DESIGN OF GENERIC LIBRARIES

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HISTORY OF THE ACTIVITY

1. 79-84 TECTON
   - specialized functional forms
   - algorithms on algebraic structures
   - complexity signatures

2. 84-87 Higher Order Imperative Programming
   - extensive library
   - complex graph algorithms
   - extensive use of state

3. 87-89 Ada Generic Library
   - Common Lisp functionality
   - deep layering
   - high efficiency

4. 88-91 C++ Component Library
   - production quality
   - developed structuring

OBJECTIVE

To develop a way to construct libraries of software components.

Components should be:

- useful;
- efficient;
- generic;
- correct.

Libraries should be:

- comprehensive;
- well-structured;
- well-documented.

Bentley and Binary Search

```
L:=1; U:=N
loop
if L>U then
          P:=0; break
M:=(L+U) div 2
case
          X[M]<T  :  L:=M+1
          X[M]=T  :  P:=M; break
          X[M]>T  :  L:=M-1
```

lessThan:

returns the smallest index K in the sorted segment such that COMP is negative for all indices smaller than K.

greaterThan:

returns the smallest index K in the sorted segment such that COMP is non-positive for all indices smaller than K.

equalTo:

returns a pair of
    (lessThan(), greaterThan()).
But is faster than calling them separately.

lessThan

Declaration

```
Index SortedSegment::lessThan();
```

Description

lessThan returns the index of the rightmost element in the sorted segment such that for all indices in the segment that are smaller than it **comp** is negative. Normally, **lessThan()-first()** is equal to the number of the elements in the segment for which **comp** is negative, and **length()-(lessThan()-first())** is equal to the number of the elements in the segment for which **comp** is non-positive. (Subtraction of indices is not required by the algorithm, but is normally defined.)

See Also **greaterThan**, **equalTo**, **insert**, **setInsert**

Time Complexity Logarithmic. If n is the number of elements in the segment then at most $\lfloor \log_2 n \rfloor + 1$ operations **comp** are performed.

Space Complexity Constant

Mutative? No

Implementation

```
Index SortedSegment::lessThan()
{
    register Index start = first();
    register Integer len = length();

    while (len>0)
    {
        register Integer half = len>>1;
        register Index middle = half+start;

        if (comp(middle)<0)
        {
            start = middle+(Integer)1;
            len = (len-half)-(Integer)1;
        }
        else
            len = half;
```

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Index SortedSegment::lessThan()
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    while (len>0)
    {
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        if (comp(middle)<0)
        {
            start = middle+(Integer)1;
            len = (len-half)-(Integer)1;
        }
        else
            len = half;
    }

    return start;
}
```

```
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{
    Index start = first();
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    while (len>0)
    {
        Integer half = len>>1;
        Index middle = start+half;

        if (comp(middle)<0)
        {
            start = middle+(Integer)1;
            len = (len-half)-(Integer)1;
        }
        else
            len = half;
    }

    return start;
}
```

CLASS ASSUMPTIONS

```
classtype Integer;
// an (unsigned) integral type


classtype Index
{
public:
     Index operator+(Integer);
implied:
     int operator<(Index);
meaning:
     {Index s; Integer x, y;
      (s+x)+y==s+(x+y);
     }
     {Index s; Integer x;
      s<s+x;
     }
};

classtype SortedSegment
{
public:
     Index first();
     Integer length();
     int comp(Index);
meaning:
     {Integer x, y;
      x>y ||
      y>length() ||
      comp(first()+x)<=comp(first()+y);
     }
};
```

MEANING OF BINARY SEARCH

```
SortedSegment::lessThan::meaning()
{
     {Integer x;
          !(x>=0) ||
          !(x<length()) ||
          !(first()+x<lessThan()) ||
          comp(x)<0;
     }

     { !(lessThan()<length()) ||
       comp(lessThan())>=0;
     }
}
```

DOING IT FOR VECTORS

```
typedef float Type;
typedef int Integer;
typedef Type* Index;

class Fvector
{
private:
     Index b;
     Integer l;
     Type v;
public:
     Fvector(Index x, Integer y, Type z) :
     b(x), l(y), v(z){};
     Integer length() {return l;}
     Index first() {return b;}
     void set_value(type z){v=z;}
     int comp(Index x){return int(*x-t);}
     Index lessThan();
};

#define SortedSegment Fvector
#include "lessThan.H"
```

DOING IT FOR LISTS (1)

