Algorithm Analysis

```
public final class MaxSumTest
{  // Fig 5.4, p155
   static private int seqStart = 0;
   static private int seqEnd = -1;
   public static int maxSubSum1( int [ ] a )
   {
      int maxSum = 0;

      for( int i = 0; i < a.length; i++ )
         for( int j = i; j < a.length; j++ )
         {
            int thisSum = 0;

            for( int k = i; k <= j; k++ )
               thisSum += a[ k ];

            if( thisSum > maxSum )
            {
               maxSum   = thisSum;
               seqStart = i;
               seqEnd   = j;
            }
         }

      return maxSum;
   }
}
```

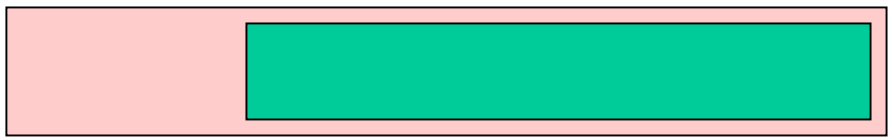
$O(n^3)$

```
public final class MaxSumTest
{  // Fig 5.5, p157
   public static int maxSubSum2( int [ ] a )
   {
      int maxSum = 0;

      for( int i = 0; i < a.length; i++ )
      {
         int thisSum = 0;
         for( int j = i; j < a.length; j++ )
         {
            thisSum += a[ j ];

            if( thisSum > maxSum )
            {
               maxSum = thisSum;
               seqStart = i;
               seqEnd   = j;
            }
         }
      }

      return maxSum;
   }
}
```

$O(n^2)$

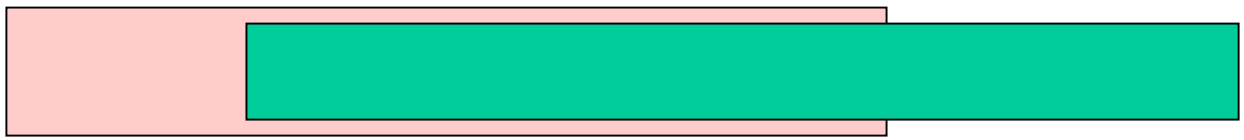
Improved Algorithm: 2 Observations

Fix the start (s) and end (e). Assume it results in a positive sum for every block ending at e or to the left of e.



No other start (s') with the same end (e) can result in a larger sum.

Fix the start (s) and end (e). Assume it results in a positive sum for every block ending to the left of e and a negative sum for the block ending at e.



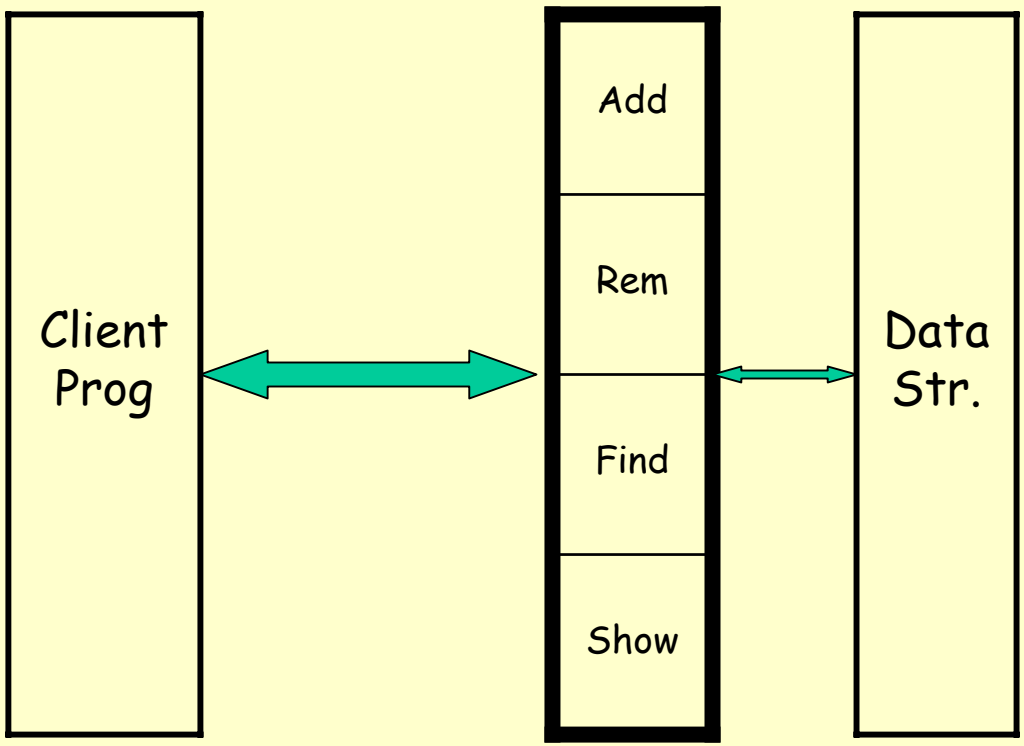
No other start (s') between s and e can result in a larger sum.

