Look at that sequence... Is it a vector? Is it a list? No! It's a Super Tree!!

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indizen C++ using std::cpp

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Presentation available in my semiabandoned blog:
http://www.mkrevuelta.com

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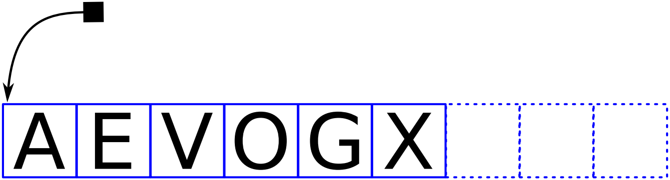
Introduction to the problem

Are lists evil?–Bjarne Stroustrup

https://isocpp.org/blog/2014/06/stroustrup-lists

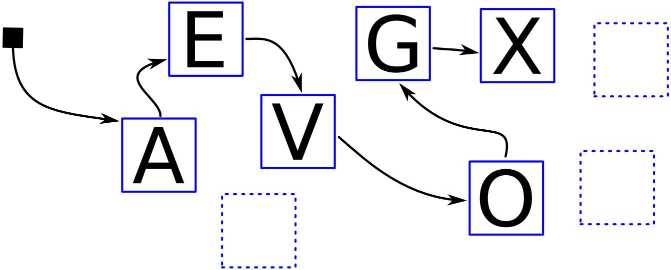
Array

- Random access is fast
- Insertion/extraction are... slow

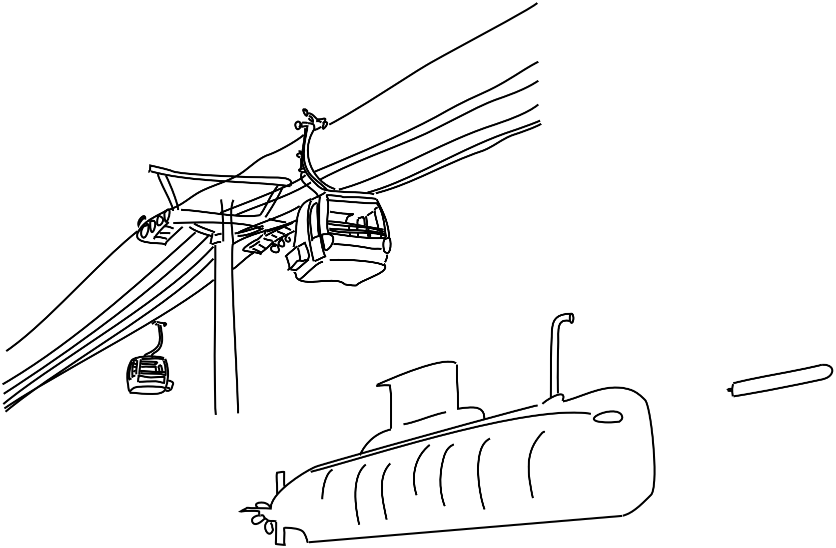


Linked list

- Insertion/extraction are fast
- Random access is... slooooow



How to compare them?



Jon Bentley's suggestion

```
for (;;)
{
```

Random access

Insertion / extraction

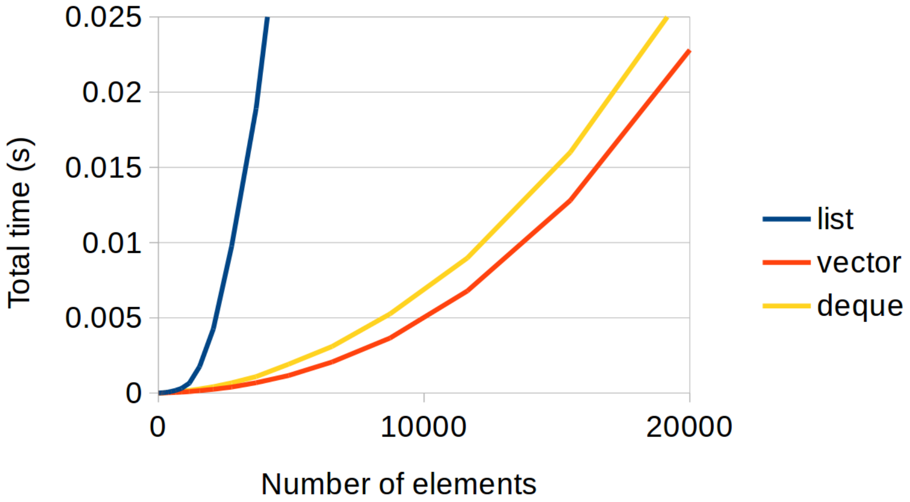
```
}
```

Jon Bentley's suggestion

"Insert a sequence of random integers
into a sorted sequence,

then **remove** those elements **one by one**
as determined by
a **random** sequece of **positions**"

