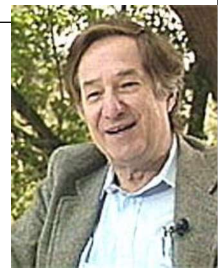
Topic 25
Tries



"In 1959, (Edward) Fredkin recommended that BBN (Bolt, Beranek and Newman, now BBN Technologies) purchase the very first PDP-1 to support research projects at BBN. ***The PDP-1 came with no software whatsoever.***

Fredkin wrote a PDP-1 assembler called FRAP (Free of Rules Assembly Program);"

Tries were first described by René de la Briandais in *File searching using variable length keys*.

Clicker 1

- How would you pronounce "Trie"

A. "tree"

B. "tri – ee"

C. "try"

D. "tiara"

E. something else

Tries aka Prefix Trees

- Pronunciation:
- From re**<u>trie</u>**val
- Name coined by Computer Scientist Edward Fredkin
- Re**trie**val so "tree"
- … but that is very confusing so most people pronounce it "try"

Predictive Text and AutoComplete

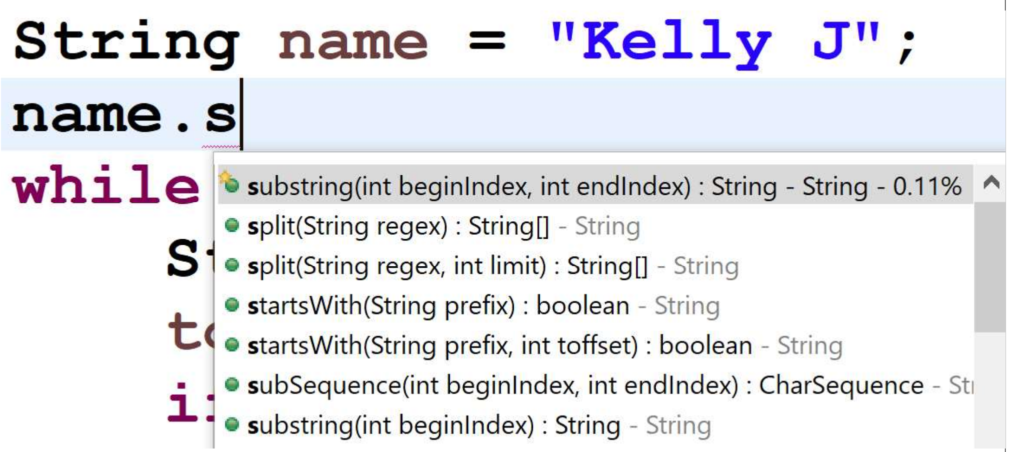
- Search engines and texting applications guess what you want after typing only a few characters

Hel

hel**lo**
hel**lboy**
hel**lo fresh**
hel**en keller**
hel**ena christensen**
hel**lo may**
hel**l or high water**
hel**lo neighbor**
hel**zberg**
hel**p synonym**

AutoComplete

- So do other programs such as IDEs



Searching a Dictionary

- How?
- Could search a set for all values that start with the given prefix.
- Naively O(N) (search the whole data structure).
- Could improve if possible to do a binary search for prefix and then localize search to that location.

Tries

- A general tree
- Root node (or possibly a list of root nodes)
- Nodes can have many children
  - not a binary tree
- In simplest form each node stores a character and a data structure (list?) to refer to its children
- Stores all the words or phrases in a dictionary.
- How?