Algorithm Analysis

O(n)

```
public final class MaxSumTest
{  // Fig 5.8, p160
   public static int maxSubSum3( int [ ] a )
   {
      int maxSum = 0;
      int thisSum = 0;

      for( int i = 0, j = 0; j < a.length; j++ )
      {
         thisSum += a[ j ];

         if( thisSum > maxSum )
         {
            maxSum = thisSum;
            seqStart = i;
            seqEnd   = j;
         }
         else if( thisSum < 0 )
         {
            i = j + 1;
            thisSum = 0;
         }
      }

      return maxSum;
   }
}
```

Abstract Data Types



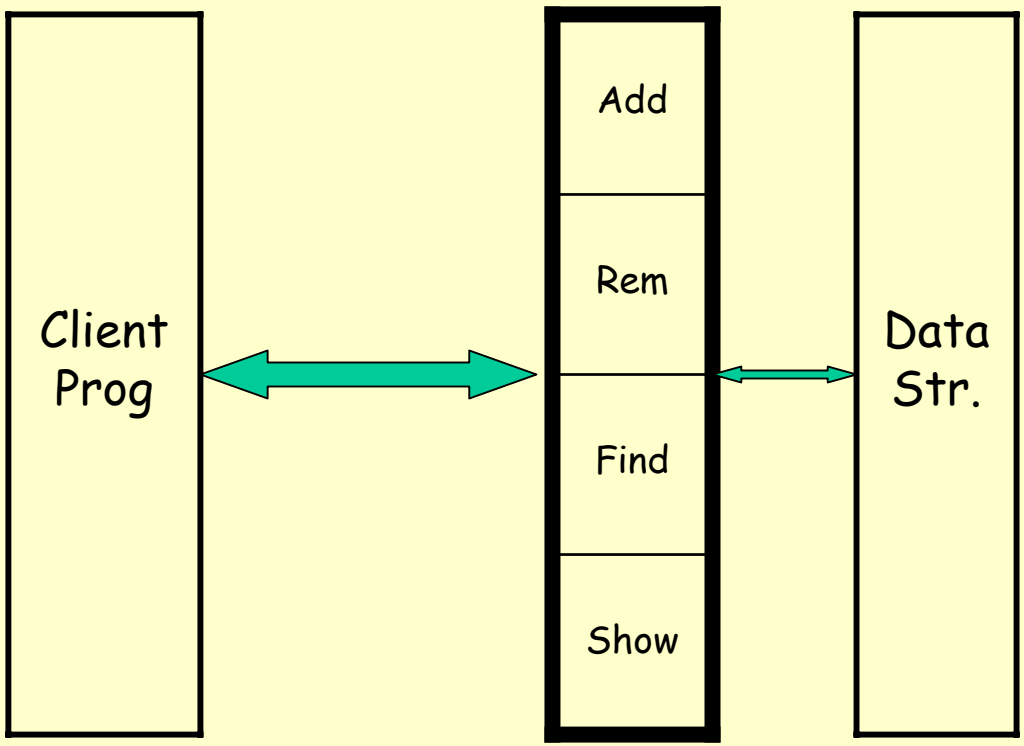
Containers

- Powerful tool for programming data structures
- Provides a library of container classes to "hold your objects"
- 2 types of Containers:
  - Collection: to hold a group of elements e.g., List, Set
  - Map: a group of key-value object pairs. It helps to return "Set of keys, collection of values, set of pairs. Also works with multiple dimensions (i.e., map of maps).
- Iterators give you a better handle on containers and helps to iterate through all the elements. It can be used without any knowledge of how the collection is implemented.
- Collections API provides a few general purpose algorithms that operate on all containers.

```
// Fig 6.9, 6.10, pg 192, 194.
package weiss.util;

public interface Collection extends java.io.Serializable
{
   int size( );
   boolean isEmpty( );
   boolean contains( Object x );
   boolean add( Object x );
   boolean remove( Object x );
   void clear( );
   Iterator iterator( );
   Object [ ] toArray( );
}

public interface Iterator
{
   boolean hasNext( );
   Object next( );
   void remove( );
}
```

```
// Fig 6.11, pg 195
public static void printCollection
                (Collection c)
{
    Iterator itr = c.iterator();
    while (itr.hasNext())
        System.out.println(itr.next());
}
```

Abstract Data Types



Linear Lists

- It is an ordered collection of elements.
- Lists have items, size or length.
- Elements may have an index.
- Main operations:
  - isEmpty(), size(),
  - get(idx), indexOf(elem),
  - remove(idx), add(idx, elem),
  - display()
- Java's linear lists:
