
Initially:



After pass 1:



After pass 2:



After pass 3:

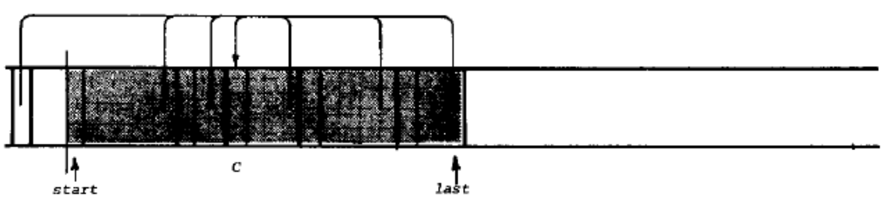
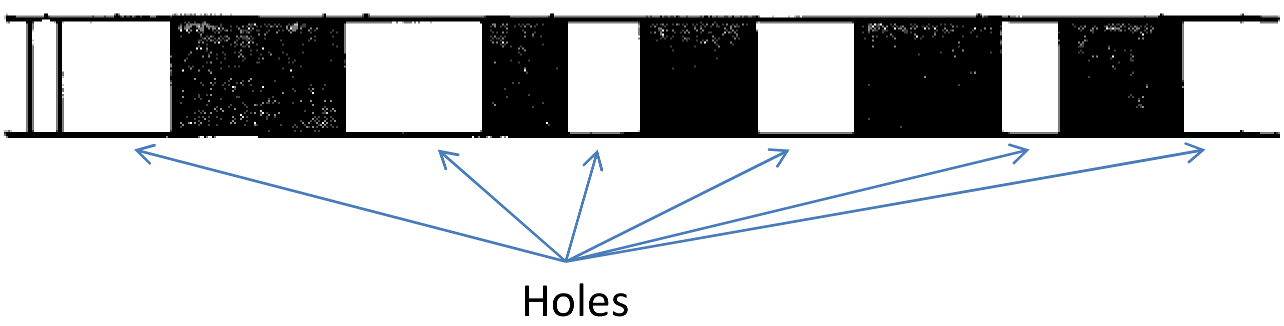


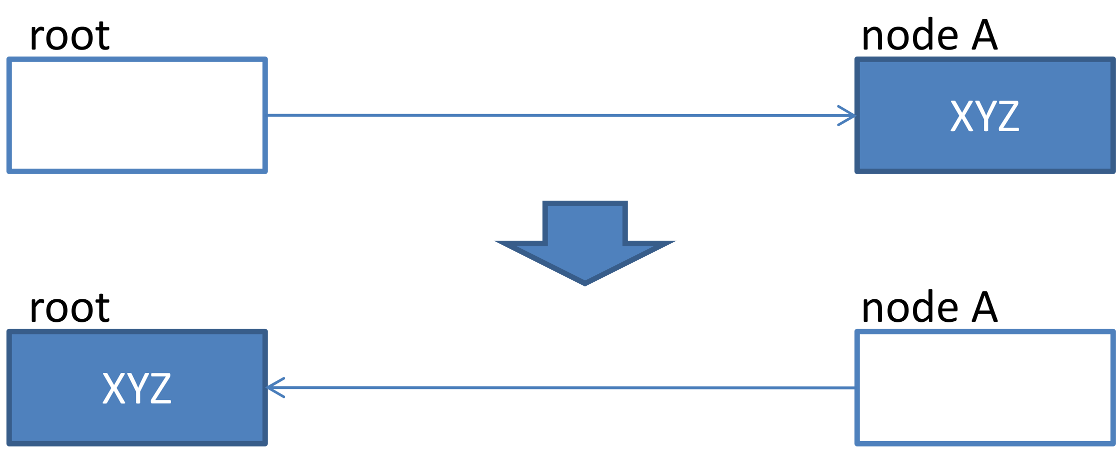
Table Compactor

- Stores relocation data in garbage cells
- Fundamental: cells are moved forward by the total size of holes preceding the cell
- Pointers are updated similarly



