3.2.5 Time series

In statistics, signal processing and financial mathematics, a time series is a sequence of data points $\{X_0, X_1, ..., X_n\}$, measured typically at successive times $\{t_0, t_1, ..., t_n\}$ spaced at uniform time intervals such that $t_i - t_{i-1} = \Delta t$. For analysing time series some basic methods are necessary in order to extract meaningful statistics and other characteristics of the data.

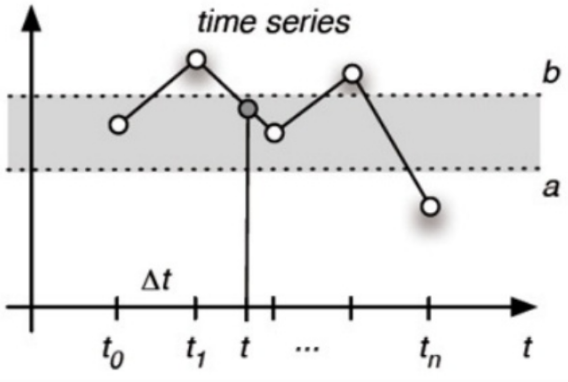
`getDuration` The duration of a time series can be calculated by $t_n - t_0$.

`getTime` Returns the point in time t_i of the i-th measurement.

`count` Counts the number of data points X_i lying inside a band between a and b such that $a \leq X_i \leq b$.

`valueAt` Returns the linearly interpolated data point for a specified point in time t.

`isMonotonous` Tests whether the time series is either ascending or descending. The series is ascending if $X_i \leq X_{i+1}$ for $i = 0, ..., n-1$ and descending if $X_i \geq X_{i+1}$ for $i = 0, ..., n-1$.



Class design

Design a new class `TimeSeries`. The attributes are the array of data values, Δt and t_0. Specify a constructor that takes values for all attributes as arguments. Define the signatures of the above mentioned methods. Create the UML diagram of the `TimeSeries` class. Develop the Nassi-Schneiderman diagrams of the methods `valueAt` and `isMonotonous`.

Implementation

Implement the class `TimeSeries` in Java. Specify some useful test cases (test programs, test units) to verify the results of your implemented methods.

Linear interpolation (used formula):

If the two known points are given by the coordinates (x_0, y_0) and (x_1, y_1), the **linear interpolant** is the straight line between these points. For a value x in the interval (x_0, x_1), the value y along the straight line is given from the equation of slopes

$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0},$$

which can be derived geometrically from the figure on the right. It is a special case of polynomial interpolation with $n = 1$.

