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// src/Calculator.java

import java.util.Scanner;
import com.github.sahasatvik.math.*;

/**
 * Calculator is a simple java application which parses mathematical expressions and evaluates
 * the result. Calculator can parse arithmetic operators as well as some functions, store variables,
 * and carry out some pre-defined commands.
 *
 * A complete manual on how to use this application can be found in the README files, or by entering
 * <code>/help</code> during runtime.
 *
 * A continuously updated version of this project can be found online at my
 * <a href="http://github.com/sahasatvik/Calculator">Github repository</a>.
 *
 * @author Satvik Saha
 * @version 1.0, 17/10/2016
 * @see <a href="http://github.com/sahasatvik/Calculator">
 *      http://github.com/sahasatvik/Calculator
 * </a>
 * @see com.github.sahasatvik.math.ExpressionParser
 * @since 1.0
 */

public class Calculator {

    /**
     * Regex which matches a command. This is simply a string of characters following a forward
     * slash (<code>/</code>).
     */
    public static String commandRegex = "(\\s+)?(/)(.*)";

    /**
     * Stores the previously calculated answer. This can be retrieved during runtime as a variable.
     */
    public static String previousAns;

    /**
     * ExpressionParser object which contains methods for parsing arithmetic expressions.
     */
    public static ExpressionParser expParser;

    /**
     * Main method of Calculator.

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*
*      @param  args                the command-line arguments supplied to Calculator
*      @since  1.0
*/
public static void main (String[] args) {

    /* Store the expression entered by the user */
    String expression;
    /* If the expression is a command, store it here */
    String command;
    /* Initialize the previous answer cache */
    previousAns = "";

    /* Startup message */
    System.out.print("\nCalculator by Satvik Saha");
    System.out.print("\n-----");
    System.out.print("\n    An up-to-date version of Calculator can be found at : ");
    System.out.print("\n        https://github.com/sahasatvik/Calculator");
    System.out.print("\n");
    System.out.print("\n    Type  /help  to read a guide on how to use this program.");
    System.out.print("\n");

    /* Setup the input system */
    Scanner inp = new Scanner(System.in);

    /* Setup the ExpressionParser, which will parse the input */
    expParser = new ExpressionParser(32);
    /* Add some commonly used mathematical constants */
    expParser.addVariable("e", (" " + Math.E));
    expParser.addVariable("pi", (" " + Math.PI));
    expParser.addVariable("phi", (" " + (Math.sqrt(5.0) + 1.0) / 2.0));

    /* Start the input loop */
    while (true) {
        /* Display a simple prompt */
        System.out.print("\n?> ");

        /* Accept a line of input */
        expression = inp.nextLine().trim();

        /* Check whether the input is a command */
        if (expression.matches(commandRegex)) {
            /* Extract the content of the command */
            command = expression.substring(expression.indexOf("/") + 1).trim();

            try {

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        /* Parse the command */
        parseCommand(command);
    } catch (CommandNotFoundException e) {
        /* Display an error message if the command is not recognized */
        System.out.print("!> Command " + e.getCommand() + " not found !");
        System.out.print("\n    Try /list for a complete list of available commands.");
    }
    /* Go back to the start of the loop and get a new line of input */
    continue;
}

/* Enclose the expression processing section within a 'try' block */
try {
    /* Evaluate the expression and store it in the cache */
    previousAns = evaluate(expression);
    /* Display the result */
    System.out.print("=> " + previousAns);
} catch (NullExpressionException e) {
    /* Catch empty input */
    System.out.print("!> Null Expression !");
} catch (MissingOperandException e) {
    /* Catch input missing an operand */
    System.out.print("!> Missing operand to " + e.getOperator() + " !");
} catch (VariableNotFoundException e) {
    /* Catch input containing undefined variables */
    System.out.print("!> Variable " + e.getVar() + " not found !");
    System.out.print("\n    Try /list vars for a complete list of available variables.");
} catch (FunctionNotFoundException e) {
    /* Catch input containing unrecognized functions */
    System.out.print("!> Function " + e.getFunc() + "[] not found !");
    System.out.print("\n    Try /list funcs for a complete list of available functions.");
} catch (UnmatchedBracketsException e) {
    /* Catch input with unclosed brackets */
    System.out.print("!> Unmatched brackets in expression !");

    /* Display the expression entered */
    System.out.print("\n    " + e.getFaultyExpression());
    System.out.print("\n    ");

