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Building a Multi-Function Scientific Calculator

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PROBLEM 1

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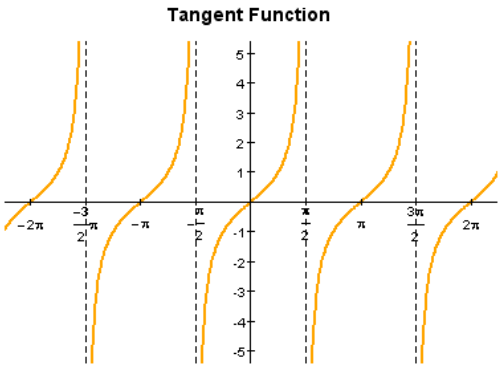
1 Tangent Function

In right triangle trigonometry (for acute angles only), the tangent is defined as the ratio of the opposite side to the adjacent side. The unit circle definition is $\tan(\theta) = \frac{sin(\theta)}{cos(\theta)}$.

Domain: $x \neq \frac{\pi}{2} + \pi k, k \in Z$

(in other words function is not defined for those values of x where cos(x)=0)

Range: All real numbers.



Unique Characteristics:

- Function is odd and periodic with main period π.
- Function is increasing on intervals $[\frac{-\pi}{2} + \pi k, \frac{\pi}{2} + \pi k]$

  where k $\in Z$
- As x passes through any point of discontinuity from the left to the right , the value of tan(x) suddenly changes from $(+\infty) to (-\infty)$.
- Lines (x) are vertical asymptotes where x= $\frac{\pi}{2}$ + $\pi k, k \in Z$

PROBLEM 2

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Software Requirements Document Of A Multi-Function Scientific Calculator

2 Introduction

This document describes the behavior of a simple multi-function scientific calculator application intended for use on both Windows and Macintosh personal computers.

3 Environment and Interface Requirements

3.1 Hardware(Version 1.0)

The application shall run on both IBM-compatible and Macintosh Hardware
Priority : 3

3.2 Software(Version 1.0)

The application shall be written in Java The application shall use only standard Java library functions(basic arithmetic). The application shall be usable on any system which supports the compiler, and shall not require any particular hardware or software.
Priority : 5

3.3 Operating System(Version 1.0)

The application shall be run on Windows, macOS and Linux based systems.
Priority : 3

3.4 Human Interfaces(Version 1.0)

The application shall function in a similar way as a regular calculator.
Priority : 4

3.4.1 Input

The user shall input the number(s) when the application prompts to do so. The application shall ask the user to press the buttons available on the UI or the application shall allow the user to enter the numbers manually through his/her keyboard.
Priority : 5

3.4.2 Output

The application shall display the results on the appropriate output area.
Priority : 5

4 Major Functional Requirements/Description

4.1 Input(Version 1.0)

The input function shall accept the input from the user via the terminal, validate it and send it to the appropriate function to calculate the output. All user interaction with the program shall take place through this function and all the input data shall be stored in a variable of a compatible data type. The input function can be written in the form of a basic Scanner.
Priority : 5
Risk: 2
Difficulty: Easy

4.2 Calculate(Version 1.0)

This function will accept the correct input from the input function(through arguments) and will perform the operations requested by the input.
Priority : 5
Risk: 5
Difficulty: Hard

4.3 Output(Version 1.0))

This function will display the results of the calculate function. Results shall be displayed under the following conditions.

- When the equals(=) sign button is pressed(GUI).
- When the enter key is pressed(terminal).

Priority : 5
Risk: 2
Difficulty: Moderate

5 Response to undesirable events

5.1 Illegal Input Sequence

Appropriate error message shall be printed, if an illegal sequence is detected.

5.2 Division By zero

Division by zero shall be detected by the program and an appropriate error message is printed.

5.3 Overflow/Underflow

Overflow and underflow doesn't need to be detected.

6 Constraints

The value of x for tan(x) shall be input in radians.

7 Potential changes

- Other functions may be added.
- Other display formats, such as scientific notation may be added.

- The visual appearance of the calculator may be updated.