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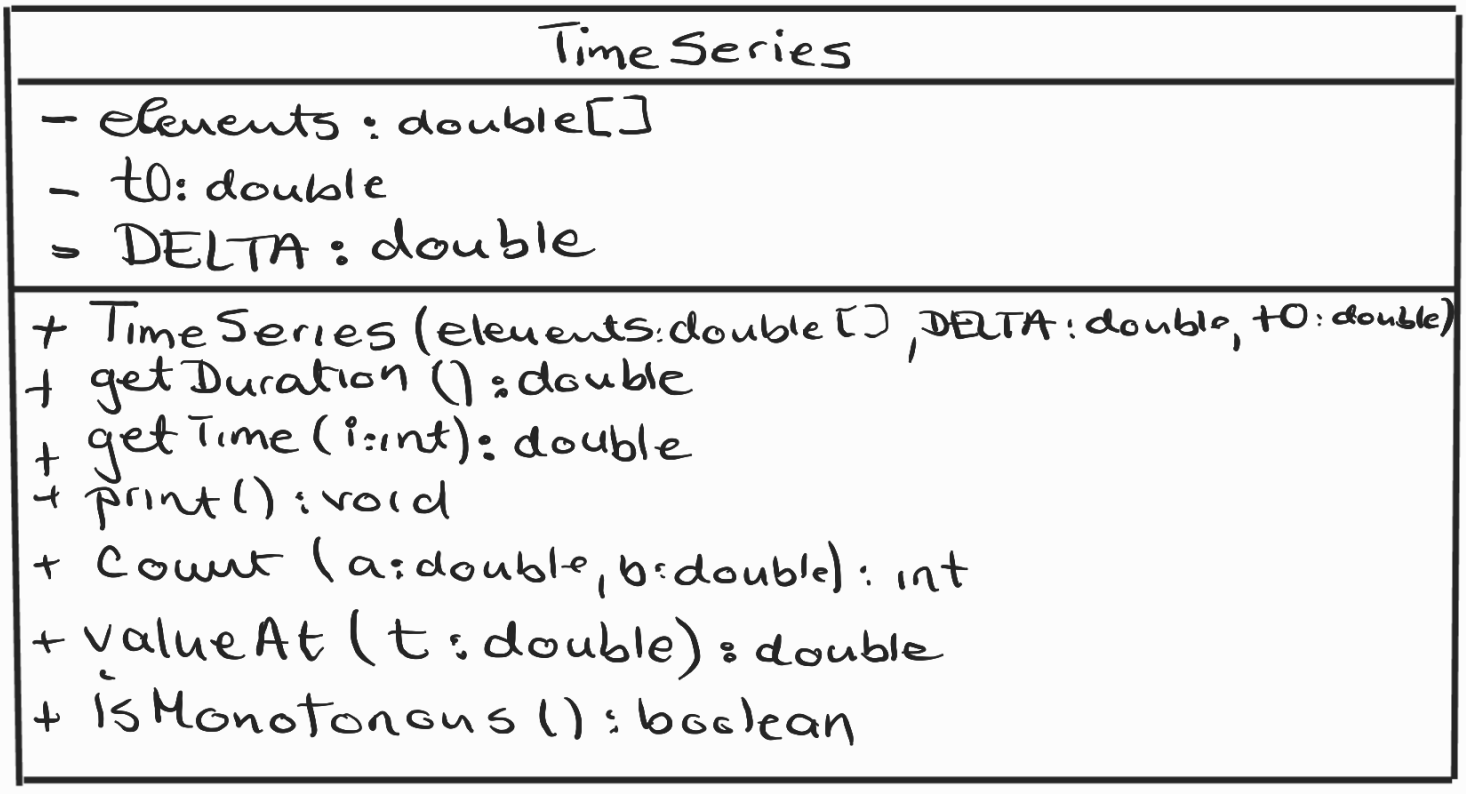