  - java.util.ArrayList and java.util.LinkedList.

Useful List Operations

- Return item from position j
- Search for item x
- Add (anywhere)
- Insert at position j; Insert at position 0 (or size-1)
- Add before (after) item x
- Remove any item
- Remove item in position j; Remove last (first) item
- Remove item x
- Search for item x in sorted list
- Add (remove) to (from) sorted list (item x or position j)
- Max, Min, Concatenate, Sort, Sum, Average, Etc.

Generic Operations: get(idx), set(idx, x), iterator(pos)

Using Iterators

- Why use them?
- Compare these 2 pieces of code:
  - for (int j = 0; j < A.size(); j++)
    visit(A.get(j))
  - iterator h = A.iterator();
    while (h.hasNext())
    visit(h.next());
- Which one is better? Why?

```
// Fig 6.16,6.17, pg 201, 202
package weiss.util;

public interface List
        extends Collection
{
    Object get( int idx );
    Object set( int idx,
        Object newVal );
    ListIterator listIterator( int pos );
}

public interface ListIterator
        extends Iterator
{
    boolean hasPrevious( );
    Object previous( );
    void remove( );
}
```

```
class TestArrayList // Fig 6.18, pg 203
{
    public static void main( String [ ] args )
    {
        ArrayList lst = new ArrayList( );
        lst.add( "2" );  lst.add( "4" );
        ListIterator itr1 = lst.listIterator( 0 );
        System.out.print( "Forward: " );
        while( itr1.hasNext( ) )
            System.out.print( itr1.next( ) + " " );
        System.out.println( );

        System.out.print( "Backward: " );
        while( itr1.hasPrevious( ) )
            System.out.print( itr1.previous( ) + " " );
        System.out.println( );

        System.out.print( "Backward: " );
        ListIterator itr2 = lst.listIterator( lst.size( ) );
        while( itr2.hasPrevious( ) )
            System.out.print( itr2.previous( ) + " " );
        System.out.println( );
    }
}
```

Caveats about iterators

- Consider, for e.g. the following problem: Delete all students that have dropped the class (have the drop flag ON) from the class roster.

```
Iterator itr = c.iterator();
while (itr.hasNext() && (dropped(itr))
        remove(itr);
```