René de la Briandais Original Paper

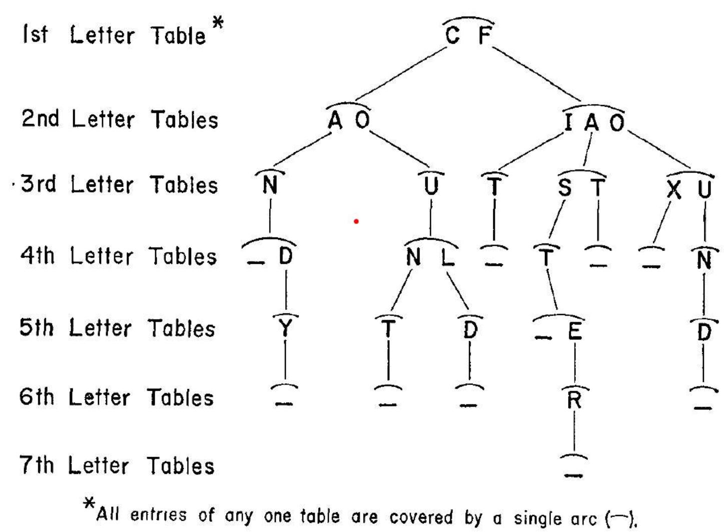
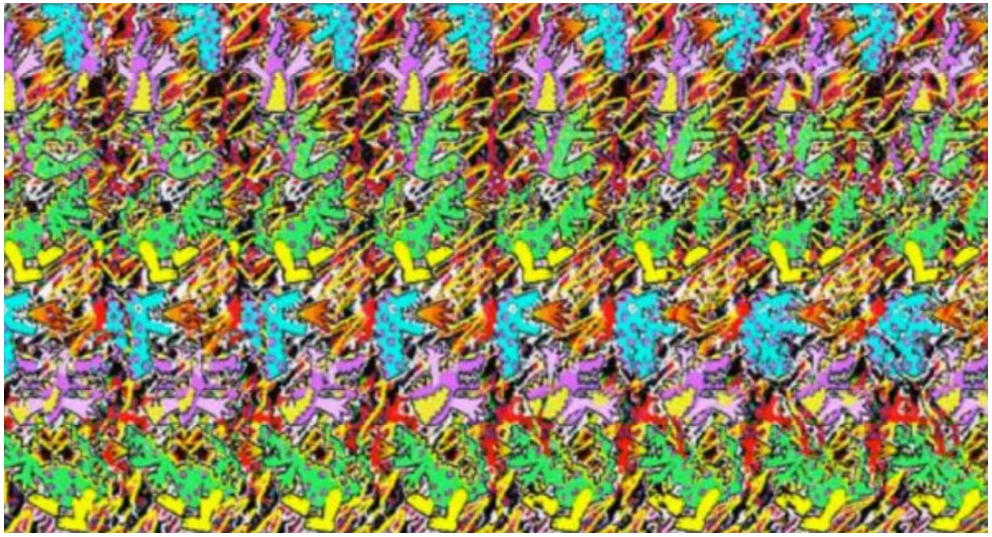
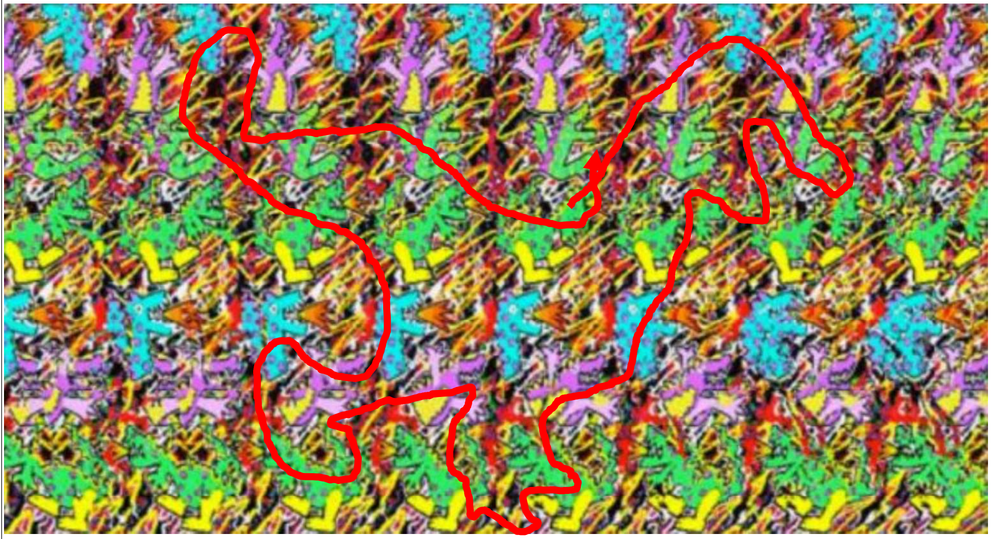


Fig. 1—Formation of a set of tables.

????