    /* Display a character pointing to where the unmatched bracket is */
    for (int i = 0; i < e.getIndexOfBracket(); i++) {
        System.out.print(" ");
    }
    System.out.print("^");
} catch (ExpressionParserException e) {
    /* Catch any other Exception encountered while parsing */

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        System.out.print("!> Invalid Expression !");
    }
}

/**
 * Evaluate a mathematical expression and return the result.
 *
 * @param exp the expression to be parsed
 * @return the evaluated result
 * @throws com.github.sahasatvik.math.ExpressionParserException
 *         thrown when an exception is encountered while parsing
 *         the expression
 * @see com.github.sahasatvik.math.ExpressionParser#evaluate(String)
 * @since 1.0
 */

public static String evaluate (String exp) throws ExpressionParserException {
    /* Substitute all instances of '<ans>' with the previously evaluated answer in the cache */
    exp = exp.replaceAll("<(\s+)?ans(\s+)?>", previousAns);
    /* Return the expression as evaluated by the ExpressionParser library */
    return expParser.evaluate(exp);
}

/**
 * Parses a command intended for the Calculator shell.
 *
 * @param command the command to be parsed
 * @throws CommandNotFoundException
 *         thrown when an unrecognized command is passed here
 * @see CommandNotFoundException
 * @since 1.0
 */

public static void parseCommand (String command) throws CommandNotFoundException {
    if (command.equals("exit")) {
        /* If the command is '/exit', display an exit message exit the runtime */
        System.out.print("$> Exiting !");
        System.exit(0);
    } else if (command.equals("help")) {
        /* Display some general helptext */
        System.out.print("$> Calculator Helptext");
        System.out.print("\n ~~~~~~");
        System.out.print("\n Welcome to 'Calculator', a simple java application written to");
        System.out.print("\n evaluate mathematical expressions.");
        System.out.print("\n This program displays a prompt (?>), after which you can enter");
    }
}

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System.out.print("\n      a mathematical expression. 'Calculator' will display the result,");
System.out.print("\n      or point out errors in the expression.");
System.out.print("\n");
System.out.print("\n      'Calculator' can evaluate simple arithmetic expressions, using the");
System.out.print("\n      operators (+, -, *, /, ^(power)), as well as parenthesis ('(', ')').");
System.out.print("\n      'Calculator' follows the BODMAS rule.");
System.out.print("\n");
System.out.print("\n      Following are some valid expressions : ");
System.out.print("\n      1 + 1                      =>          2.0");
System.out.print("\n      1 * (2 + 3)                =>          5.0");
System.out.print("\n      10 * (64 ^ -0.5)           =>          1.25");
System.out.print("\n");
System.out.print("\n      For help on more advanced topics, try entering the following : ");
System.out.print("\n      /help vars                  >          help on Variables");
System.out.print("\n      /help funcs                 >          help on Functions");
System.out.print("\n      /help cmds                  >          help on Commands");
System.out.print("\n");
System.out.print("\n      Enter '/list' for a complete list of valid commands.");
} else if (command.equals("help vars")) {
    /* Display help on 'variables' */
    System.out.print("\n$> Variables");
    System.out.print("\n      'Calculator' can also store user-defined variables.");
    System.out.print("\n      The syntax for assigning and using variables is as follows : ");
    System.out.print("\n      var = value                >          assign 'value' to 'var'");
    System.out.print("\n      <var>                      >          <var> will be replaced");
    System.out.print("\n                                   its value.");
    System.out.print("\n");
    System.out.print("\n      Following are some valid uses of variables : ");
    System.out.print("\n      x = 3                      =>          3.0");
    System.out.print("\n      y = <x> + 1                 =>          4.0");
    System.out.print("\n      (<x>^2 + <y>^2)^0.5          =>          5.0 ");
    System.out.print("\n");
    System.out.print("\n      Nesting of assignments is also supported, as follows : ");
    System.out.print("\n      x = 1 + (y = 1)            =>          2.0");
    System.out.print("\n      <x>                          =>          2.0");
    System.out.print("\n      <y>                          =>          1.0");
    System.out.print("\n");
    System.out.print("\n      A special variable <ans> stores the previous expression.");
    System.out.print("\n      Thus, the following is valid : ");
    System.out.print("\n      1 * 2 * 3 * 4              =>          24.0");
    System.out.print("\n      <ans> * 5                   =>          120.0");
    System.out.print("\n");
    System.out.print("\n      Enter '/list vars' for a list of stored variables.");
} else if (command.equals("help funcs")) {
    /* Display help on 'funcitons' */