- What item is "current" if it has been "removed".
- What happens if we are within a "for-loop"?
  - Removal might change for-loop bounds.

```
// pg 205
package weiss.util;

public class LinkedList extends AbstractCollection implements List
{
    public void addFirst( Object x )
    public void addLast( Object x )
    public Object getFirst( )
    public Object getLast( )
    public Object removeFirst( )
    public Object removeLast( )
}
```

```
public interface Stack
{
    public Object push( Object x );
    public Object pop( );
    public boolean isEmpty( );
}

public interface Queue
{
    public boolean isEmpty( );
    public void enqueue( Object x );
    public Object dequeue( );
}
```

```
package weiss.util; // Fig 6.9-10, pg 192-4.

public interface Collection
        extends java.io.Serializable
{
  int size( );
  boolean isEmpty( );
  boolean contains( Object x );
  boolean add( Object x );
  boolean remove( Object x );
  void clear( );
  Iterator iterator( );
  Object [ ] toArray( );
}

public interface Iterator
{
  boolean hasNext( );
  Object next( );
  void remove( );
}
```

```
// Fig 6.16,6.17, pg 201-2
package weiss.util;

public interface List
        extends Collection
{
   Object get( int idx );
   Object set( int idx,
        Object newVal );
   ListIterator listIterator( int pos );
}

public interface ListIterator
        extends Iterator
{
   boolean hasPrevious( );
   Object previous( );
   void remove( );
}
```

```
package weiss.util;  // Fig 15.10, pg 501
public abstract class AbstractCollection
                implements Collection
{
   public boolean isEmpty( )  { return size( ) == 0; }
   public void clear( ) {
      Iterator itr = iterator( );
      while( itr.hasNext( ) ) {
         itr.next( );
         itr.remove( );
      }
   }
   public Object [ ] toArray( ) { /* not shown */ }
   public boolean contains( Object x ) {
      if( x == null ) return false;
      Iterator itr = iterator( );
      while( itr.hasNext( ) )
         if( x.equals( itr.next( ) ) ) return true;
      return false;
   }
   public boolean remove( Object x ) {
      if( x == null ) return false;
      Iterator itr = iterator( );
      while( itr.hasNext( ) )
         if( x.equals( itr.next( ) ) ) {
            itr.remove( );
            return true;
         }
      return false;
   }
```

```
package weiss.util;  // Fig 15.12, pg 503
public class ArrayList extends AbstractCollection
                 implements List
{
   private static final int DEFAULT_CAPACITY = 10;
   private static final int NOT_FOUND = -1;
   private Object [ ] theItems;
   private int theSize;
   private int modCount = 0;
   public ArrayList( )  { clear( ); }
   public ArrayList( Collection other ) {
      clear( );
      Iterator itr = other.iterator( );
      while( itr.hasNext( ) ) add( itr.next( ) );
   }
   public int size( ) { return theSize; }
   public Object get( int idx )  {
      if( idx < 0 || idx >= size( ) )
         throw new ArrayIndexOutOfBoundsException();
      return theItems[ idx ];
   }
   public Object set( int idx, Object newVal ) {
      if( idx < 0 || idx >= size( ) )
         throw new ArrayIndexOutOfBoundsException();
      Object old = theItems[ idx ];
      theItems[ idx ] = newVal;
      return old;
   }
  public boolean contains( Object x ) {
      return findPos( x ) != NOT_FOUND;
   }
```

```
   private int findPos( Object x ) {
      for( int i = 0; i < size( ); i++ )
         if( x == null ) {
            if( theItems[ i ] == null )  return i;  }
         else if( x.equals( theItems[ i ] ) )  return i;
      return NOT_FOUND;
   }
   public boolean add( Object x )  {
      if( theItems.length == size( ) )  {
         Object [ ] old = theItems;
         theItems = new Object[ theItems.length * 2 + 1 ];
         for( int i = 0; i < size( ); i++ )   theItems[ i ] = old[ i ];
      }
      theItems[ theSize++ ] = x;
      modCount++;
      return true;
   }
   public boolean remove( Object x )  {
      int pos = findPos( x );
      if( pos == NOT_FOUND ) return false;
      else {
         remove( pos );
         return true;
      }
   }
   public Object remove( int idx )  {
      Object removedItem = theItems[ idx ];
      for( int i = idx; i < size( ) - 1; i++ )
         theItems[ i ] = theItems[ i + 1 ];
      theSize--;   modCount++;    return removedItem;
   }
```

```
public void clear( )
    {
        theSize = 0;
        theItems = new Object[ DEFAULT_CAPACITY ];
        modCount++;
    }
public Iterator iterator( )
    {
        return new ArrayListIterator( 0 );
    }
public ListIterator listIterator( int idx )
    {
        return new ArrayListIterator( idx );
    }
private class ArrayListIterator implements ListIterator
    { // See next slide
    }
}
```

```
public Iterator iterator( ) { return new ArrayListIterator( 0 );  }
public ListIterator listIterator( int idx ) {return new ArrayListIterator( idx );}
private class ArrayListIterator implements ListIterator  {
      private int current;
      private int expectedModCount = modCount;
      private boolean nextCompleted = false; private boolean prevCompleted = false;
      ArrayListIterator( int pos )  {
         if( pos < 0 || pos > size( ) ) throw new IndexOutOfBoundsException( );
         current = pos;
      }
      public boolean hasNext( )  {
         if( expectedModCount != modCount )
            throw new ConcurrentModificationException( );
         return current < size( );
      }
      public boolean hasPrevious( ) { /* OMITTED */ }
      public Object next( )  {