Results


0.025
0.02
0.015
0.01
0.005
0
Total time (s)
0
10000
20000
Number of elements
list
vector
deque

Conclusion

Vectors are faster
by some fixed proportion
(a considerable proportion)

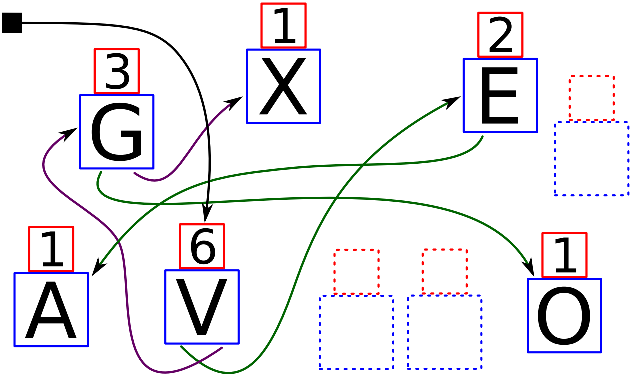
But...

Are we really interested
in Jon Bentley's problem?

Super Tree

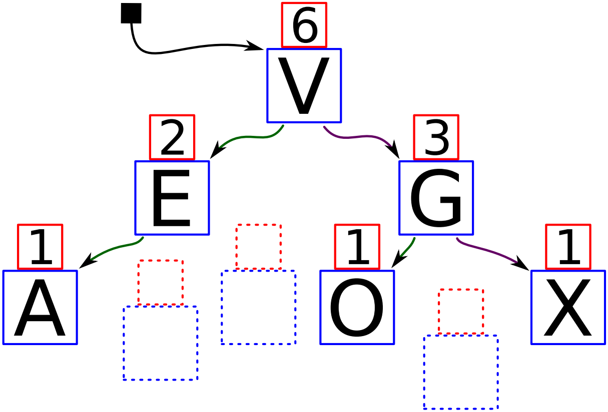
Augmented tree (messed up)

Like a list, but with two "next"s (left, and right)



Augmented tree

Special metadata: number of nodes in the sub-tree



Random access (1/3)

```
template <typename T>
struct node
{
  node<T> * left;       // Left sub-tree
  node<T> * right;      // Right "    "
  std::size_t count;    // Num. of nodes
  T value;              // Payload
};
```

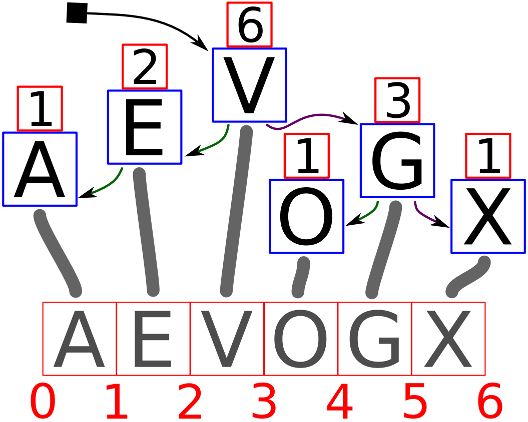
Random access (2/3)

```
template <typename T>
node<T> * RandomAccess (node<T> * root,
                        std::size_t pos)
{
  if (pos >= root->count)
    return nullptr;

  node<T> * p = root;
```

Random access (3/3)

```
for (;;)
{
  std::size_t nLeft = p->left ?
                      p->left->count : 0;

  if (pos == nLeft)          return p;
  else if (pos < nLeft)      p = p->left;
  else // (pos > nLeft)
  {
    pos -= nLeft + 1;
    p = p->right;
  }                                   } } // end
```

Proportional view



Computational complexity

	Random access	Insertion/ Extraction	**Sum of both**
Array	$O(1)$	$O(N)$	$O(N)$
List	$O(N)$	$O(1)$	$O(N)$
Super Tree	$O(log(N))$	$O(log(N))$	$O(log(N))$

Computational complexity (legend)

- $O(1)$ = constant
- $O(log(N))$ = logarithmic
- $O(N)$ = linear
- $O(N\ log(N))$ = "linearithmic"
- $O(N^c)$ = polinomic
- $O(c^N)$ = exponential
- $O(N!)$ = factorial