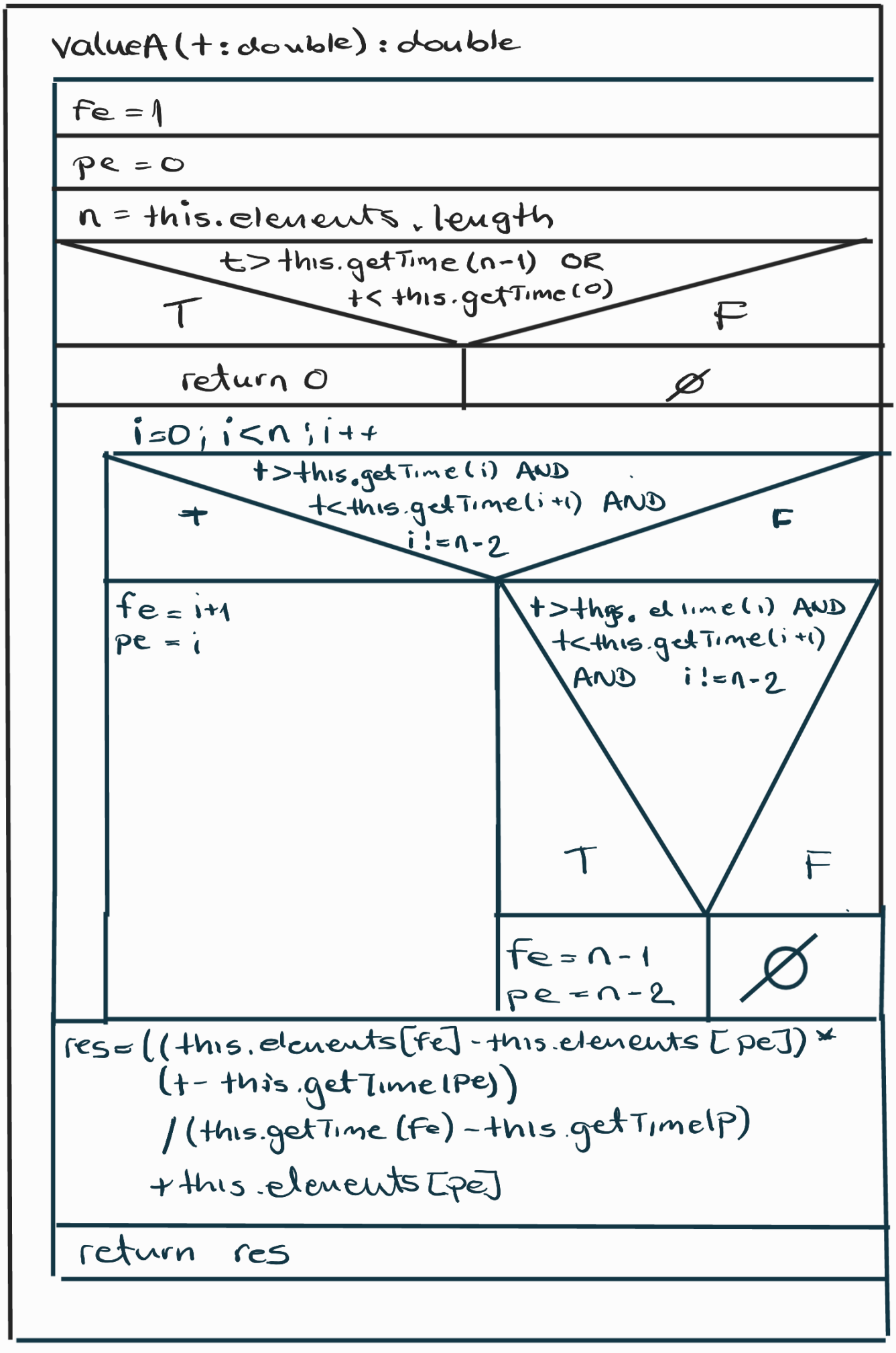
UML diagram