         if( !hasNext( ) )  throw new NoSuchElementException( );
         nextCompleted = true;   prevCompleted = false;
         return theItems[ current++ ];
      }
      public Object previous( ) { /* OMITTED */ }
      public void remove( ) {
         if( expectedModCount != modCount )
            throw new ConcurrentModificationException( );
         if( nextCompleted ) ArrayList.this.remove( --current );
         else if( prevCompleted )  ArrayList.this.remove( current );
         else throw new IllegalStateException( );
         prevCompleted = nextCompleted = false;  expectedModCount++;
      }
   }
}
```

```
package weiss.nonstandard;
class ListNode
{
   public ListNode( Object theElement ) { this( theElement, null ); }
   public ListNode( Object theElement, ListNode n ) {
      element = theElement;
      next    = n;
   }
   public Object   element;
   public ListNode next;
}

public class LinkedListIterator
{
   LinkedListIterator( ListNode theNode ){ current = theNode; }
   public boolean isValid( ) { return current != null; }
   public Object retrieve( )
            {return isValid( ) ? current.element : null;}
   public void advance( ) {
      if( isValid( ) )  current = current.next;
    }
    ListNode current;    // Current position
}
```

```
package weiss.util;

public class LinkedList extends AbstractCollection
                implements List
{
   public LinkedList( ) { clear( ); }
   public LinkedList( Collection other ) {
      clear( );
      Iterator itr = other.iterator( );
      while( itr.hasNext( ) )
         add( itr.next( ) );
   }
   public int size( ) { return theSize; }
   public boolean contains( Object x ) {
      return findPos( x ) != NOT_FOUND;
   }
   private Node findPos( Object x ) {
      for( Node p = beginMarker.next;
                  p != endMarker; p = p.next )
         if( x == null ) {
            if( p.data == null ) return p;
         }
         else if( x.equals( p.data ) ) return p;
      return NOT_FOUND;
   }
   public boolean add( Object x ) {
      addLast( x );
      return true;
   }
   public void addFirst( Object x ) { add( 0, x ); }
   public void addLast( Object x ) { add( size( ), x ); }
   public void add( int idx, Object x ) {
      Node p = getNode( idx );
      Node newNode = new Node( x, p.prev, p );
      newNode.prev.next = newNode;
      p.prev = newNode;
      theSize++;
      modCount++;
   }
   public Object getFirst( ) {
      if( isEmpty( ) )
         throw new NoSuchElementException( );
      return getNode( 0 ).data;
   }
   public Object getLast( ) {
      if( isEmpty( ) )
         throw new NoSuchElementException( );
      return getNode( size( ) - 1 ).data;
   }
   public Object get( int idx ) {return getNode( idx ).data;}
   private Node getNode( int idx ) {
      Node p;
      if( idx < 0 || idx > size( ) )
         throw new IndexOutOfBoundsException( );
      if( idx < size( ) / 2 ) {
         p = beginMarker.next;
         for( int i = 0; i < idx; i++ )    p = p.next;
      } else {
         p = endMarker;
         for( int i = size( ); i > idx; i-- )  p = p.prev;
      }
      return p;
   }
```

```
public Object removeFirst( ) {
    if( isEmpty( ) ) throw new NoSuchElementException( );
    return remove( getNode( 0 ) );
}
public Object removeLast( ) {
    if( isEmpty( ) ) throw new NoSuchElementException( );
    return remove( getNode( size( ) - 1 ) );
}
public boolean remove( Object x ) {
    Node pos = findPos( x );
    if( pos == NOT_FOUND )   return false;
    else {
        remove( pos );
        return true;
    }
}
public Object remove( int idx ) { return remove( getNode( idx ) );}
private Object remove( Node p ) {
    p.next.prev = p.prev;
    p.prev.next = p.next;
    theSize--;
    modCount++;
    return p.data;
}
public void clear( ) {
    beginMarker = new Node( "BEGINMARKER", null, null );
    endMarker = new Node( "ENDMARKER", beginMarker, null );
    beginMarker.next = endMarker;
    theSize = 0;
    modCount++;
}
```

```
private class LinkedListIterator implements ListIterator
  {
    private Node current;
    private Node lastVisited = null;
    private boolean lastMoveWasPrev = false;
    private int expectedModCount = modCount;

    public LinkedListIterator( int idx ){current = getNode( idx );
    public boolean hasNext( ) {
      if( expectedModCount != modCount )
        throw new ConcurrentModificationException( );
      return current != endMarker;
    }
    public Object next( ) {
      if( !hasNext( ) ) throw new NoSuchElementException( );
      Object nextItem = current.data;
      lastVisited = current;
      current = current.next;
      lastMoveWasPrev = false;
      return nextItem;
    }
    public void remove( ){
      if( expectedModCount != modCount )
        throw new ConcurrentModificationException( );
      if( lastVisited == null ) throw new IllegalStateException( );
      LinkedList.this.remove( lastVisited );
      lastVisited = null;
      if( lastMoveWasPrev )
        current = current.next;
      expectedModCount++;
    }
```

```
    public boolean hasPrevious( )
    {
      if( expectedModCount != modCount )
        throw new ConcurrentModificationException( )
      return current != beginMarker.next;
    }

    public Object previous( )
    {
      if( expectedModCount != modCount )
        throw new ConcurrentModificationException( )
      if( !hasPrevious( ) )
        throw new NoSuchElementException( );

      current = current.prev;
      lastVisited = current;
      lastMoveWasPrev = true;
      return current.data;
    }
  }
```

