Alexandria University
Faculty of Engineering
Computer and Systems Engineering Department

Automatic Control

Searching Report

March 12

2009

Sequential, Binary, Interpolation, BST-trees, AVL-trees

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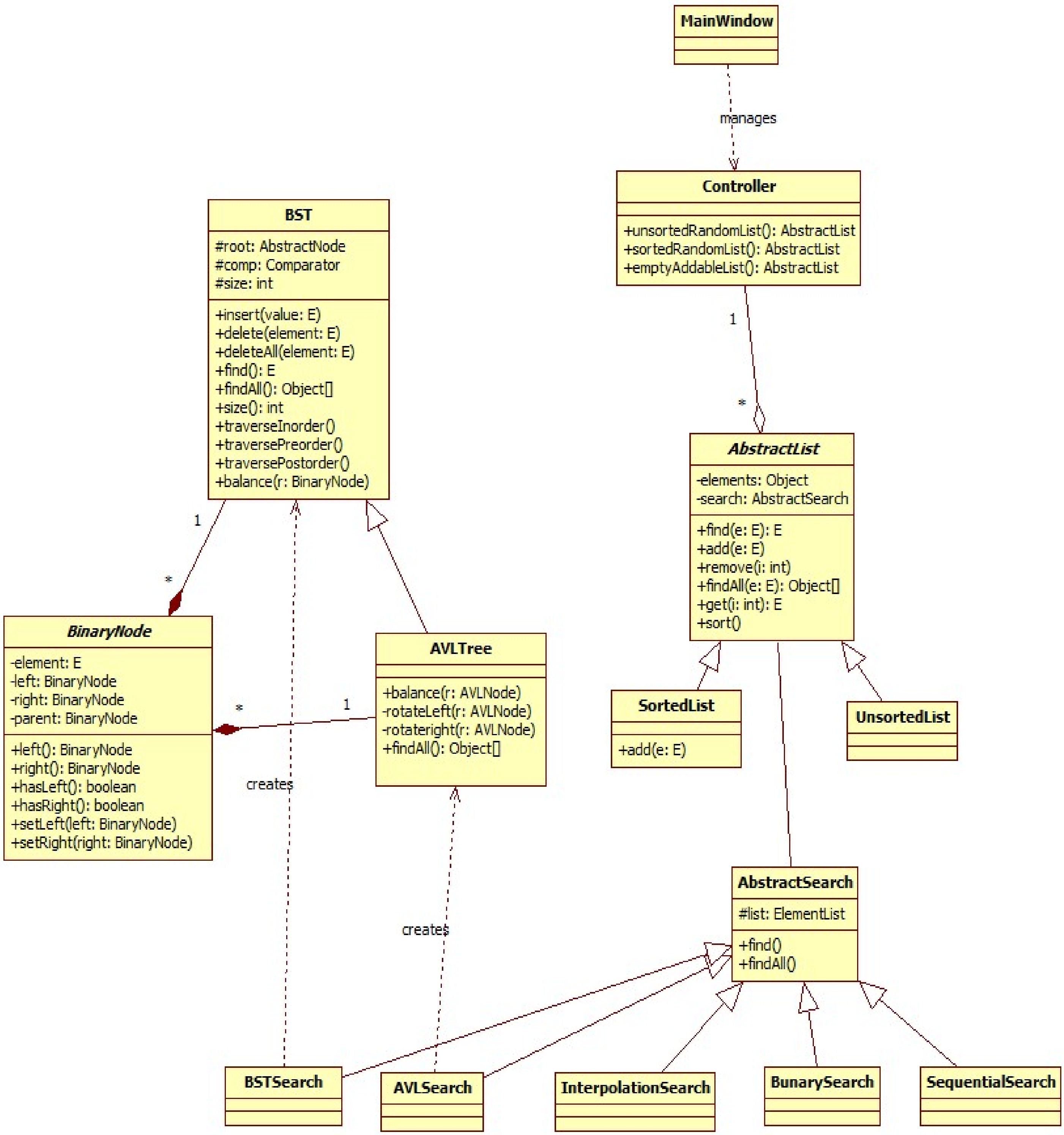
Class Diagram



Sequential Search

Advantages

- Simple to implement.
- Maintainable and easy to change and use its internal data.
- Used in ever day's program for simple non-requiring operations.
- Consumes no external or internal space for recursive operations as it can be easily implemented iteratively.
- Goes the same on sorted and unsorted lists.

Disadvantages

- Slow.
- Always eliminating one item per iteration even if it is much far from the desired destination. (Normal step <-- 1).
- O (n).

Binary Search

Advantages

- Fast as it eliminates half of the elements in the list by one iteration.
- Can be implemented both iteratively and recursively.
- O ($\log_2$(n))
- Runs the same for any distribution of the list.

Disadvantages

- Requiring a previously sorted list
- Always eliminating half of the list even if the desired element is in one of the edges if the list.

Interpolation Search

Advantages

- Fast as it eliminates most of the elements in the list by one iteration.
- Can be implemented both iteratively and recursively.
- O ($\log_2 \log_2(n)$) if the list is normally distributed.

Disadvantages

- Requires previous knowledge that the data is normally distributed to achieve the best performance.

BST (Binary Search Trees)

Advantages

- Structured search.
- Can be used in implementing decision trees as in games or artificial intelligence.
- Having the data ready for searching instead of having the method ready for the list.
- O($\log_2 n$) for randomly inserted lists.

Disadvantages

- Can reach to a linked list behavior when the data sequence is already sorted O (n).
- Consumes additional memory to save the tree nodes.
- Requires additional effort for implementation.

AVL Trees

Advantages

- Structured search.
- Can be used in implementing decision trees as in games or artificial intelligence.
- Having the data ready for searching instead of having the method ready for the list.
- $O(\log_2 n)$ for the worst case.
- Consumes less memory than BST for dereferenced nodes (not noticeable).

Disadvantages

- Consumes additional memory to save the tree nodes. O(n).
- Requires much more additional effort for implementation.