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        System.out.print("\n$> Functions");
        System.out.print("\n      ~~~~~~");
        System.out.print("\n      'Calculator' supports the use of some basic functions.");
        System.out.print("\n      They can be used with the following syntax : ");
        System.out.print("\n      fnc[ value ]      >      evaluate 'fnc' of 'value'");
        System.out.print("\n");
        System.out.print("\n      Following are some valid uses of functions : ");
        System.out.print("\n      sin[<pi> / 2]      =>      1.0");
        System.out.print("\n      1 + abs[2 - 3]      =>      2.0");
        System.out.print("\n      log[<e> ^ 3]      =>      3.0");
        System.out.print("\n");
        System.out.print("\n      Enter '/list funcs' for a list of valid functions.");
    } else if (command.equals("help cmds")) {
        /* Display help on 'commands' */
        System.out.print("\n$> Commands");
        System.out.print("\n      ~~~~~~");
        System.out.print("\n      'Calculator' interprets expressions starting with '/' as");
        System.out.print("\n      'commands'. These are special expressions which are not parsed as");
        System.out.print("\n      mathematical expressions, but as instructions to the 'Calculator'.");
        System.out.print("\n");
        System.out.print("\n      Enter '/list' for a complete list of valid commands.");
    } else if (command.equals("list") || command.equals("list cmds")) {
        /* Display a list of valid, acceptable commands */
        System.out.print("$> Commands : \n");
        System.out.print("\n      /help      >      general help");
        System.out.print("\n      /help vars  >      help on Variables");
        System.out.print("\n      /help funcs >      help on Functions");
        System.out.print("\n      /help cmds  >      help on Commands");
        System.out.print("\n      /list vars  >      list variables");
        System.out.print("\n      /list funcs >      list functions");
        System.out.print("\n      /list cmds  >      list commands");
        System.out.print("\n      /exit      >      exit Calculator");
    } else if (command.equals("list vars")) {
        /* Display a list of defined variables, currently stored in the ExpressionParser */
        System.out.print("$> Variables : \n");
        /* Loop through the variables in the array belonging to the ExpressionParser */
        for (int i = 0; i < expParser.numberOfVars; i++) {
            /* Pretty-print the variables */
            System.out.printf("%n\t%s\t\t\t=%30s", expParser.variables[i][0]
                               , expParser.variables[i][1]);
        }
        /* Display the previously evaluated answer as a special variable : 'ans' */
        System.out.printf("%n\t%s\t\t\t=%30s", "ans", previousAns);
    } else if (command.equals("list funcs")) {
        /* Display a list of valid functions */
        System.out.print("$ Functions : \n");
    }
}

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        System.out.print("\n      abs[ x ]      >      absolute value of <x>");
        System.out.print("\n      exp[ x ]      >      exponent of <x> (<e> ^ <x>)");
        System.out.print("\n      log[ x ]      >      logarithm of <x> (base <e>)");
        System.out.print("\n      fct[ x ] or x! >      factorial of <x>");
        System.out.print("\n      deg[ x ]      >      convert <x> to degrees from radians");
        System.out.print("\n      rad[ x ]      >      convert <x> to radians from degrees");
        System.out.print("\n");
        System.out.print("\n      sin[ x ]      |      ");
        System.out.print("\n      cos[ x ]      |      ");
        System.out.print("\n      tan[ x ]      >      trigonometric functions");
        System.out.print("\n      csc[ x ]      |      ( <x> in radians )");
        System.out.print("\n      sec[ x ]      |      ");
        System.out.print("\n      ctn[ x ]      |      ");
        System.out.print("\n      ~              ");
    } else {
        /* Throw an Exception if the command does not match any of the above */
        throw new CommandNotFoundException(command);
    }
}
}

```

```
// src/CommandNotFoundException.java

/**
 * Exception thrown when an unrecognized command is passed to Calculator.
 *
 * @author Satvik Saha
 * @version 1.0, 17/10/2016
 * @see Calculator
 * @since 1.0
 */

public class CommandNotFoundException extends Exception {
    private String command;

    /**
     * Constructor of CommandNotFoundException.
     *
     * @param command the command which could not be parsed
     * @since 1.0
     */

    public CommandNotFoundException (String command) {
        super("CommandNotFoundException");
        this.command = command;
    }