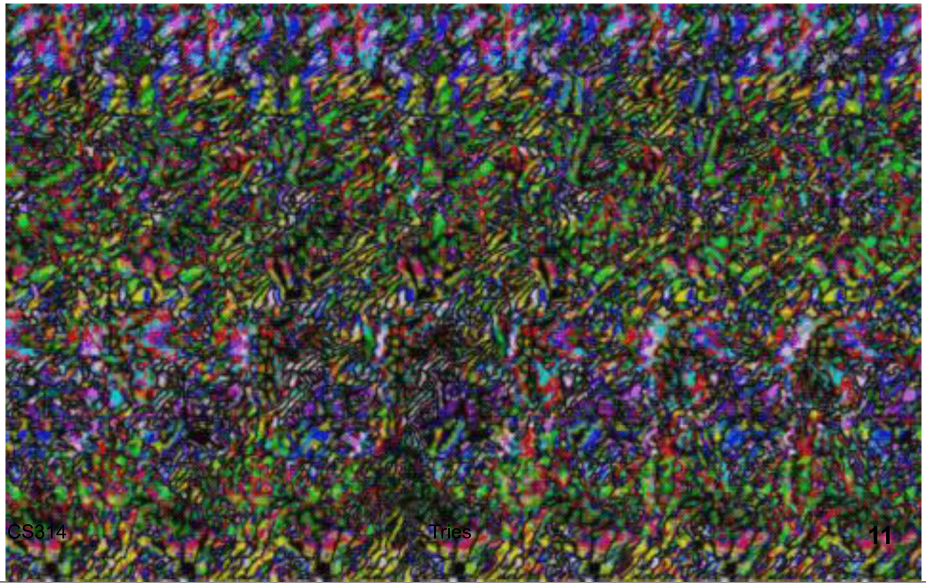
????



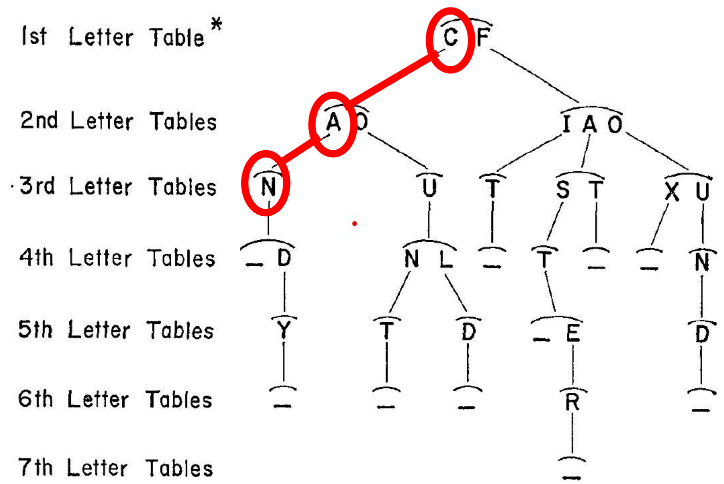
Picture of a Dinosaur

Fall 2022 - Ryan P.

Created with Procreate: https://procreate.art/



Can



*All entries of any one table are covered by a single arc (⌒).

Fig. 1—Formation of a set of tables.

Candy

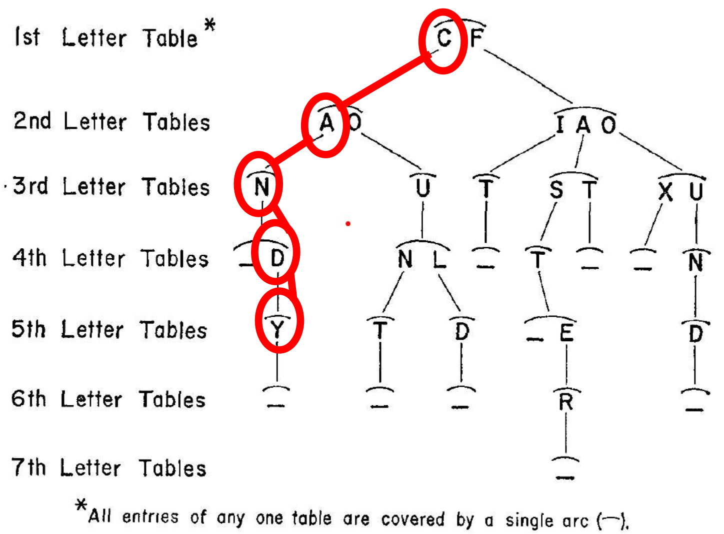


Fig. 1—Formation of a set of tables.