AVL Tree Algorithms (Specialized)

```
Algorithm findAll(key e) {
            if (size equals 0)
                  return NOT_FOUND;
            temp ← find(root, element);
            found ← findAll(list, temp, element);
            return found;
      }

      Algorithm  findAll(list, Node temp, Element e) {
            if (temp equals NULL)
                  return;
            if (compare(temp.element, e) equals 0) then
                  list.add(temp);
            findAll(list, temp.right, e);
            findAll(list, temp.left, e);
      }

      Algorithm Node balance(Node r) {
            if (r.hl > r.hr) then
                  if (r.left.hr > r.left.hl) then
                        Node node ← rotateLeft(r.left);
                        node.parent ← r;
                        r.left ← node;
                  Node temp ← r.parent;
```

```
            r ← rotateRight(r);
            r.parent ← temp;
      else
            if (r.right.hl > r.right.hr) then
                  Node node ← rotateRight(r.right);
                  node.parent ← r;
                  r.right ← node;
            Node temp ← r.parent;
            r ← rotateLeft(r);
            r.parent ← temp;
      }
      return r;
}

Algorithm Node rotateLeft(Node A) {
      Node B ← A.right;
      A.right ← B.left;
      A.hr ← B.hl;
      B.parent ← A.parent;
      A.parent ← B;
      B.left ← A;
      If (B.hasRight) then
      B.hr ← Max(B.right.hl, B.right.hr) + 1
      else
            B.hr ← 0;
      If (B.hasLeft) then
      B.hl ← Max(B.left.hl, B.left.hr) + 1 : 0;
      return B;
}

Algorithm Node rotateRight(Node A) {
      Node B ← A.left;
      A.left ← B.right;
      A.hl ← B.hr;
      B.parent ← A.parent;
      A.parent ← B;
      B.right ← A;
      If (B.hasRight) then
            B.hr ← Max(B.right.hl, B.right.hr) + 1
      Else
            B.hr ← 0;
      if (B.hasLeft)
            B.hl ← Max(B.left.hl, B.left.hr) + 1;
      else
            B.hl ← 0;
      return B;
}
```

BST Tree Algorithms (generalized)

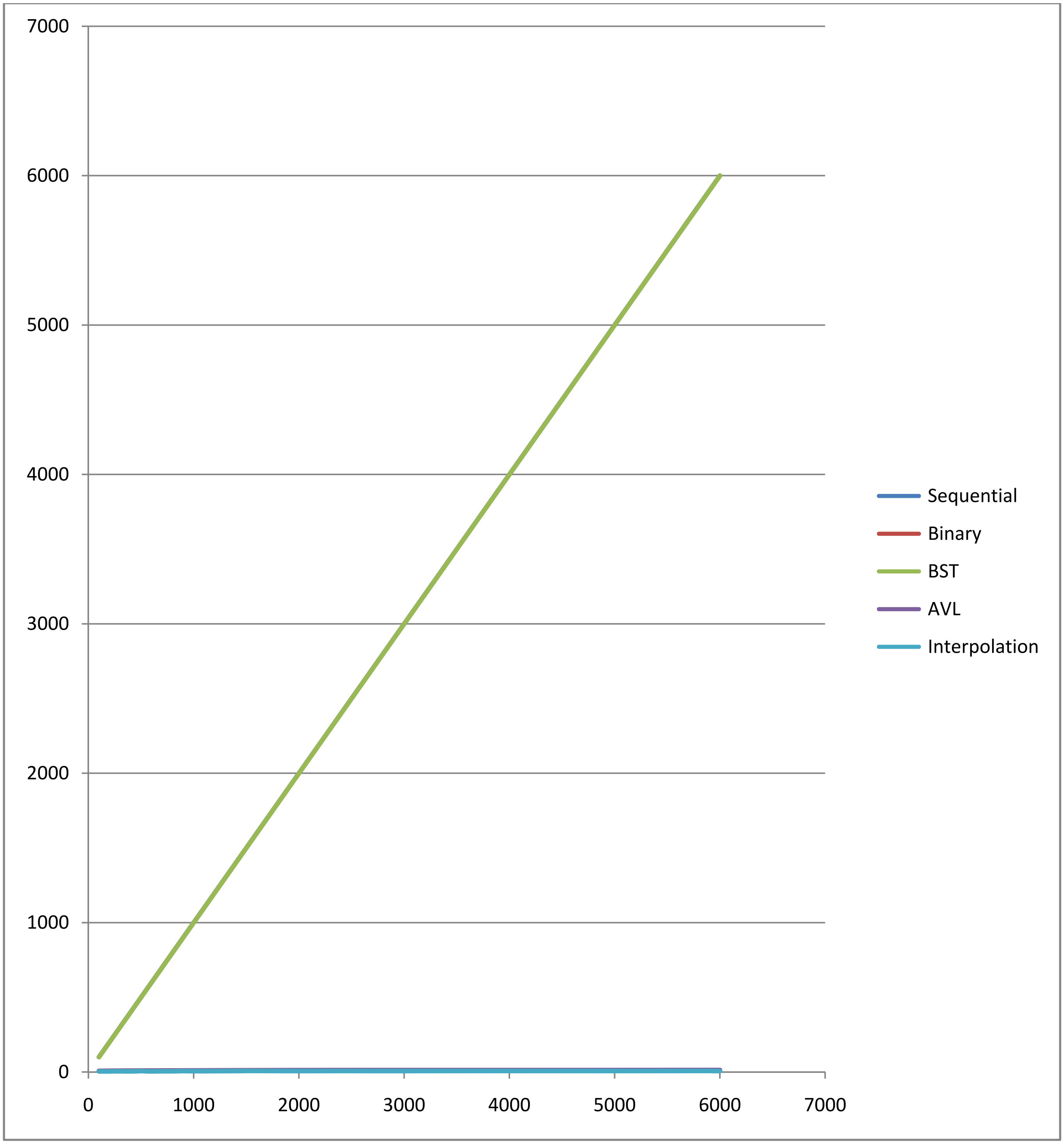
```
Algorithm  insert(E value) {
      if (size equals 0) then
            addRoot(new Node(value));
      else
            Node node ← new Node(value);
            root ← insertRec(root, node);
            size = size + 1;
}

Algorithm Node insertRec(Node r, Node n) {
      if (r equals NULL) then
            return n;
      int comparison ← compare(n.element, r.element);
      if (comparison < 0) then
            Node temp ← insertRec(r.left, n);
            r.left ← temp;
            temp.parent ← r);
            r.hl ← Max(r.left.hl, r.left.hr) + 1;
      } else {
            Node temp ← insertRec(r.right, n);
            r.right ← temp;
            temp.parent ← r;
            r.hr ← Max((r.right.hl, (r.right.hr) + 1;
      }
      if (Math.abs(r.hl - r.hr) > 1)
            r ← balance(r);
      return r;
}

Algorithm find(e) {
      if (size equals 0)
            return NULL;
      Node temp ← find(root, element);
      if (temp equals NULL)
            return NULL;
      else
            return temp.element;
}

Algorithm Node find(Node root, e) {
      Node next ← root;
      comparison ← 0;
      comparisons ← 0;
      while (next not equals NULL) {
            comparisons = comparisons + 1;
            comparison ← compare(element, next.element);
            if (comparison < 0) then
                  next ← next.left;
            else if (comparison > 0) then
                  next ← next.right;
             else
                  return next;
      return NULL;
```

```
}

Algorithm findAll(E element) {
      if (size equals 0)
            return NULL;
      Node temp ← find(root, element);
      int counter ← 0;
      while (temp not equals NULL AND compare(element, temp.element)
                                                           equals 0)
            found[counter++] ← temp.element;
            temp ← temp.right;
      }
      return found;
}

Algorithm  delete(element) {
      root ← deleteRec(root, element);
      size = size - 1;
}

Algorithm  deleteAll(element) {
      int n ← findAll(element).length;
      size ← n;
      for (int i ← 0; i < n; i = i + 1)
            root ← deleteRec(root, element);
}

Algorithm Node deleteRec(Node node, element) {
      if (node equals NULL)
            return NULL;
      int comparsion ← compare(element, node.element);
      if (comparsion < 0) then
            node.left ← deleteRec(node.left, element));
            node.hl ← Max(node.hasLeft() ? node.left.hl : 0, node
                        .hasLeft() ? node.left.hr : 0) + 1;
            if (Math.abs(node.hl - node.hr) > 1)
                  node ← balance(node);
            return node;
      } else if (comparsion > 0) {
            node.right ← deleteRec(node.right, element));
            node.hr ← Max(node.hasRight() ? node.right.hl : 0, node
                        .hasRight() ? node.right.hr : 0) + 1;
            if (Math.abs(node.hl - node.hr) > 1)
                  node ← balance(node);
            return node;
      } else {
            if (!(node.hasLeft() OR node.hasLeft())) then
                  return NULL;
            else if (NOT node.hasRight()) then
                  return node.left;
            else if (NOT node.hasLeft() then
                  return node.right;
            else
                  Node temp ← successor(node);
                  node.setElement(temp.element);
                  node.right ← deleteRec(node.right, temp.element));
```