    /**
     * Get the command which could not be parsed.
     *
     * @return the command which could not be parsed
     * @since 1.0
     */

    public String getCommand () {
        return command;
    }
}
```



```
// src/com/github/sahasatvik/math/ExpressionParserException.java

package com.github.sahasatvik.math;

/**
 * Superclass of all Exceptions thrown by ExpressionParser.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParser
 * @since 1.0
 */

public class ExpressionParserException extends Exception {
    private String faultyExpression;

    /**
     * Constructor of ExpressionParserException.
     *
     * @param faultyExpression the expression which could not be parsed
     * @since 1.0
     */

    public ExpressionParserException (String faultyExpression) {
        super("ExpressionParserException");
        /* Store the bad expression */
        this.faultyExpression = faultyExpression;
    }

    /**
     * Gets the expression which could not be parsed.
     *
     * @return the expression which could not be parsed
     * @since 1.0
     */
    public String getFaultyExpression () {
        return faultyExpression;
    }
}

```

```
// src/com/github/sahasatvik/math/ExpressionParser.java

package com.github.sahasatvik.math;

/**
 * ExpressionParser provides methods for evaluating mathematical expressions, specifically
 * tailored for parsing with this library. ExpressionParser supports basic arithmetic operators,
 * parenthesized expressions, variable substitution as well as basic functions.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.MathParser
 * @since 1.0
 */

public class ExpressionParser extends MathParser {

    /**
     * Regex which matches a number. It may be signed or use scientific notation.
     */
    protected static final String numberRegex = "([+-]?\\d+(\\.\\d+)?([eE](-?)\\d+)?)";

    /**
     * Regex which matches a signed number. It may use scientific notation.
     */
    protected static final String signedNumberRegex = "([+-]\\d+(\\.\\d+)?([eE](-?)\\d+)?)";

    /**
     * Regex which matches an assignment statement. It is simply a word, followed by an
     * equals sign (=) and an expression.
     */
    protected static final String assignmentRegex = "(\\s+)?(\\w+)(\\s+)(=)(.*)";

    /**
     * Array of supported operators. The operators are arranged in their order of precedence.
     * Thus, operators to the left will be evaluated before those to the right.
     */
    protected static final String[] operators = {"^", "%", "/", "*", "+", "-"};