Fox

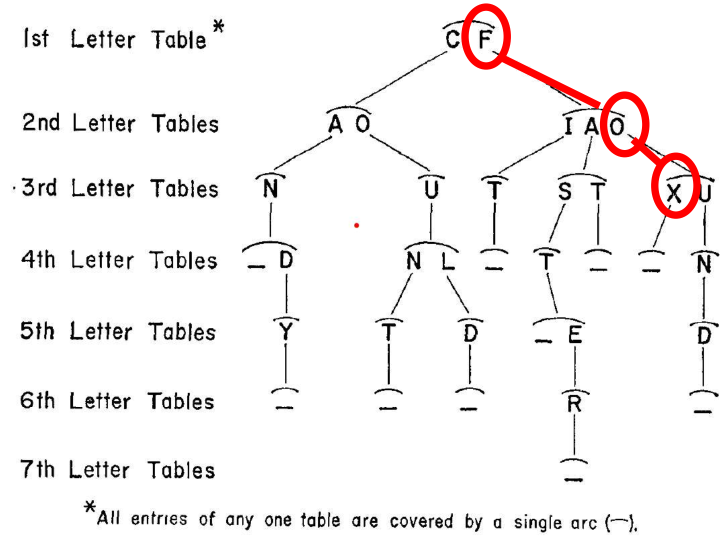


Fig. 1—Formation of a set of tables.

Clicker 2

- Is "fast" in the dictionary represented by this Trie?

A. No

B. Yes

C. It depends

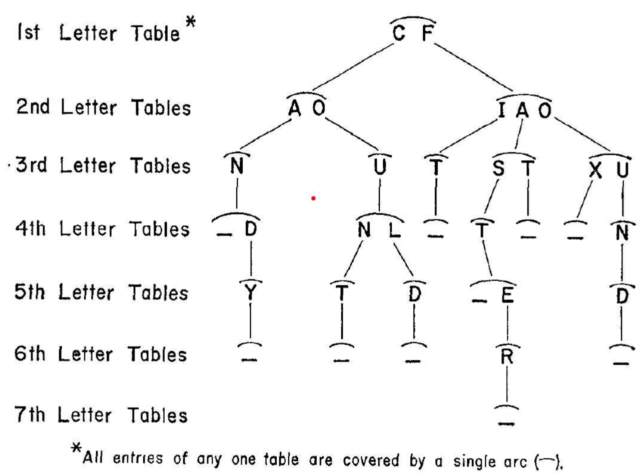


Fig. 1—Formation of a set of tables.

Clicker 3

- Is "fist" in the dictionary represented by this Trie?

A. No

B. Yes

C. It depends

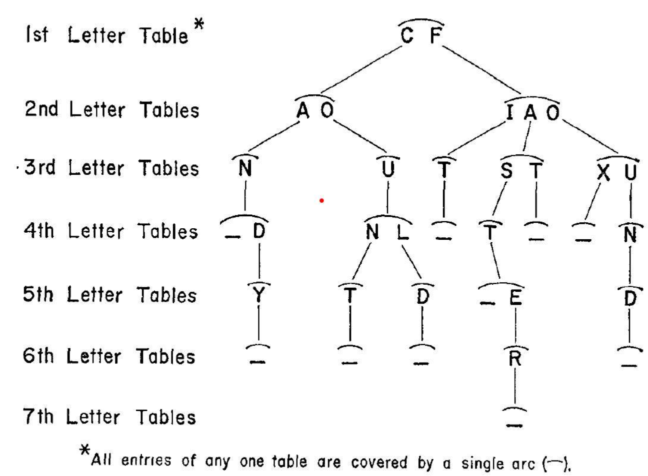
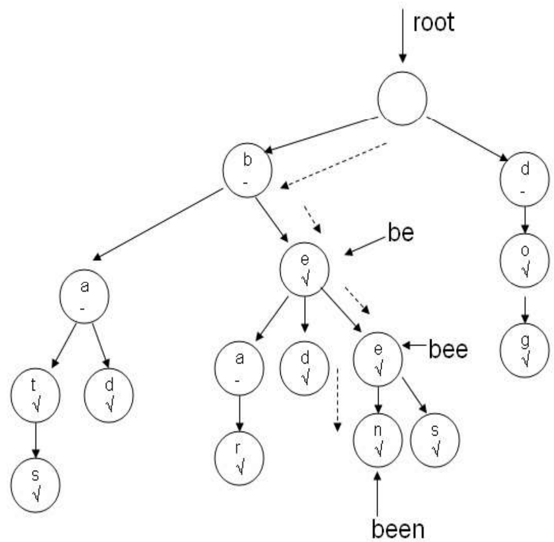


Fig. 1—Formation of a set of tables.