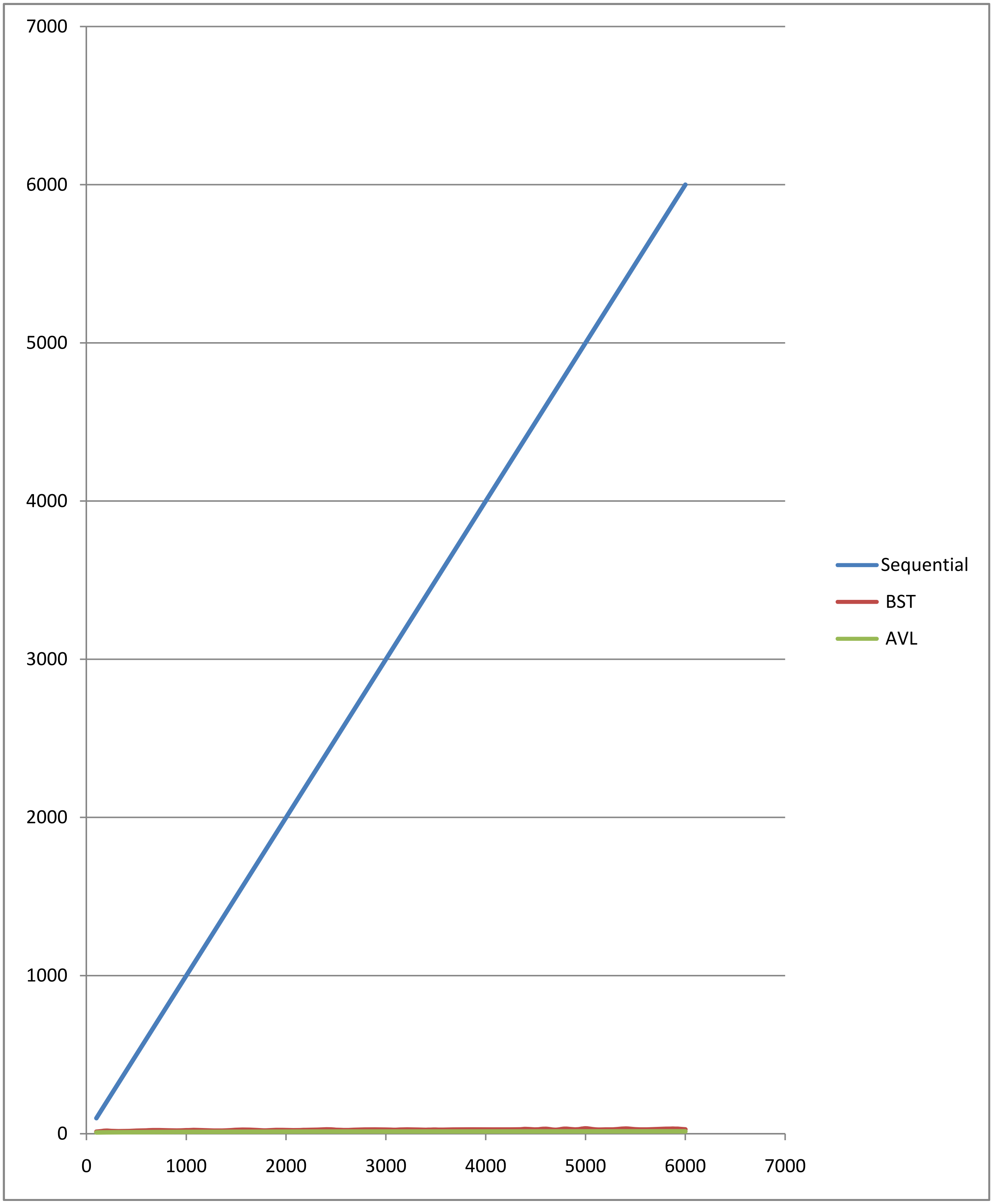
```
                return node;
        }
}

Algorithm Node successor(Node node) {
        Node temp ← node.right;
        while (temp.hasLeft)
                temp ← temp.left;
        return temp;
}

Algorithm  postOrder(Node node, StringBuffer buffer) {
        if (node equals NULL)
                return;
        postOrderHelper(node.left, buffer);
        postOrderHelper(node.right, buffer);
        visit(node.element);
}
```