    /**
     * Array of variables maintained by an ExpressionParser object. The first String in each
     * line stores the variable name, while the second stores the value.
     */
    public String[][] variables;
}
```

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/**
 * Index of the last variable in the 'variables' array. Elements in the 'variables' array
 * after this index are all blank, so they are not parsed during expression evaluation.
 */
public int numberOfVars;

/**
 * Constructor of ExpressionParser. This constructor initializes the variable cache with
 * the specified maximum size.
 *
 * @param maxVars the maximum number of variables to be stored
 * @since 1.0
 */

public ExpressionParser (int maxVars) {
    variables = new String[maxVars][2];
    numberOfVars = 0;
}

/**
 * Adds a variable to the variable cache. This method accepts the variable
 * name, as well as the String each occurrence is to be substituted with.
 *
 * @param name the name of the variable
 * @param value the value the variable holds
 * @since 1.0
 */

public void addVariable (String name, String value) {
    /* Loop through the stored variables */
    for (int i = 0; i < numberOfVars; i++) {
        /* If the variable already exists, simply update the value */
        if (variables[i][0].equals(name)) {
            variables[i][1] = value;
            return;
        }
    }
    /*
     * Create a new variable by storing the name and value in the variables array,
     * then update numberOfVars
     */
    variables[numberOfVars][0] = name;
    variables[numberOfVars][1] = value;
    numberOfVars++;
}

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/**
 * Evaluates a String representation of a mathematical expression into a
 * number (stored as a String).
 *
 * @param exp the expression to be evaluated
 * @return the result after evaluating the expression
 * @throws com.github.sahasatvik.math.NullExpressionException
 *         thrown when the expression is empty
 * @throws com.github.sahasatvik.math.ExpressionParserException
 *         thrown when the expression cannot be parsed
 *
 * @see #addVariable(String, String)
 * @see #parseVariables(String)
 * @see #parseParenthesis(String)
 * @see #parseFunctions(String)
 * @see #parseOperators(String)
 * @since 1.0
 */

public String evaluate (String exp) throws ExpressionParserException {
    String result = exp;
    if (exp.trim().length() == 0) {
        /* Throw an Exception if the expression is blank */
        throw new NullExpressionException();
    } else if (isNumber(exp)) {
        /* If the expression is already a number, there is nothing to evaluate */
        return "" + Double.parseDouble(exp);
    } else if (exp.matches(assignmentRegex)) {
        /*
         * If the expression is an assignment statement, interpret everything before
         * the equals sign (=) as the variable name. The rest is simply another
         * expression, which is also the value of the variable.
         */
        String varName = exp.substring(0, exp.indexOf("=")).trim();
        String varValue = evaluate(exp.substring(exp.indexOf("=") + 1));

        /*
         * Add the variable in the cache, then use the value of the variable
         * as the evaluated result
         */
        addVariable(varName, varValue);
        exp = varValue;
    } else {
        /*
         * Replace all variables with their values,
         * solve everything within parenthesis,

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        * then Solve all functions
        */
        exp = parseVariables(exp);
        exp = parseParenthesis(exp);
        exp = parseFunctions(exp);

        /*
        * The expression is now simply a collection of numbers and arithmetic operators.
        * Finish off the process by solving each operation, following the BODMAS rule.
        */
        exp = parseOperators(exp);
    }

    try {
        /* Check if the result is a valid number */
        result = "" + Double.parseDouble(exp);
    } catch (Exception e) {
        /* Throw an Exception if the result is not a number */
        throw new ExpressionParserException(exp);
    }
    return result;
}

/**
 * Substitutes all instances of the variables in the cache with their values.
 * A variable name present in the expression must be enclosed within angled brackets
 * (<code>#{code}</code>, <code>#{code}</code>) in order to be recognized.
 * For example, if <code>x = 10.0</code>, then all instances of <code>#{code}</code>x#{code}</code>
 * will be replaced with <code>10.0</code>
 *
 * @param exp the expression to be parsed
 * @return the expression after substituting known values
 *         of variables stored in the cache
 * @throws com.github.sahasatvik.math.VariableNotFoundException
 *         thrown when an unrecognized variable name is
 *         found in the expression
 *
 * @since 1.0
 */

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```

protected String parseVariables (String exp) throws VariableNotFoundException {
    /*
    * Loop through the variable cache, checking for occurrences of the variables
    * (enclosed within angled brackets)(<var_name>)
    */
    for (int i = 0; i < numberOfVars; i++) {
        /* Replace all instances of the variable with its value directly */
    }
}

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        exp = exp.replaceAll("<(\s+)?" + variables[i][0] + "(\s+)?>"
                                , variables[i][1]);
    }

    /*
     * Check if any unrecognized variables are present. This can be done very simply as
     * the presence of angled brackets (<>) indicates an unreplaced variable.
     */
    int start = exp.indexOf("<");
    int end = exp.indexOf(">");
    if (start != -1 && end != -1 && start < end) {
        /*
         * Extract the unreplaced variable name, which is clearly in between the angled
         * brackets, then throw an Exception.
         */
        throw new VariableNotFoundException(exp, exp.substring(start, end + 1));
    }

    /* Adjust the number spacing before passing the expression back to the evaluator */
    exp = adjustNumberSpacing(exp);
    return exp.trim();
}

/**
 * Substitutes expressions within parenthesis (<code></code>, <code></code>) with their results.