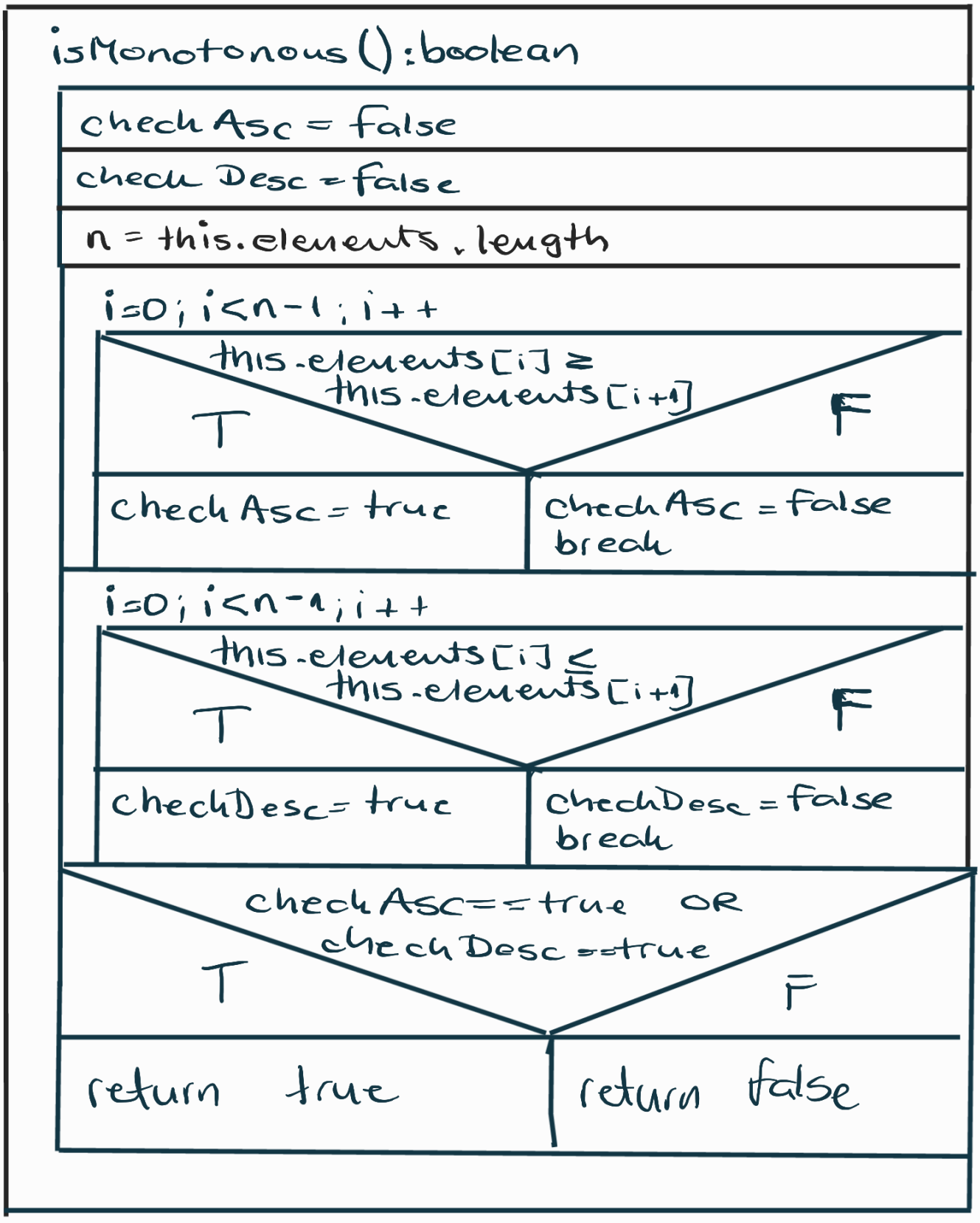

TimeSeries
- elements : double[]
- t0: double
- DELTA : double
+ TimeSeries (elements:double[], DELTA : double, t0 : double)
+ getDuration () :double
+ getTime (i:int): double
+ print() : void
+ Count (a:double, b:double) : int
+ valueAt (t : double) : double
+ IsMonotonous () : boolean

Nassi - Shneiderman diagrams

1) valueAt method



Nassi-Shneiderman diagram (isMonotonous method)