$\boldsymbol{N}$: size of the problem, $\boldsymbol{c}$: constant > 1

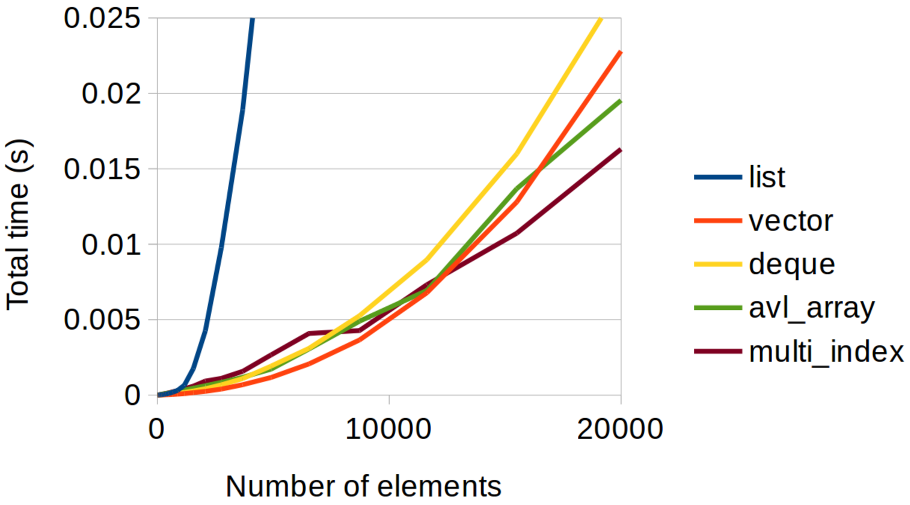
Computational complexity

	Random access	Insertion/ Extraction	**Sum of both**
Array			
List			
Super Tree			

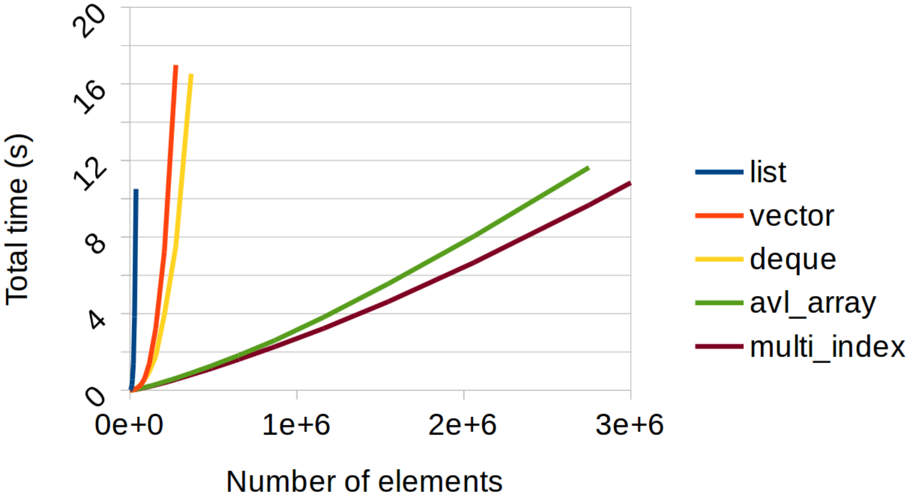
Computational complexity

	(1 rand. access + 1 ins./extr.)	$\times N =$ **total**
Array		
List		
Super Tree		

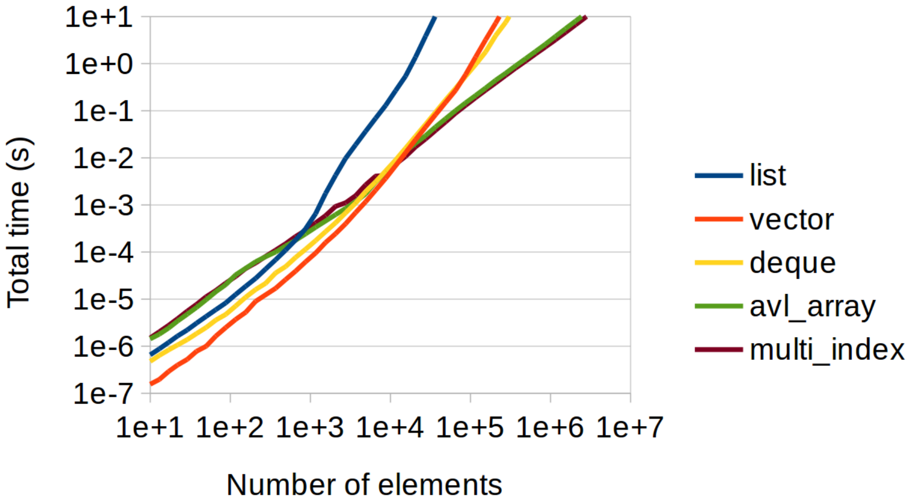
Results (1/3) — few elements



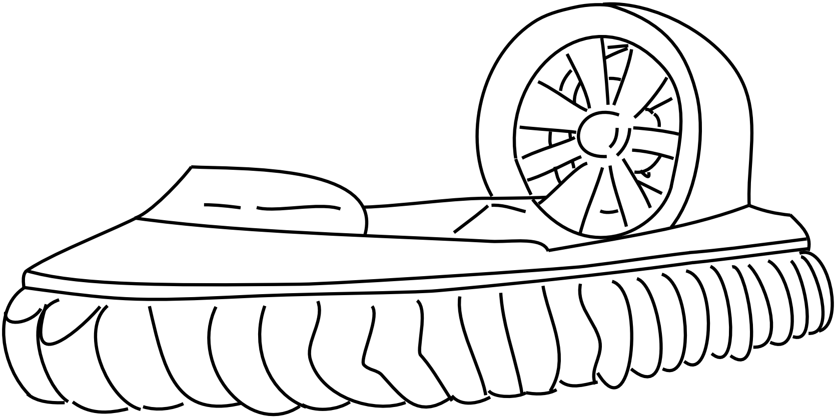
Results (2/3) — many elements



Results (3/3) — logarithmic scale

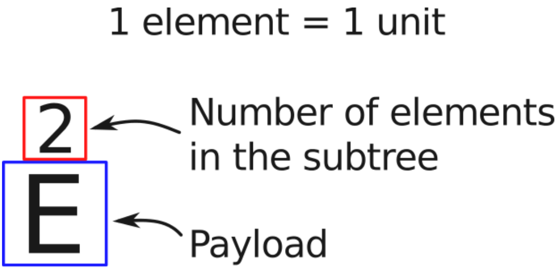


Ideal for the beach

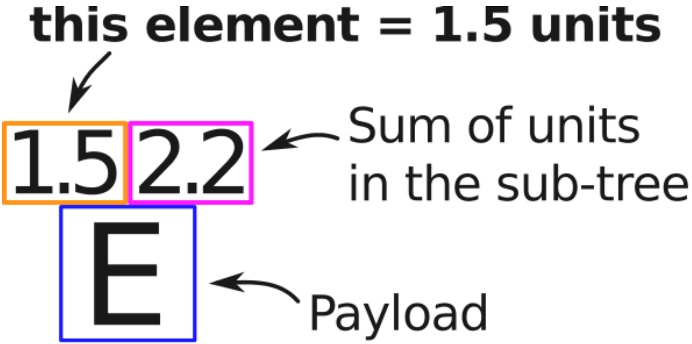