Maximum Comparisons

Sorted Lists

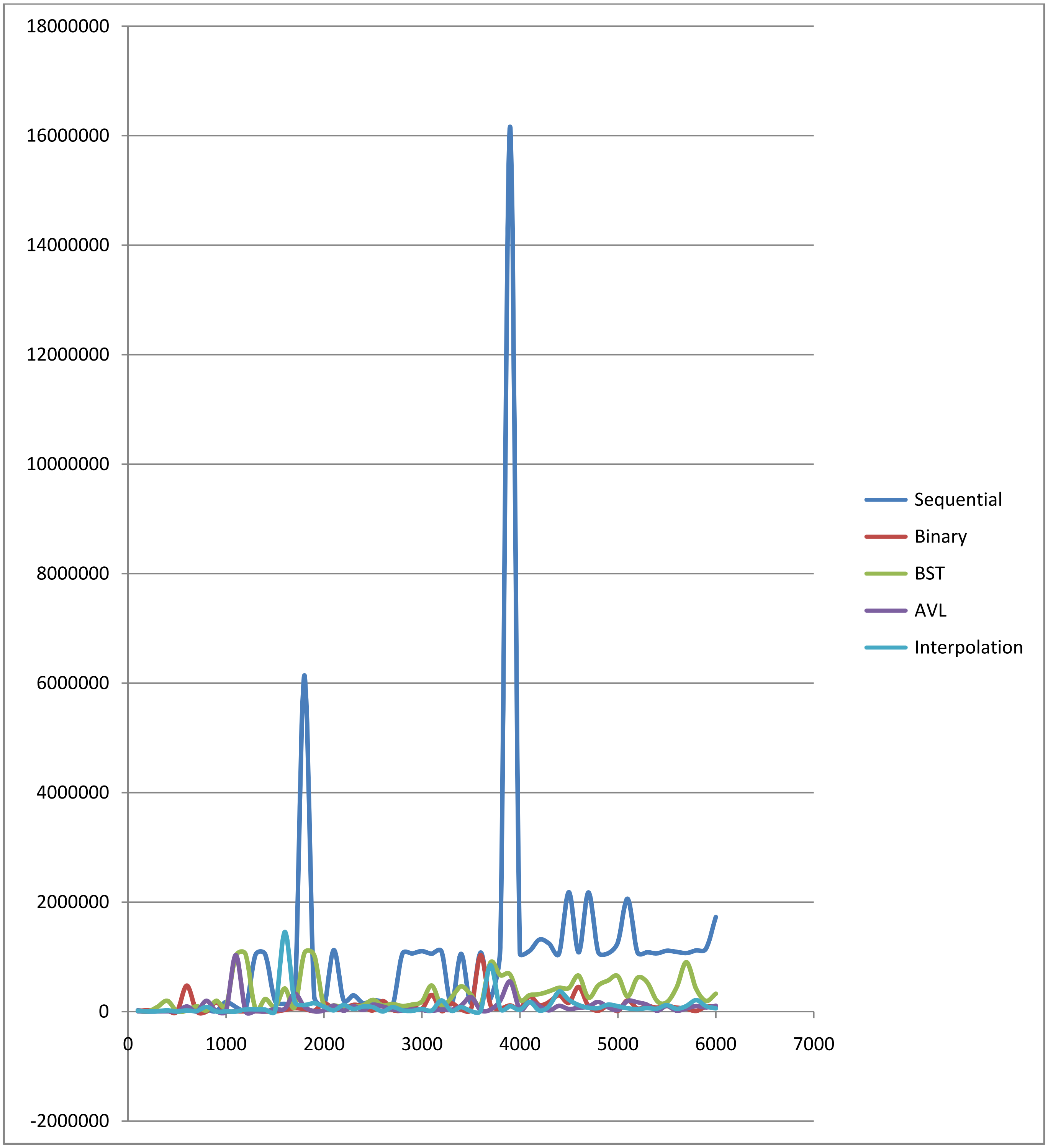


Unsorted Lists

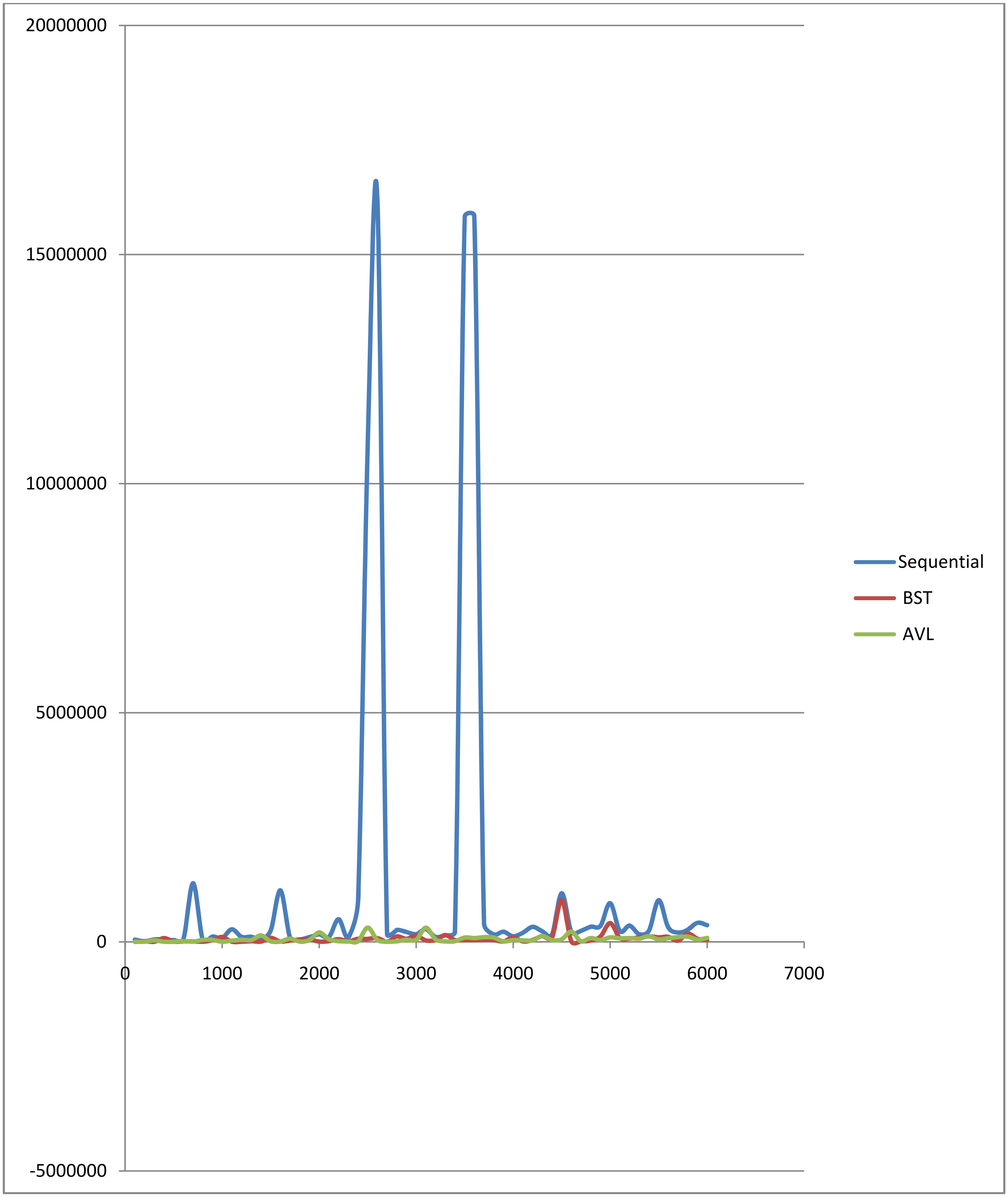


Maximum Running Time

Sorted Lists

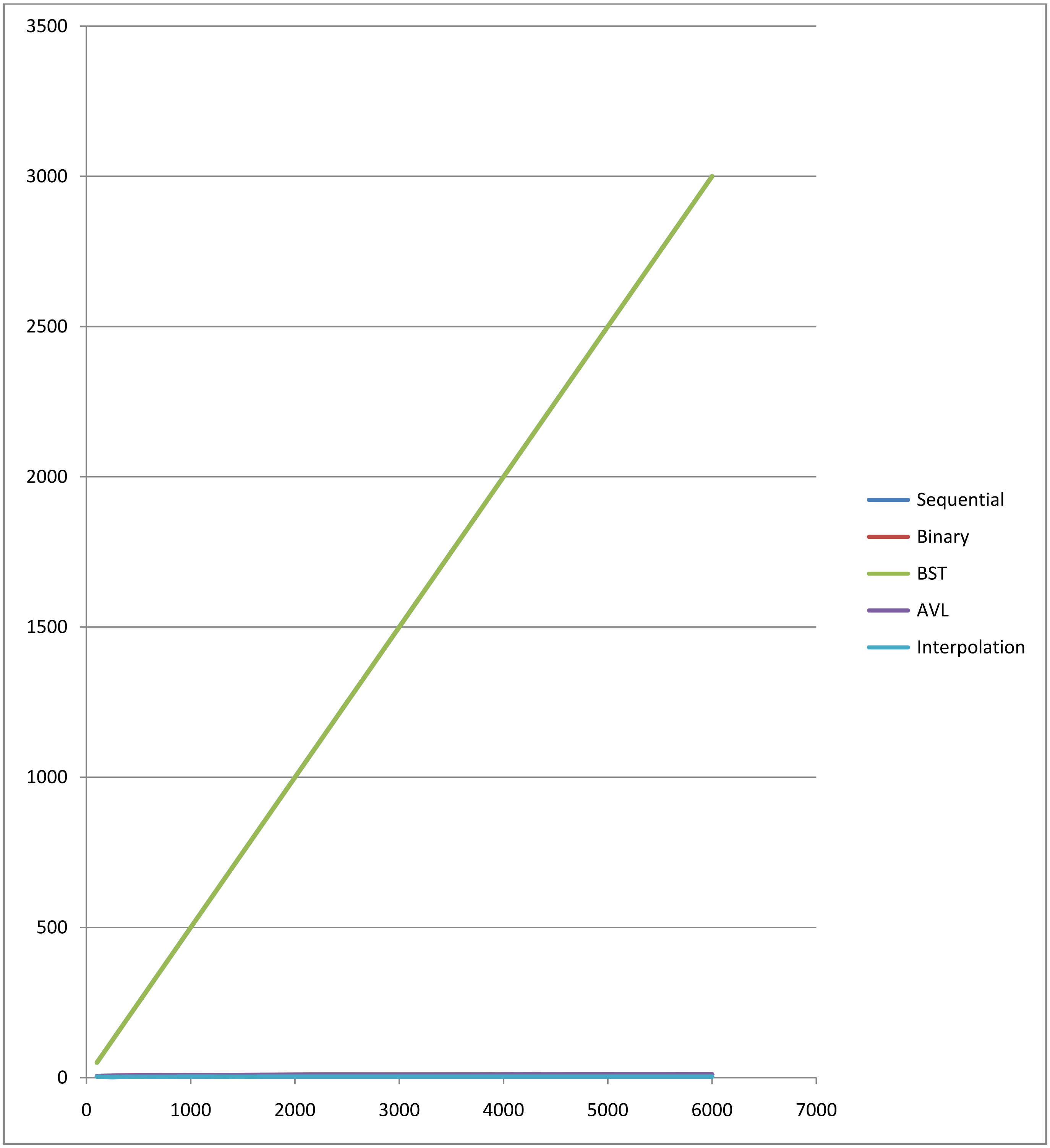


Unsorted Lists