My code

```
package chapter1;

public class TimeSeries {

    private double [] elements;
    private double DELTA;
    private double t0;

    //Constructor for the class TimeSeries. We assign parameters to the attributes of the object
    public TimeSeries (double [] x, double t0, double DELTA) {
        this.elements=x;
        this.DELTA = DELTA;
        this.t0 = t0;
    }
```

```
  //Method to calculate the duration of the series.
  public double getDuration () {
      int n = this.elements.length;
  //Duration is the period from time of the last element minus the time of the first element
      double duration = this.getTime(n-1) - this.getTime(0);
      System.out.println("\n"+"Duration of the time series is:" + duration);
      return duration;
  }

  //Method that return the point in time of the i-th measurement.
  public double getTime (int i) {
  //We have to define the corresponding time values for each element in the data array
      int n = this.elements.length;
      double [] ts = new double [n+1];
      for (int j=0; j<n; j++) {
          ts[j] = this.t0 + this.DELTA*j; }
  //We just return the time value from the corresponding position
      return ts[i];       }
```

```
 //Method for printing the time series with their corresponding time values
 void print () {
     int n = this.elements.length;
     System.out.println("Defined timeseries is:" );
     for ( int i=0; i<n; i++) {
         System.out.println("Element at the measurement number " + i + " has the time " + this.getTime(i) + " and it's value is " + this.elements[i]);

 //Method that counts the numbers of data points between two values a and b
 public int Count (double a, double b) {
     int number = 0;
 //If one data point lies between this two values, the number increases by one
     for (int i=0; i<this.elements.length; i++) {
         if (this.elements[i] >=a && this.elements[i]<=b) {
             number = number + 1;
         }}
 System.out.println("\n"+"Number of data points between values " + a + " and " +  b + " is " + number);
 return number;
 }
```

```
public double valueAt (double t) {
    int fe=1;
    int pe=0;
    int n = this.elements.length;

    //We check between which measurements does the inserted value lie
    if (t> this.getTime(n-1) || t<this.getTime(0)){
        System.out.println("Entered value of t is out of the limits of this time series.");
        return 0;
    } else {
    for (int i = 0; i<n-1; i++) {
        if ( t>=this.getTime(i) && t<=this.getTime(i+1) &&  i!=this.elements.length-2) {
            fe = i+1; pe = i;
            }
        else if (t>=this.getTime(i) && t<=this.getTime(i+1) &&  i==this.elements.length-2) {
            fe = this.elements.length-1;
            pe = this.elements.length -2;   }}}
    //Printing this results for checking
    System.out.println("\n"+"Entered value is between values of time " + this.getTime(pe) + " and " + this.getTime(fe) + " , which correspond to the
        + fe + "\n");
    //Calculating the value of the data point at the time t according to linear interpolation formulae
    double res;
    res = ((this.elements[fe]-this.elements[pe])*(t-this.getTime(pe)))/(this.getTime(fe)-this.getTime(pe))+this.elements[pe];
    System.out.println("Calculated value is " + res);
    return res;
}
```

```java
public boolean isMonotonous () {
    boolean checkAsc=false;;
    boolean checkDesc=false;
    int n = this.elements.length;
    //For loop to check if our time series is ascending
    for (int i = 0; i<n-1; i++) {
        if (this.elements[i]>=this.elements[i+1]) {
            checkAsc=true;} else {
            checkAsc=false;
            break;} }
    //For loop to check if our time series is descending
    for (int i = 0; i<n-1; i++) {
        if (this.elements[i]<=this.elements[i+1]) {
            checkDesc=true;} else {
            checkDesc=false;
            break;} }
    //If our time series is either ascending or descending we say it is monotonous
    if (checkAsc==true || checkDesc==true) {
    System.out.println("Time series is montonous.");
    return true; }
    else {
        System.out.println("Time series is not montonous.");
        return false;}}
```

```java
public static void main (String [] args) {

    //For loop to create a time series with random values
    double [] x = new double [10];
    for (int i = 0; i<10; i++) {
        x [i] = Math.random()*10;}
    TimeSeries ts = new TimeSeries (x, 1.0, 0.5);

    //For loop to create an ascending time series
    double [] x1= new double [10];
    for (int i = 0; i<10; i++) {
                x1 [i] = i;}
    TimeSeries tsA= new TimeSeries (x1, 1.0, 0.5);

    //For loop to create a descending time series
    double [] x2= new double [10];
    for (int i = 0; i<10; i++) {
                x2 [i] = (10-i);}
    TimeSeries tsD= new TimeSeries (x2, 1.0, 0.5);

    //Testing our methods
    ts.print();
    ts.getDuration();
    int measurement = 4;
    double f = ts.getTime(measurement);
    System.out.println("\n"+"Value of time at the position " + measurement + " is " + f);
    ts.Count(2.4, 3.8);
    ts.valueAt(3.8);
    ts.isMonotonous();
    tsA.isMonotonous();
    tsD.isMonotonous();
}
```

Console output