Fig 17.30, page 562

How to insert into a linked list

```
public class LinkedList
       extends AbstractCollection
       implements List
{
    private static class Node
    {
       // some constructors
       public Object   element;
       public Node next;
    }

   private int theSize;
   private Node beginMarker;
   private Node endMarker;

   // • • •  Other stuff here
}
```

```
// Insert newNode after q
newNode.next = q.next;
q.next = newNode;

newNode.prev = q;
newNode.next.prev = newNode;
theSize++;
```

```
public void add( int idx, Object x ) {
       Node p = getNode( idx );
       Node newNode = new Node( x, p.prev, p );
       newNode.prev.next = newNode;
       p.prev = newNode;
       theSize++;
       modCount++;
}
```

How to delete & get from a linked list

```
// Delete node after q
q.next = q.next.next;

q.next.prev = q;
theSize-- ;
return q;
```

```
private Object remove( Node p )
{
        p.next.prev = p.prev;
        p.prev.next = p.next;
        theSize--;
        modCount++;
        return p.data;
}
```

```
p = beginMarker.next;
for( int i = 0; i < idx; i++ )
                p = p.next;
return p;
```

```
private Node getNode( int idx ) {
        Node p;
        if( idx < 0 || idx > size( ) )
            throw new IndexOutOfBoundsException( );
        if( idx < size( ) / 2 ) {
            p = beginMarker.next;
            for( int i = 0; i < idx; i++ )    p = p.next;
        } else {
            p = endMarker;
            for( int i = size( ); i > idx; i-- )  p = p.prev;
        }
        return p;
}
```

Stacks and Queues

```
public interface Stack
{
   public Object push( Object x );
   public Object pop( );
   public boolean isEmpty( );
}

public interface Queue
{
   public boolean isEmpty( );
   public void enqueue( Object x );
   public Object dequeue( );
}
```

How to search in a sorted list

```
public class BinarySearch // Fig 5.11, pg168
{
   public static final int NOT_FOUND = -1;
   public static int binarySearch
              ( Comparable [ ] a, Comparable x )
   {
      int low = 0;
      int high = a.length - 1;
      int mid;
      while( low <= high )
      {
         mid = ( low + high ) / 2;
         if( a[ mid ].compareTo( x ) < 0 )
            low = mid + 1;
         else if( a[ mid ].compareTo( x ) > 0 )
            high = mid - 1;
         else
            return mid;
      }
      return NOT_FOUND;     // NOT_FOUND = -1
   }
```

```
   // Test program
   public static void main( String [ ] args )
   {
      int SIZE = 8;
      Comparable [ ] a = new Integer [ SIZE ];
      for( int i = 0; i < SIZE; i++ )
         a[ i ] = new Integer( i * 2 );

      for( int i = 0; i < SIZE * 2; i++ )
         System.out.println( "Found " + i + " at " +
              binarySearch( a, new Integer( i ) ) );
   }
}
```