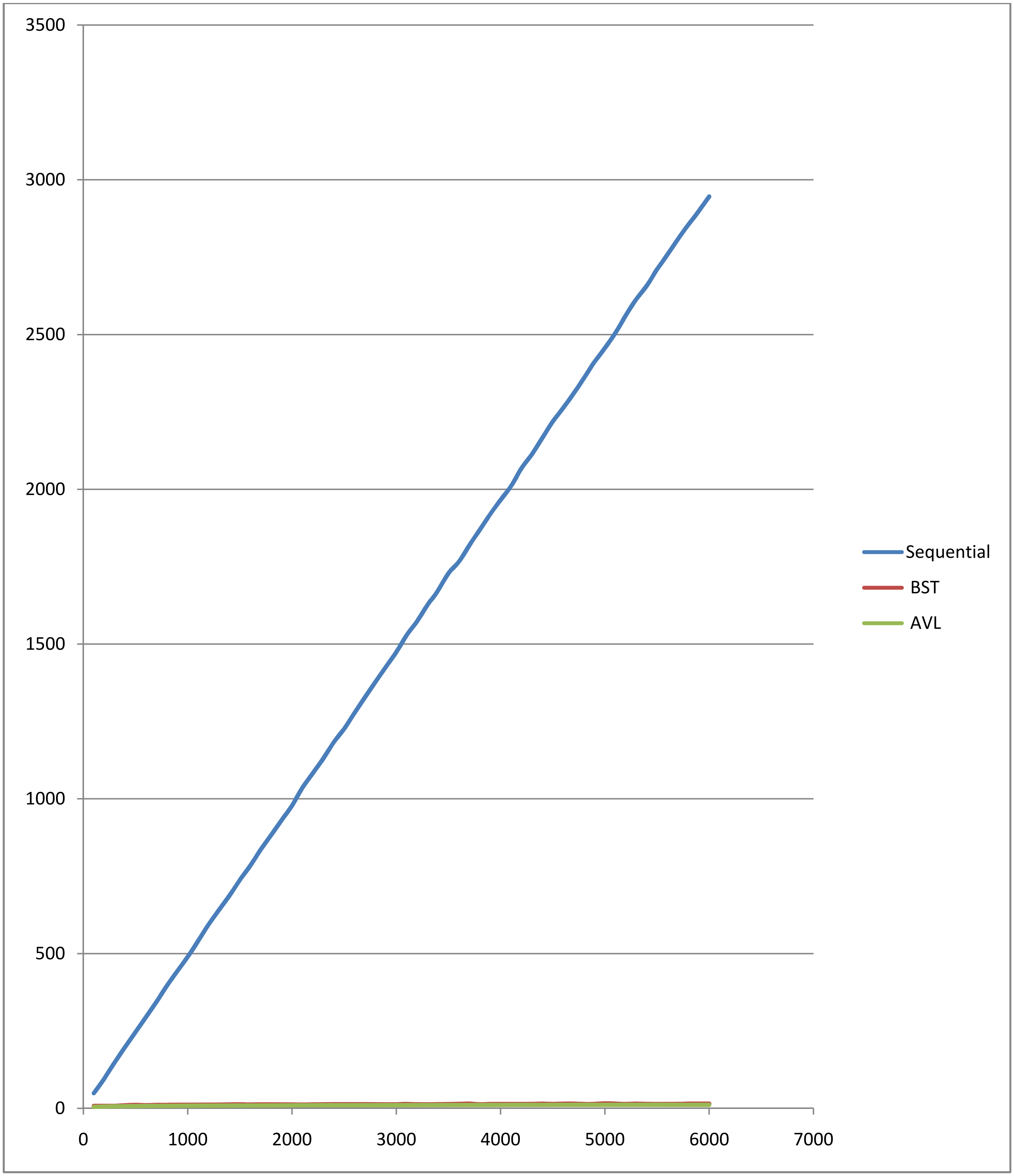


Average Comparisons

Sorted Lists

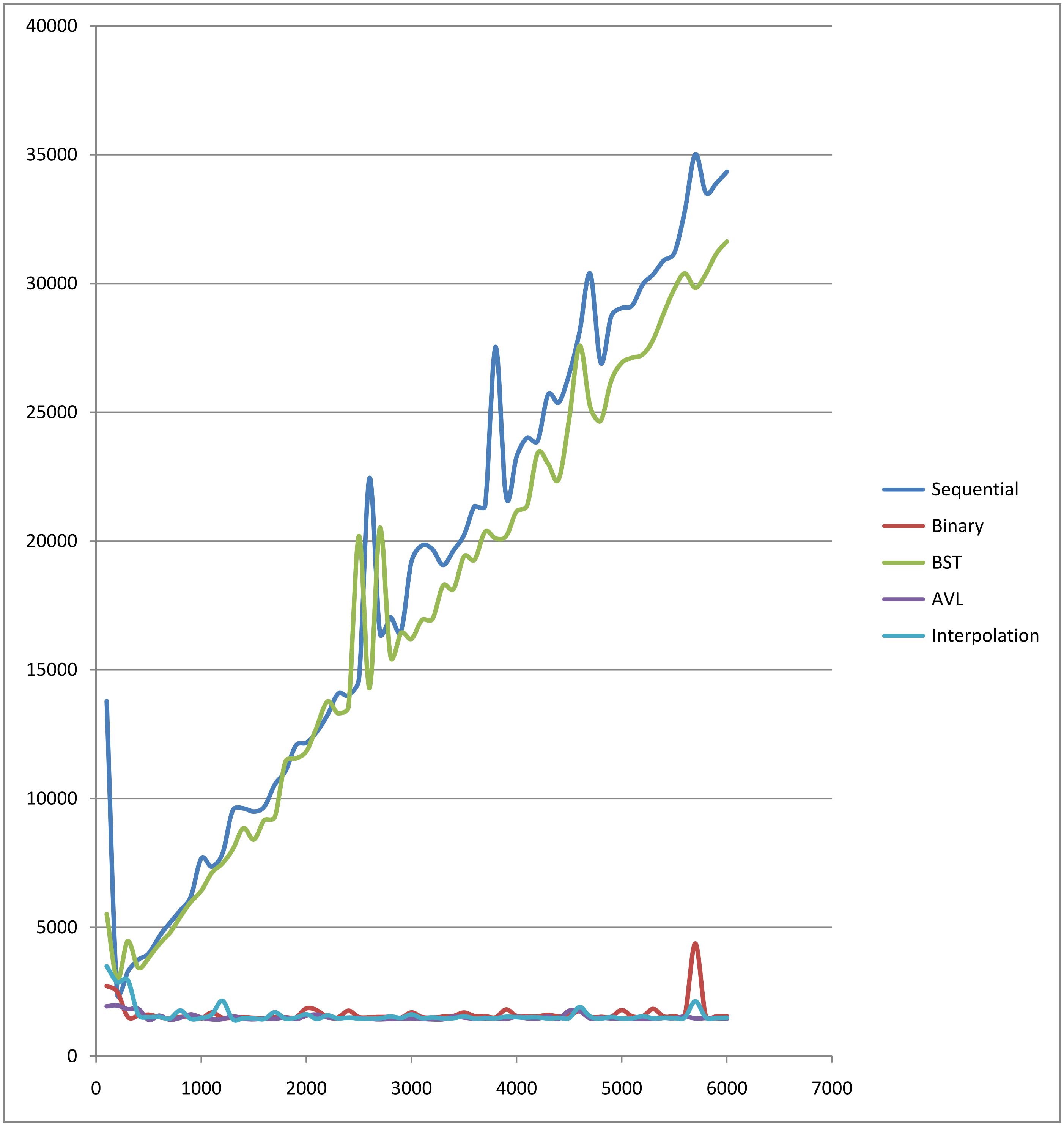


Unsorted Lists

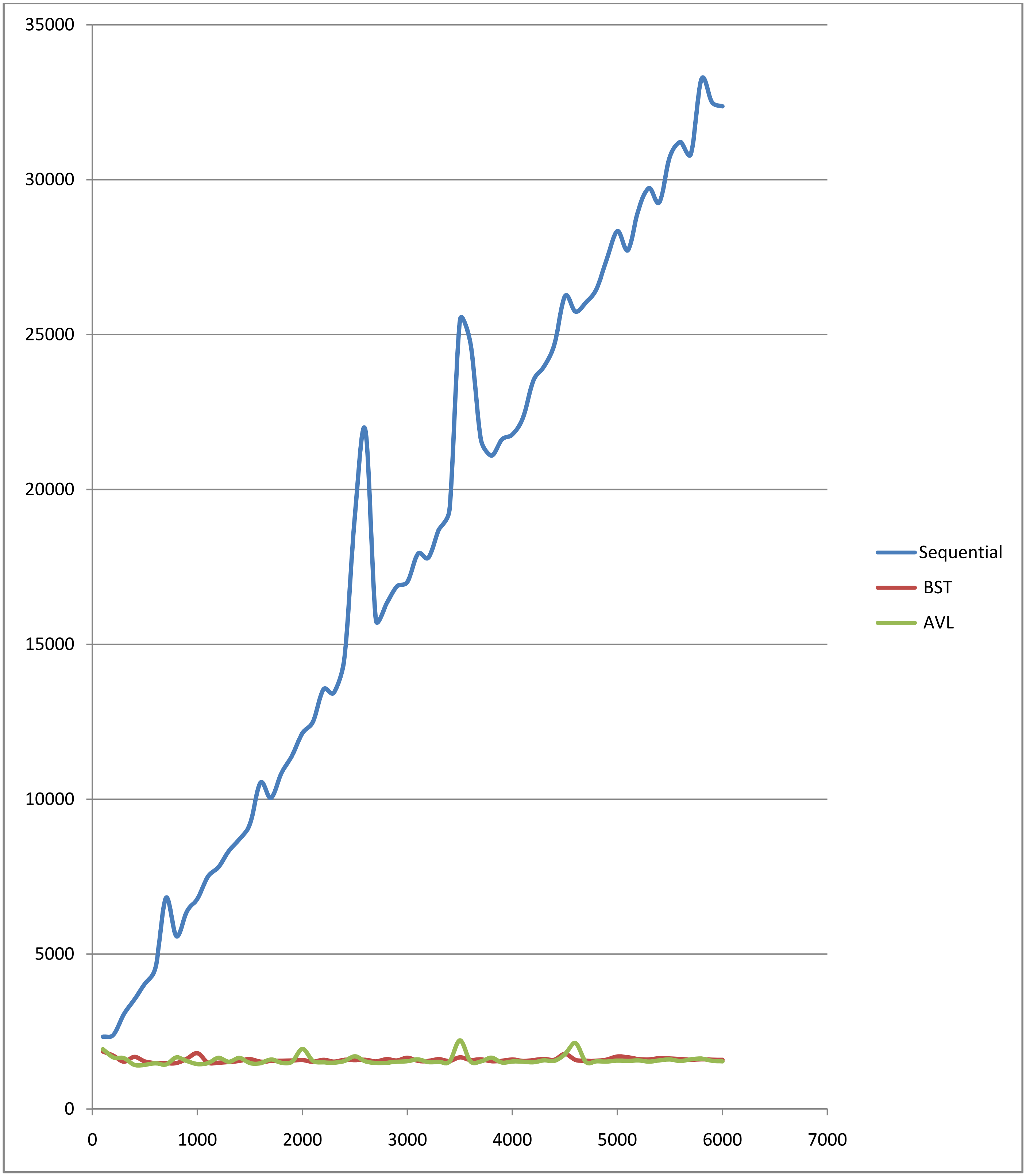


Average Time

Sorted Lists



Unsorted Lists

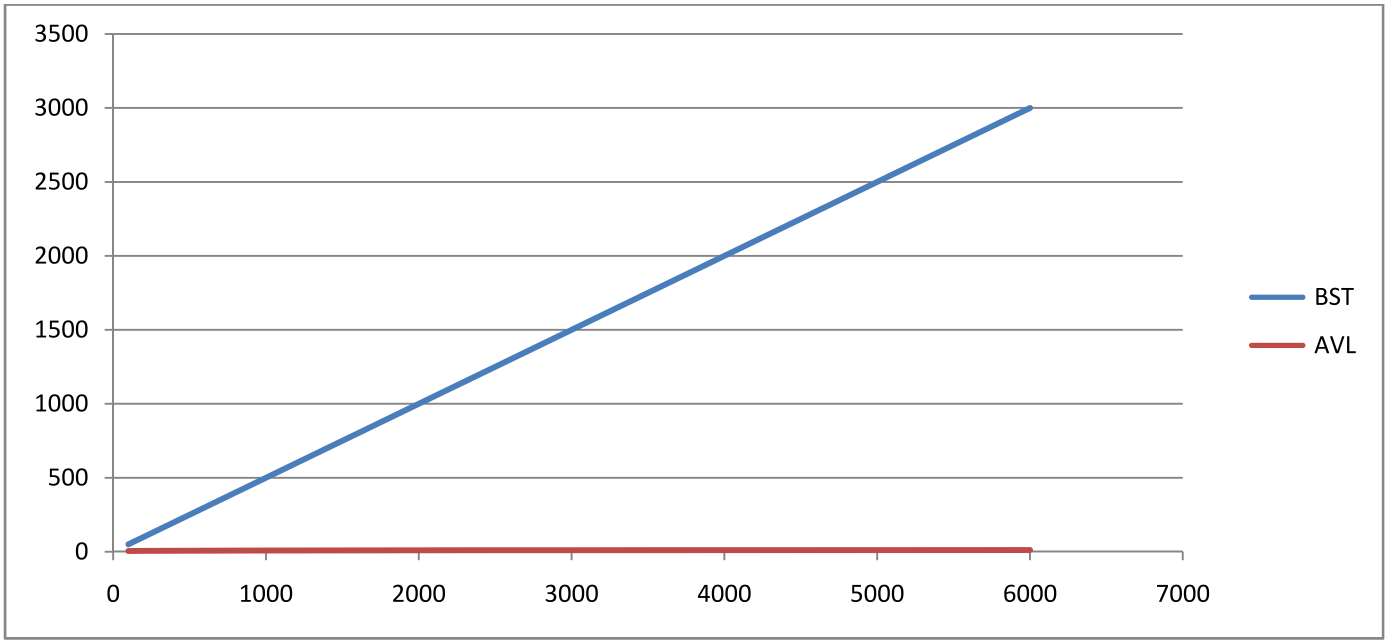