Threading

- An elegant way to answer, “Where are all the pointers to cell *X*?”
  - Threading the root:



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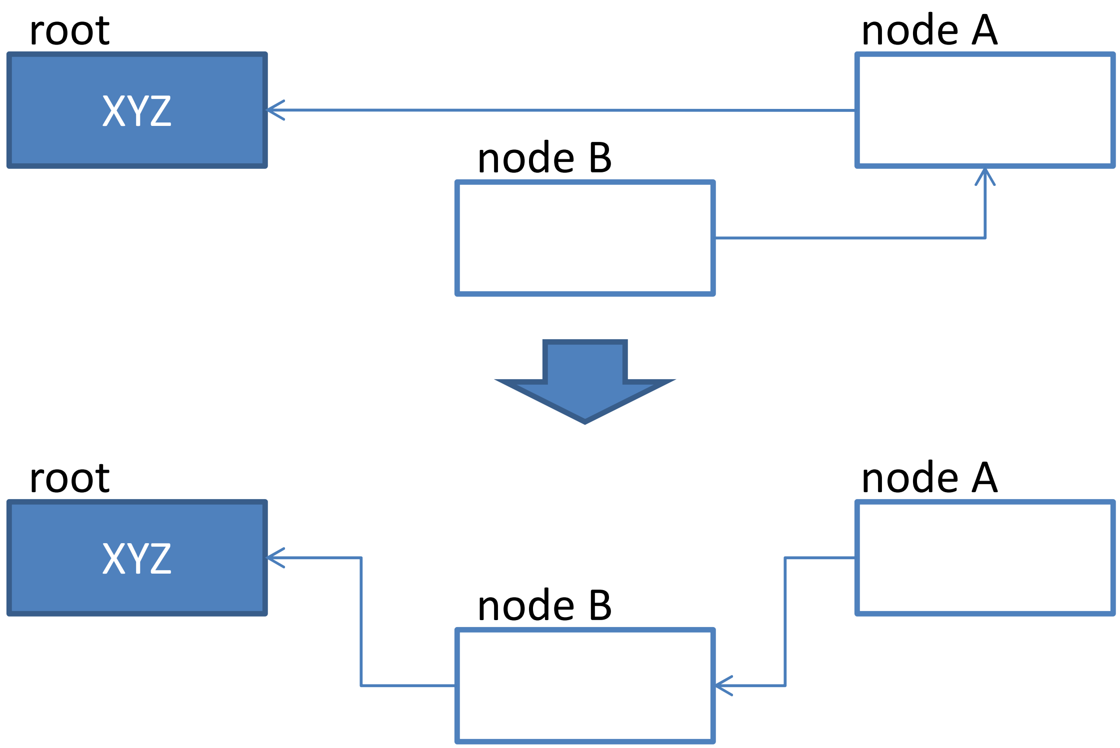
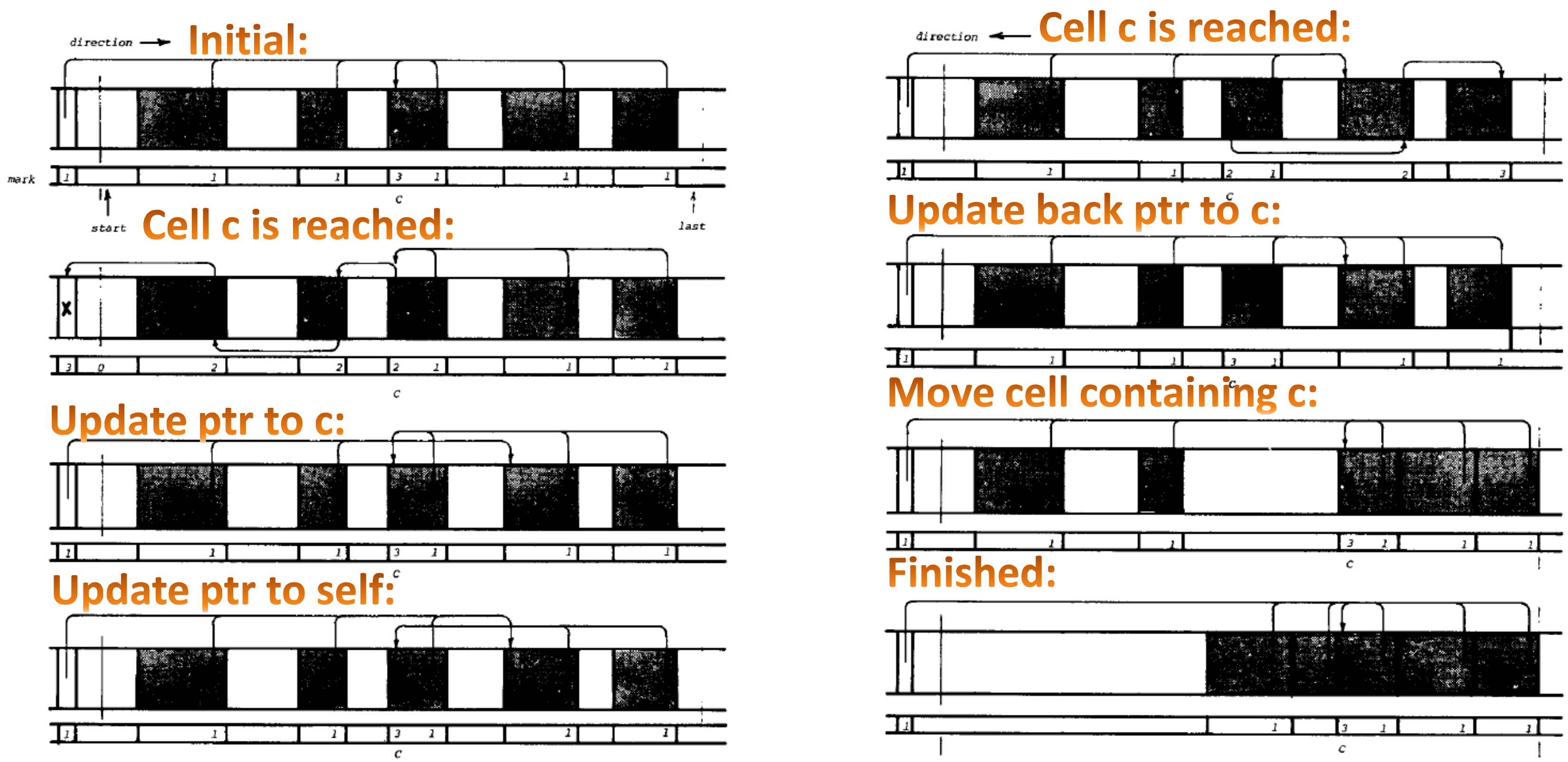