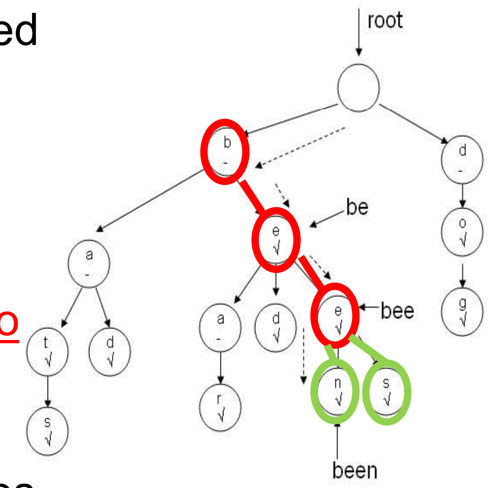
Tries

- Another example of a Trie
- Each node stores:
  - A char
  - A boolean indicating if the string ending at that node is a word
  - A list of children



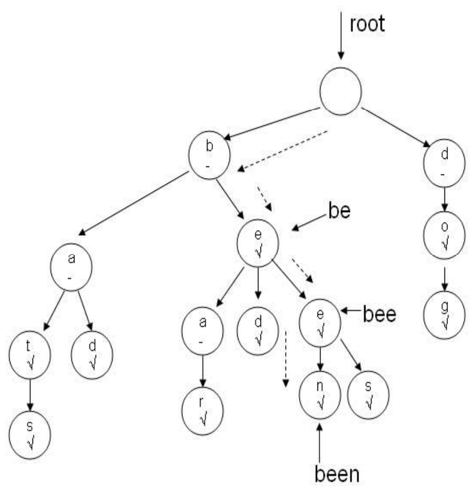
Predictive Text and AutoComplete

- As characters are entered we descend the Trie
- … and from the current node …
- … <u>we can descend to terminators and leaves to see all possible words based on current prefix</u>
- b, e, e -> bee, been, bees



Tries

- Stores words and phrases.
  - other values possible, but typically Strings
- The whole word or phrase is not actually stored in a single node.
- … rather the path in the tree represents the word.



Implementing a Trie

```
public class Trie {

    private TNode root;
    private int size; // number of words
    private int numNodes;

    public Trie() {
        root = new TNode();
        numNodes = 1;
```

TNode Class

```
private static class TNode {
        private boolean word;
        private char ch;
        private LinkedList<TNode> children;
```

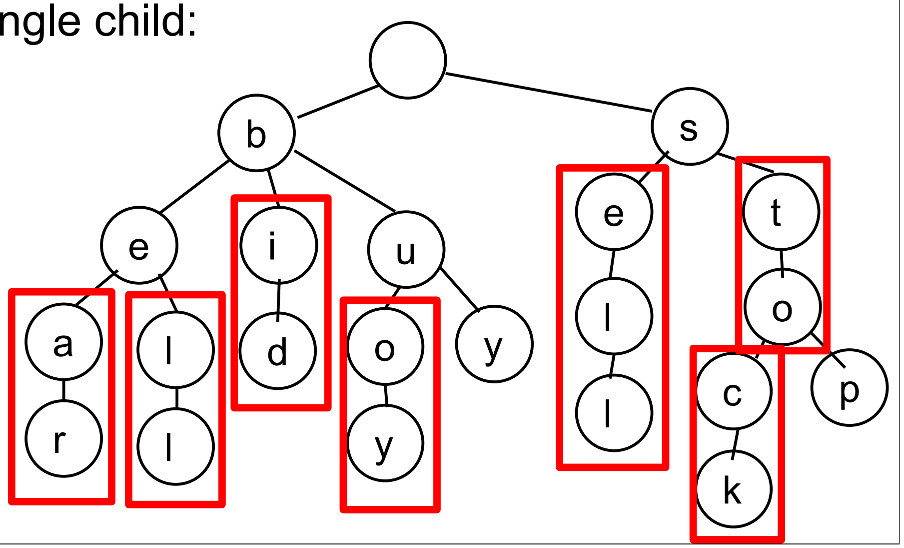
- Basic implementation uses a LinkedList of TNode objects for children
- Other options?
  – ArrayList?
  – Something more exotic?