Non proportional view

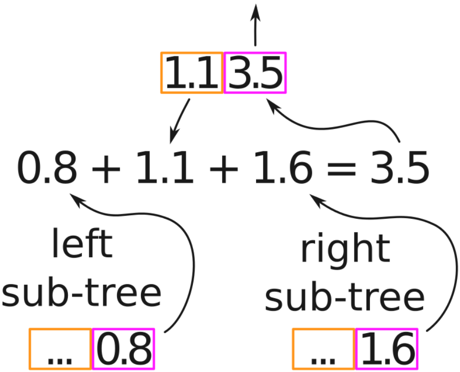
Legend in proportional view



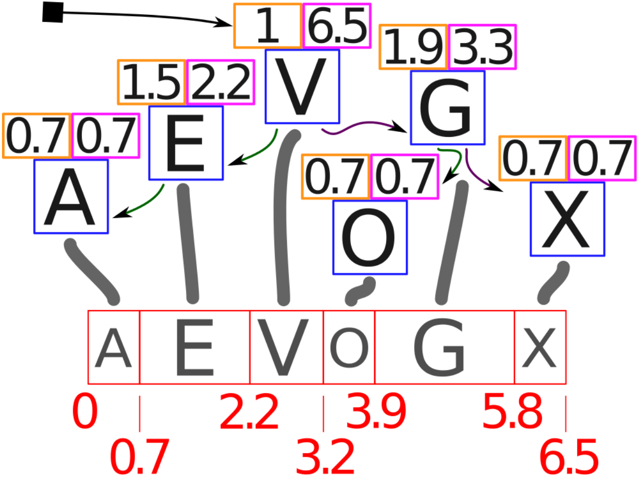
Legend in **non** proportional view



Sum in **non** proportional view



Non proportional view



Applications

Text editor

Sequence of lines

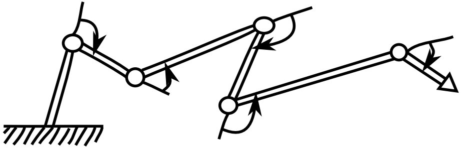
- Number of bytes
- Number of lines after word wrap
- Number of characters
- If not plain text, number of pixels

gtk

"Ad hoc" B+ tree with number of characters and lines

Robot arm or chain of molecules

- Sequence of traslation and rotation transformations
- **Non** proportional view operation:
  matrix sum and product