Morris' Algorithm

- Three-passes: one forward and two backward
- Two tag bits per field overhead (one if single cells cannot hold both pointers and data)

Morris' Algorithm

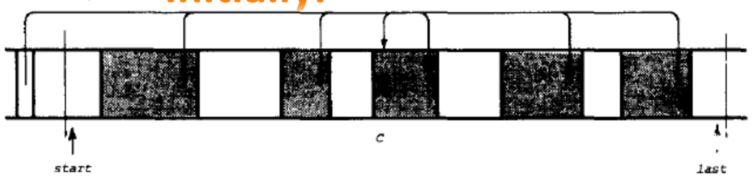


Jonkers’ Algorithm

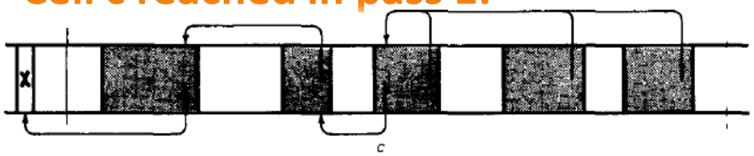
- Improved on Morris’:
  - Only two passes, both forward
  - One bit per cell overhead
- Added assumptions:
  - No pointer-to-members
  - A cell containing data is always large enough to store a pointer

Jonkers' Algorithm

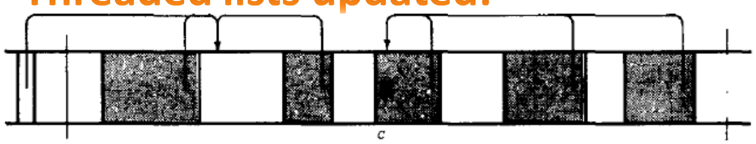
Initially:



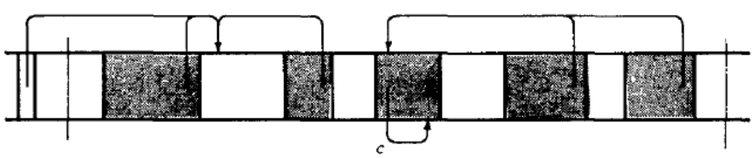
Cell c reached in pass 1:



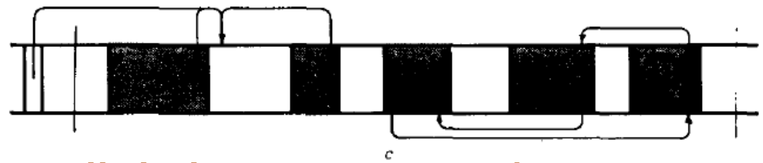
Threaded lists updated:



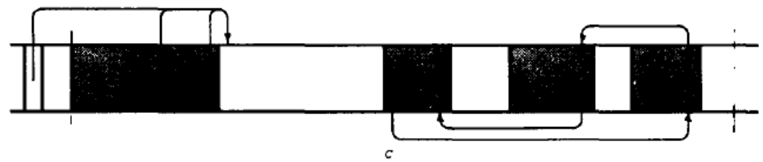
Processed self reference:



Back pointers to c threaded:

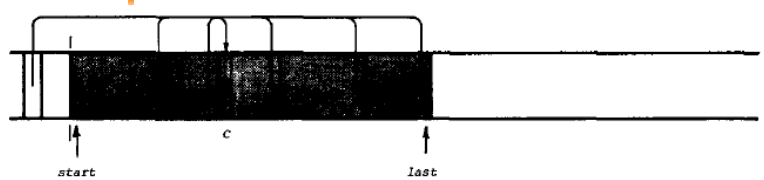


Cells below c compacted:



Threaded list updated:

Compacted:



Time-Formulas

- Create optimized versions of each algorithm
- Describe each procedure with a formula from the type and number of operations performed
- Replace unknowns in the formula with machine-specific constants, leaving the following variables:
  - α: Marked cell ratio (NMC/NC)
  - β: Live pointer ratio (NAP-1)/(NPC*NMC)

Feature Comparison

	Lisp 2	Table compact	Morris’	Jonkers’
Age	Classical (1973)	Classical (1967)	Modern (1978)	Modern (1979)
Space	1 pointer/cell	None	2 bits/field	1 bit/cell
Passes	3	3	3	2
Member ptr	No	No	Yes	No