Basic Operations

- Adding a word to the Trie
- Getting all words with given prefix
- Demo in IDE

Compressed Tries

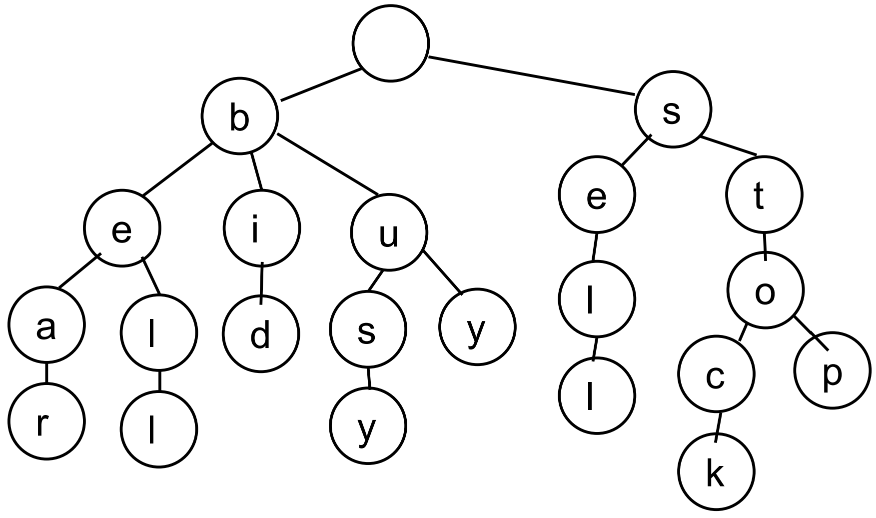
- Some words, especially long ones, lead to a chain of nodes with single child, followed by single child:



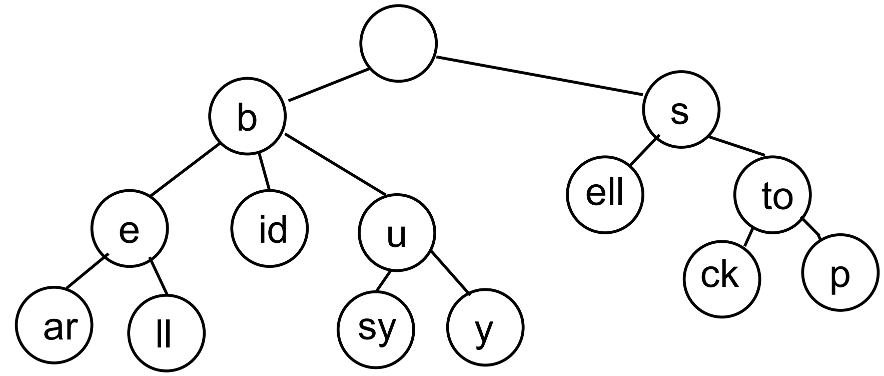
Compressed Trie

- Reduce number of nodes, by having nodes store Strings
- A chain of single child followed by single child (followed by single child …) is compressed to a single node with that String
- Does not have to be a chain that terminates in a leaf node
  – Can be an internal chain of nodes