PROBLEM 3

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1 Algorithm 1

```
Function CalculateSin(double Input)
      SET Input to an angle between -2PI & 2PI
      SET ith term in Taylor series to 1
      SET answer to 0
      FOR( COMPUTE till ith term != 0)
            SET ith term to (term*input)/Counter
            IF Counter%4==1 THEN
                  SET Answer to ith term + Answer
            END IF
            IF Counter%4==3 THEN
                  SET Answer to Answer - ith term
            END IF
      END FOR
      COMPUTE 1- Square of Answer
      CALL Function Sqrt (1- Square of Answer, Answer)
      RETURN Answer

Function Sqrt (double Number, double Answer)
      SET AnswerSqrt to Number/2
      DO( UNTIL t-AnswerSqrt !=0)
            SET AnswerSqrt to ((number/t))/2
      END LOOP
      SET Tanx to Answer/AnswerSqrt
      PRINT Tanx
      RETURN AnswerSqrt
```

2 Algorithm 2

```
Function CalculateTan(double Input)
      IF(Input == Negative Infinity OR Input NOT LESS THAN
      Positive Infinity
      THEN
            RETURN Infinity
      END IF
      IF(CALL Absolute(input) <= PI/4) THEN
            RETURN CALL Tan(Input, 0, False)
      END IF
      INITIALIZE double []
      SET N to CALL RemPiOver2(Input,y)
      RETURN Tan(y[0],y[1],(n&1)==1)

Function Absolute (Input)
      RETURN (Input<0)?-Input:Input

Function RemPiOver2(double x, double[]y)
      SET Negative to x <0
      SET x to CALL abs(x)
      IF ( x<3*PI/4)
            SET z to x- PI
      END IF
      IF(x!=(PI/2))
            SET y[0] to z-PI
            SET y[1] to z-y[0]-PI
      ELSE
            SET z to z-PI
            SET y[0] to z-PI
            SET y[1] to z-y[0]-PI
      END IF
      RETURN n-1
```

3 Description

3.1 Algorithm 1:

Tan(x) can be calculated by calculating $\frac{sin(x)}{\sqrt{1-Sin^2x}}$. This function calculates the value of sin(x) and then $1-Sin^2x$ and passes the results to Another function Sqrt that calculates the square root of $1-Sin^2x$. The final result is the return statement of the first function divided by return statement of the second function.The value of Sin(x) is calculated by using the Taylor series expansion : Sin(x) = $\sum_{k=0}^{\infty} \frac{-1^k}{(2k+1)!} x^{2k+1}$ = x- $\frac{x^3}{3!}$ + $\frac{x^5}{5!}$ - ...

3.1.1 Function 1: CalculateSin

This function takes a double number as input. The converts the angle between -2PI to 2 PI. Since this function uses Taylor series for the calculation Sin x, ith term of the Taylor series is set to 1. The For loop iterates till the ith term is not equal to zero and increments the counter by 1. After the ith term(termed as answer) is calculated by the loop, we first square the answer and subtract it from 1. Later on, this value is passed to the Sqrt function.

3.1.2 Function 2: sqrt

This function calculates the square root of the value input to it through the parameters and returns the value of sin x divided by square root of $1-Sin^2x$.

3.2 Algorithm 2:

This algorithm recursively calls the CalculateTan method to get the final answer. The method calls the absolute method to calculate the absolute value of the input. It later calls the RemPiOver2 function which is a helper function for reducing an angle to a multiple of $\frac{\pi}{2}$ within $[\frac{-\pi}{4}, \frac{\pi}{4}]$

3.2.1 Function 1: CalculateTan

This function takes the input in radians and returns the value of tan(a). If 0 is passed to this function, it retains its sign

3.2.2 Function 2: Absolute

The input to this function is angle in radians and it returns the absolute value of the input.

3.2.3 Function 3: RemPiOver2

This is a helper function for reducing an angle to a multiple of $\frac{\pi}{2}$ within $[\frac{-\pi}{4}, \frac{\pi}{4}]$. The angle x is the input in radians outside $\frac{\pi}{4}$. Y is an array of 2 doubles modified to hold the remander x mod $\frac{\pi}{2}$. The function returns the quadrant of the result.

4 Advantages and Disadvantages

Algorithm 1	**Algorithm 2**
This algorithm has to compute only one value, which is, Sinx(x)	This algorithm has to compute the values for tan(x) as well as for helper function
Has only 1 function call.	Has 2 function calls.
Need to implement only 1 more function.	Need to implement 2 more functions.
Memory efficient as it uses primitive data types.	Not memory efficient as it uses data types like arrays.
Simpler and fewer lines of code.	Complex and more lines of code.

5 Algorithm Chosen

Algorithm 1.