Performance Results

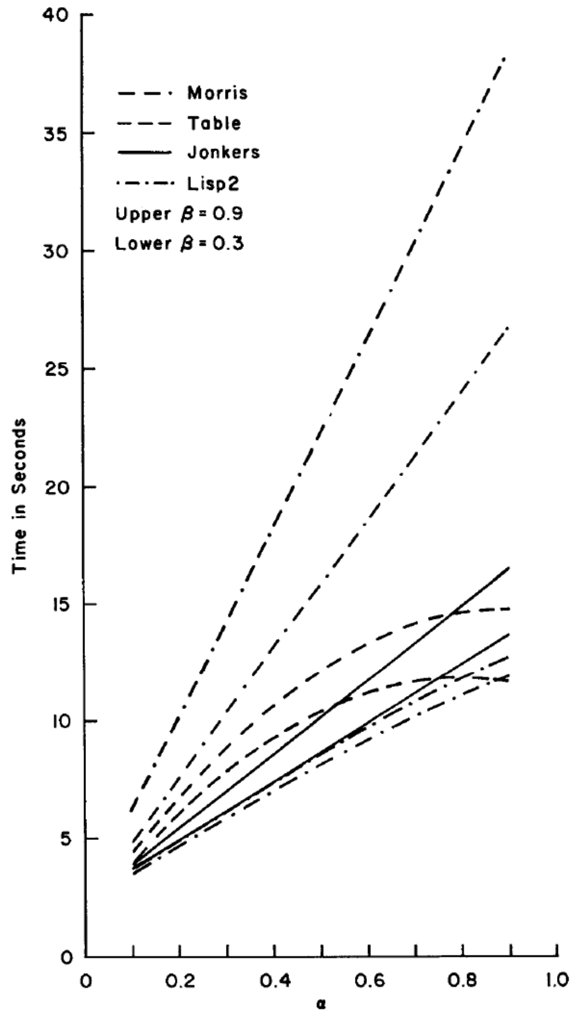
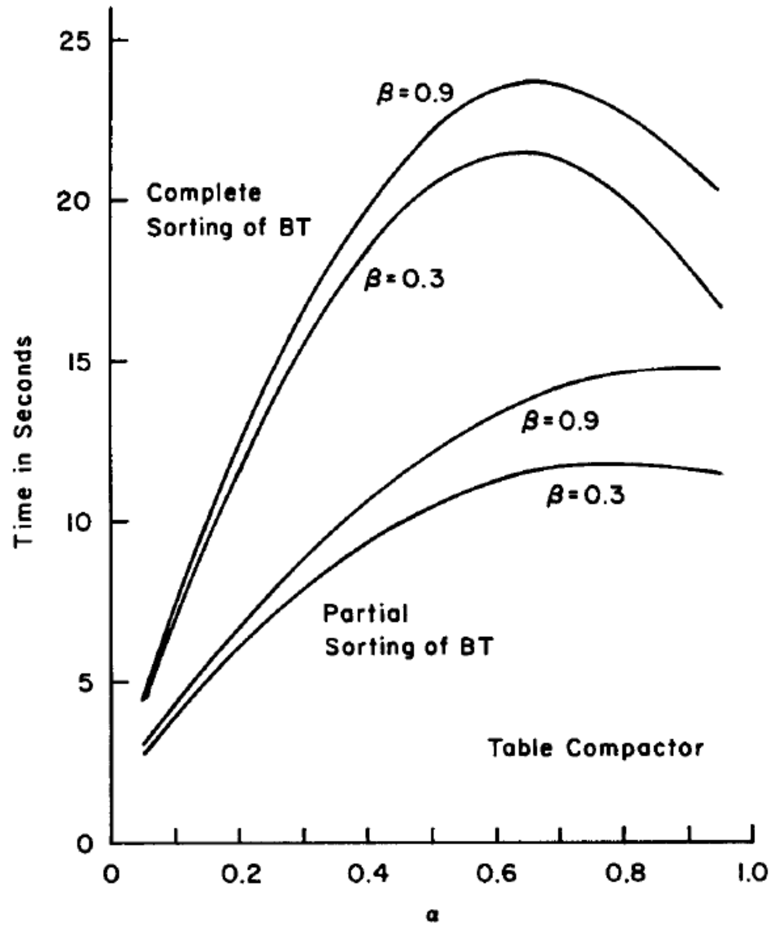


Fig. 8. Time comparisons for the four compactors.

Effects of Increased Sorting in the Table Compactor



Effects of Cell Size