Original, Uncompressed



Compressed Version



8 fewer nodes compared to uncompressed version

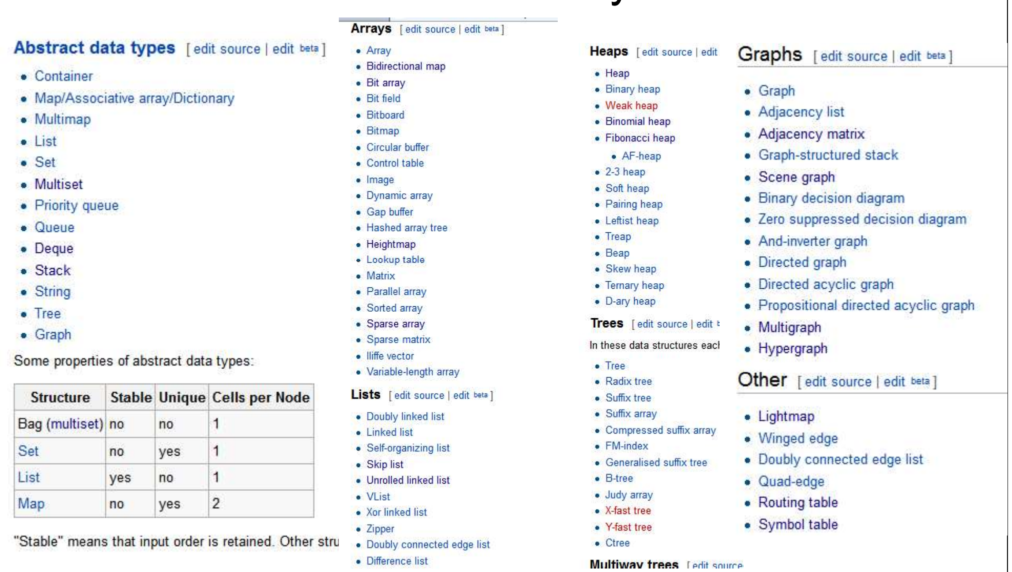
s – t – o – c - k

Data Structures

- Data structures we have studied
  - arrays, array based lists, linked lists, maps, sets, stacks, queues, trees, binary search trees, graphs, hash tables, red-black trees, priority queues, heaps, tries
- Most program languages have some built in data structures, native or library
- Must be familiar with performance of data structures
  - best learned by implementing them yourself

Data Structures

- We have ***not*** covered every data structure



Abstract data types [edit source | edit beta]

- Container
- Map/Associative array/Dictionary
- Multimap
- List
- Set
- Multiset
- Priority queue
- Queue
- Deque
- Stack
- String
- Tree
- Graph

Some properties of abstract data types:

Structure	Stable	Unique	Cells per Node
Bag (multiset)	no	no	1
Set	no	yes	1
List	yes	no	1
Map	no	yes	2

"Stable" means that input order is retained. Other stru

Arrays [edit source | edit beta]

- Array
- Bidirectional map
- Bit array
- Bit field
- Bitboard
- Bitmap
- Circular buffer
- Control table
- Image
- Dynamic array
- Gap buffer
- Hashed array tree
- Heightmap
- Lookup table
- Matrix
- Parallel array
- Sorted array
- Sparse array
- Sparse matrix
- Iliffe vector
- Variable-length array

Lists [edit source | edit beta]

- Doubly linked list
- Linked list
- Self-organizing list
- Skip list
- Unrolled linked list
- VList
- Xor linked list
- Zipper
- Doubly connected edge list
- Difference list

Heaps [edit source | edit

- Heap
- Binary heap
- Weak heap
- Binomial heap
- Fibonacci heap
  - AF-heap
- 2-3 heap
- Soft heap
- Pairing heap
- Leftist heap
- Treap
- Beap
- Skew heap
- Ternary heap
- D-ary heap

Trees [edit source | edit

In these data structures eacl

- Tree
- Radix tree
- Suffix tree
- Suffix array
- Compressed suffix array
- FM-index
- Generalised suffix tree
- B-tree
- Judy array
- X-fast tree
- Y-fast tree
- Ctree

Multiway trees [edit source

Graphs [edit source | edit beta]

- Graph
- Adjacency list
- Adjacency matrix
- Graph-structured stack
- Scene graph
- Binary decision diagram
- Zero suppressed decision diagram
- And-inverter graph
- Directed graph
- Directed acyclic graph
- Propositional directed acyclic graph
- Multigraph
- Hypergraph

Other [edit source | edit beta]

- Lightmap
- Winged edge
- Doubly connected edge list
- Quad-edge
- Routing table
- Symbol table

http://en.wikipedia.org/wiki/List_of_data_structures

Data Structures

- deque, b-trees, quad-trees, binary space partition trees, skip list, sparse list, sparse matrix, union-find data structure, Bloom filters, AVL trees, 2-3-4 trees, and more!
- Must be able to learn new and apply new data structures