```
typedef float Type;
typedef int Integer;

struct Node
{
    Node* cdr;
    Type car;
};

struct Index
{
    Node* i;
    Index(Node* j) : i(j);
    Index operator+(Integer n)
    {
        Node* t = i;
        while (n-->0) t = *t;
        return Index(t);
    }
}
```

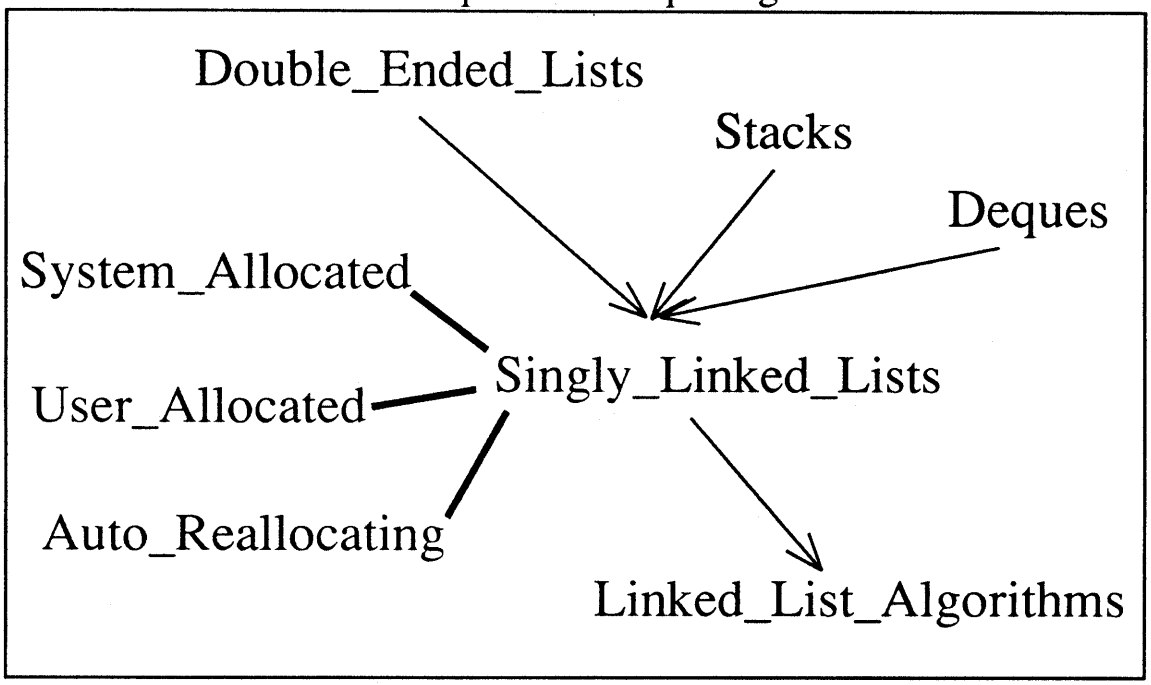
DOING IT FOR LISTS (2)

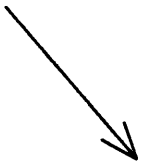
```
class Flist
{
private:
     Index b;
     Type v;
public:
     Flist(Index x, Type z) :
     b(x), v(z){};
     Integer length()
     {
          for(int i = 0; b.cdr(); i++);
          return i;
     }
     Index first() {return b;}
     void set_value(type z){v=z;}
     int comp(Index x){return int(*x-t);}
     Index lessThan();
};

#define SortedSegment Fvector
#include "lessThan.H"
```

D. R. Musser & A. A. Stepanov
Ada Generic Library:
Linear List Processing Packages
Springer-Verlag, 1989

170 Components in 8 packages



 = *implemented in terms of*

 = *plugs together with*

PARTIAL AND APPROXIMATE MODELS

A partial model is isomorphic to the complete model when the partial model is defined.

E.g.,

- bounded sequences
- fixed precision arithmetic

An approximate model may also disagree with the complete model, but all the disagreements are within well defined tolerance

E.g.,

- floating point arithmetic
- pixel representation of continuous images

ORGANIZATION OF THE LIBRARY

1. Structures
   - set of operations
   - generic meaning
   - generic algorithms

sequences

2. Realizations
   - relative complexity
   - specific meaning
   - specific algorithms

vectors, lists

3. Implementations
   - constraints
   - exact complexity
   - exeption handling

bounded vectors,
extensible vectors

singly linked lists with
  incremental garbage collection

CLASSIFICATION OF OPERATIONS

Pseudo-permutations
{some of the same elements
in a different order}

Improper permutations:
- index based:
  - subrange, even-numbered
- predicate-based:
  - remove, stable remove
- comparison-based:
  - remove-duplicates, select largest half

Proper permutations:
- index based:
  - reverse, rotate, random-shuffle
- predicate-based:
  - partition, stable partition
- comparison-based:
  - sort, stable sort, partial sort

FUNCTIONAL vs. MUTATIVE

FUTURE PLANS

* Community selection
  - formal
  - software engineering
  - systems

* CSP (Maxwell, Datamesh)
  - classification of disk algorithms
  - build DataMesh from reusable components