Comparison between BST and AVL trees

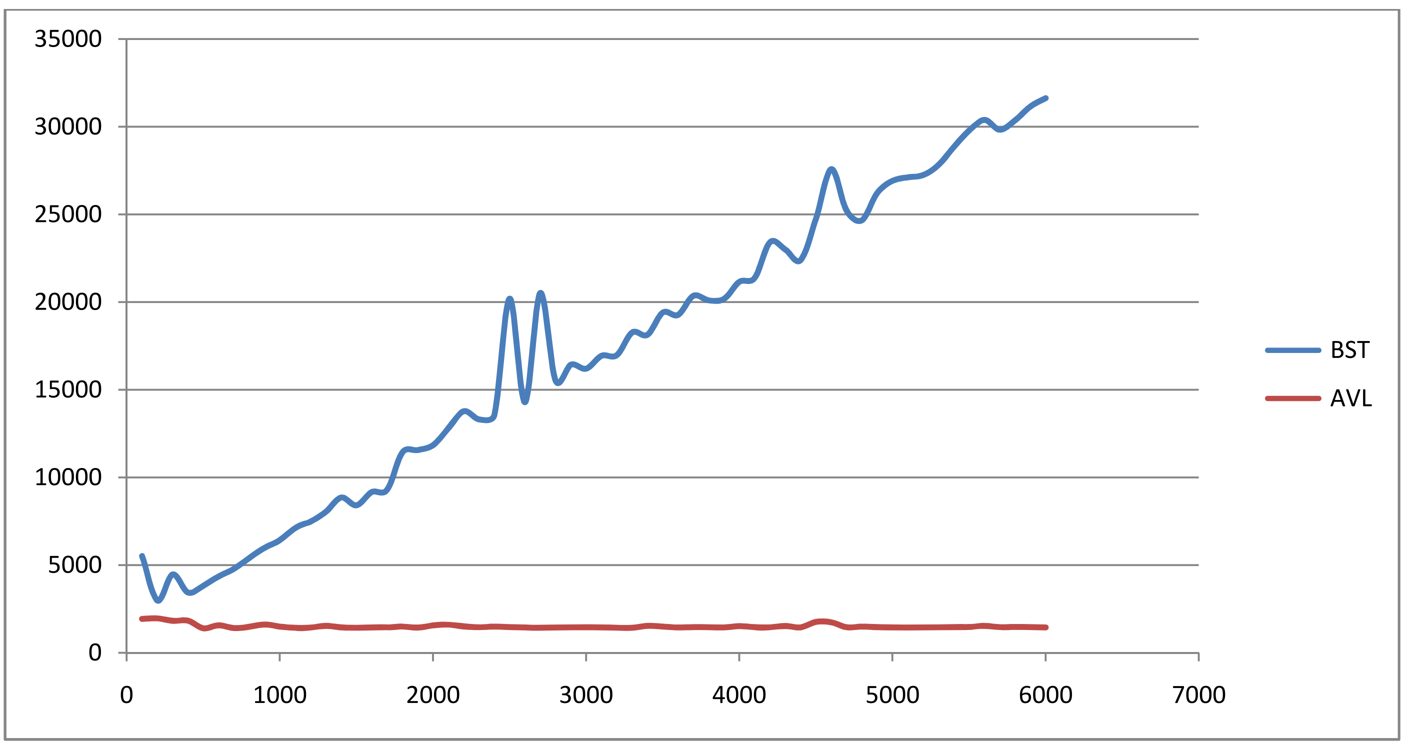
Construction time	More time is needed for balancing the tree but when the tree gets excessively big, the steps done for balancing is negligible.	