Disk version: `shiftable_files`

- Implementation based on memory mapped files
- Horrible code (macros!)
- Metadata contained in the same file
- At closing time, choose:
  1. Recompact the file, or...
  2. leave it as is, with the metadata

How to keep track of the sections?

Using an in-memory sequence with **non** proportional view

Editing giant XML files

- A first pass can build an in-memory index (not necessarily complete)
- You can insert/extract nodes without rewriting the whole file
- You must keep the index updated, of course
- Recompact at closing?
  1. Yes: it becomes a normal XML again
  2. No: faster

Similar proposals

Multi Index (1/2)

```
boost::multi_index_container
<
    T,
    boost::multi_index::indexed_by
    <
        boost::multi_index::ranked_non_unique
        <
            boost::multi_index::identity<T>,
            unordered_less<T>
        >
    >
>
```

Multi Index (2/2)

```
template<typename T>
struct unordered_less
{
    bool operator() (const T &,
                     const T &) const
    {
        return false;
    }
};
```

Similar proposals in Boost (1/2)

- 2004 – The oldest mention (I don't know if implemented), by Peter Palotas
  http://lists.boost.org/Archives/boost/2004/03/62823.php
- 2006 – "Hierarchical Data Structures" by Bernhard Reiter and René Rivera
  http://www.open-std.org/jtc1/sc22/wg21/docs/papers/2006/n2101.html#tr.hierarchy.augment
- 2006 – "AVL Array" (horrible name, I know)
  http://sourceforge.net/projects/avl-array
  "Rank List" after debate in Boost forum

Similar proposals in Boost (2/2)

- 2012 – Countertree by Vadim Stadnik
  http://dl.dropbox.com/u/8437476/works/countertree/doc/index.html (broken link)
- 2015 – SegmentedTree by Chris Clearwater
  https://det.github.io/segmented_tree/

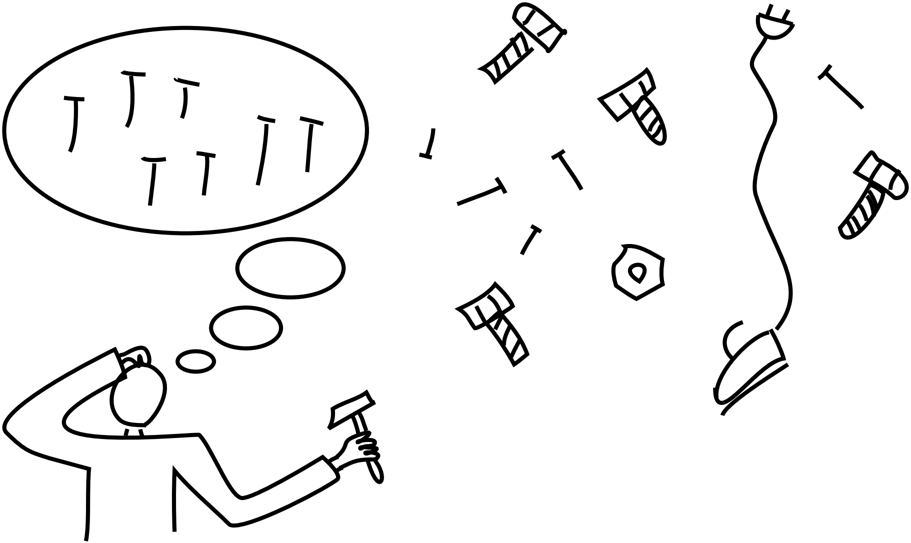
Similar proposals not in Boost

- "Simon Tatham's Algorithms Page"
  `https://www.chiark.greenend.org.uk/~sgtatham/algorithms/cbtree.html`
  "Counted B-trees: An enhancement to the well known B-tree algorithms to allow you to **look up items in the tree by numeric index**, or to **find the numeric index of an item**. Useful for finding percentiles, [...]"

Similar proposals in Python

- `https://pypi.python.org/pypi/rbtree`
- `https://pypi.python.org/pypi/pyavl`
- `https://pypi.python.org/pypi/blist`

Let's think about it



Thanks a lot

Any questions?