Good in time management but when the tree gets too big, the insertion becomes costly either. so they are two much equal.
Search time	Better	Good
Sorted list (worst)	Doesn’t matter. $O(n \log_2 n)$	Changes to a linked list. $O(n)$
Unordered	Doesn’t matter. $O(n \log_2 n)$	$O(\log_2 n)$ for average.

Statistical Charts

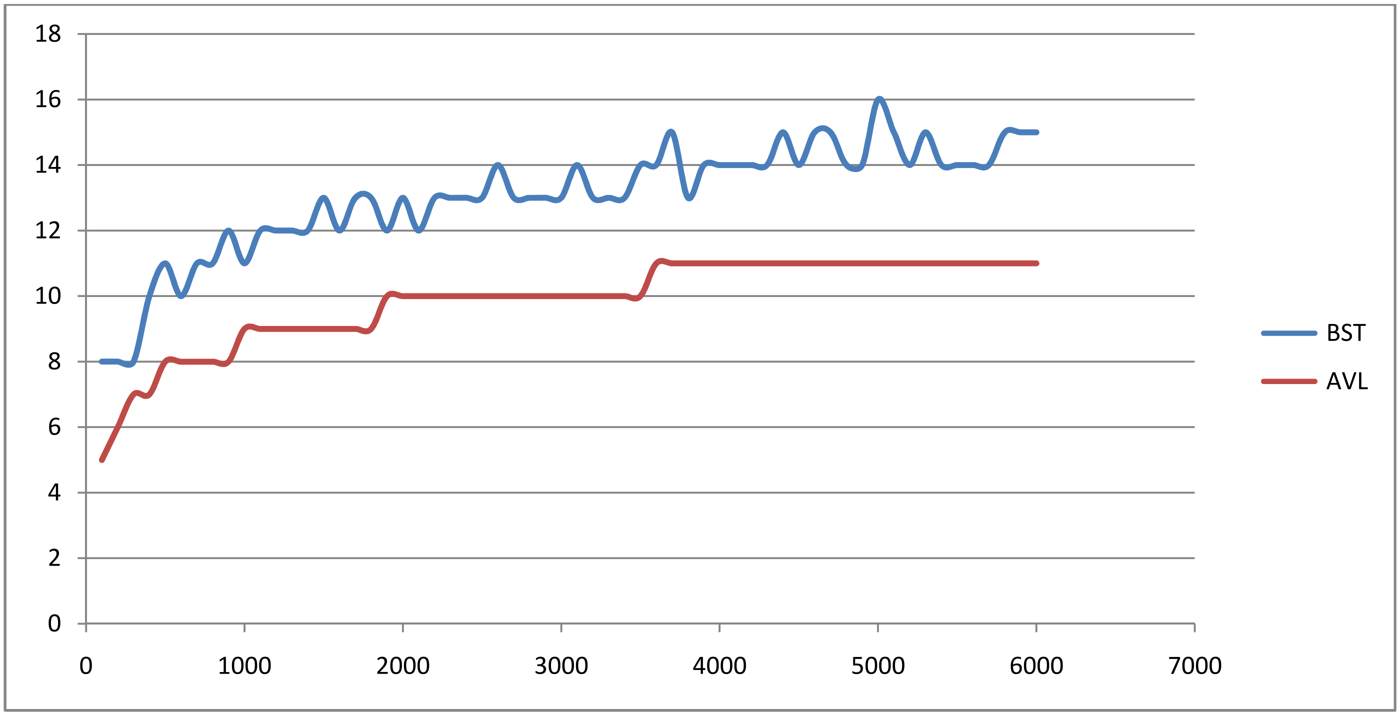
Average Comparisons **Sorted Lists**



Average Running Time **Sorted Lists**



Average Comparisons **Unsorted Lists**



Average Time **Unsorted Lists**