 * This ensures that while evaluating an expression containing parenthesized parts, those
 * parenthesized parts are evaluated first. This is done so that ExpressionParser follows the
 * BODMAS rule.
 *
 * @param exp the expression to be parsed
 * @return the expression such that all parenthesized parts
 *         have been evaluated
 * @throws com.github.sahasatvik.math.UnmatchedBracketsException
 *         thrown when brackets in the expression are not
 *         closed
 * @throws com.github.sahasatvik.math.ExpressionParserException
 *         thrown if the parenthesized sections cannot be
 *         parsed
 * @see #indexOfMatchingBracket(String, int, char, char)
 * @since 1.0
 */
protected String parseParenthesis (String exp) throws ExpressionParserException {
    String result = "";
    /*
     * Buffer the extreme ends with spaces, to make sure no Exceptions are thrown

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        * while extracting portions of the expression.
        */
exp = " " + exp + " ";

/* Continue replacing parenthesized sections as long as a parenthesis is present */
while (exp.indexOf("(") != -1) {
    /* Store the indices of the opening and closing parenthesis */
    int start = exp.indexOf("(");
    int end = indexOfMatchingBracket(exp, start, '(', ')');
    /* The enclosed section is simply another expression. Pass it to the evaluator */
    result = evaluate(exp.substring(start + 1, end));

    /*
     * This is a special case. Make sure that ' -(some_expression) ' is interpreted
     * as the negative of that expression.
     */
    if (exp.charAt(start - 1) == '-') {
        /* Multiply the enclosed section by -1, then evaluate the result */
        result = " ( -1 * ( " + result + " ) ) ";
        start--;
    }

    /* Graft the evaluated parenthesized portion back into the original expression */
    exp = exp.substring(0, start) + " "           // before the opening bracket
          + result + " "                         // evaluated part
          + exp.substring(end + 1);              // after the closing bracket
}
/* Adjust the number spacing before passing the expression back to the evaluator */
exp = adjustNumberSpacing(exp);
return exp.trim();
}

/**
 * Substitutes all occurrences of supported mathematical functions with their result.
 * A function must be present in the expression in the following format :
 * <code>function_name[function_argument]</code>, where the function argument can also
 * be an expression. The function name must be exactly 3 characters long, and be
 * immediately followed by a square bracket (<code>[</code>).
 * See {@link com.github.sahasatvik.math.MathParser#solveUnaryFunction(String, double)} for a
 * list of supported function names.
 *
 * @param exp the expression to be parsed
 * @return the expression such that all instances of
 *         functions are evaluated
 * @throws com.github.sahasatvik.math.MissingOperandException
 *         thrown if there is no function argument

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*      @throws com.github.sahasatvik.math.FunctionNotFoundException
*              thrown when an unrecognized function name
*              is found in the expression
*      @throws com.github.sahasatvik.math.UnmatchedBracketsException
*              thrown when a square bracket is not closed
*      @throws com.github.sahasatvik.math.ExpressionParserException
*              thrown if the function argument cannot be
*              parsed
*      @see      com.github.sahasatvik.math.MathParser#solveUnaryFunction(String, double)
*      @since    1.0
*/

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protected String parseFunctions (String exp) throws ExpressionParserException {
    String result = "";
    String func = "";
    double x = 0.0;
    /*
     * Buffer the extreme ends with spaces, to make sure no Exceptions are thrown
     * while extracting portions of the expression.
     */
    exp = " " + exp + " ";
    try {
        /*
         * This is another special case. Make sure that expressions of the form
         * 'number!' are interpreted as the factorial of that number. This can
         * be done simply by replacing all such cases with the expression 'fct[number]',
         * as 'fct[]' is a valid function name and can be calculated later.
         */
        exp = exp.replaceAll(numberRegex + "\\s+!", " fct[$1] ");

        /*
         * Continue evaluating functions as long as square brackets ([]) are present.
         * Here, a function is represented in the format 'fnc[expression]'. Thus, the
         * presence of square brackets ([]) implies that a function is present.
         */
        while (exp.indexOf("[") != -1) {
            /* Store the indices of the opening and closing square brackets */
            int start = exp.indexOf("[");
            int end = indexOfMatchingBracket(exp, start, '[', ']');

            /*
             * Here, all function names are exactly 3 characters long. Thus, the
             * function name is simply the 3 characters preceding the opening bracket.
             */
            func = exp.substring(start - 3, start);

```



```

/*
 * The section enclosed within the brackets is also an expression.
 * Evaluate it, and check whether it is a number. This will be the
 * function argument.
 */
x = Double.parseDouble(evaluate(exp.substring(start + 1, end)));

/* Pass the function name and argument to a function solver */
result = "" + solveUnaryFunction(func, x);

/*
 * This is a special case similar to that in parseParenthesis(String).
 * Make sure that ' -fnc[some_expression] ' is interpreted as the negative
 * of the result of that function.
 */
if (exp.charAt(start - 4) == '-') {
    /* Multiply the enclosed section by -1, then evaluate the result */
    result = evaluate(" ( -1 * ( " + result + " ) ) ");
    start--;
}
/* Graft the evaluated portion back into the original expression */
exp = exp.substring(0, start-3) + " "           // before the function
      + result + " "                             // evaluated part
      + exp.substring(end+1);                    // after the function
}
} catch (NullExpressionException e) {
    /* Throw an Exception if the function is missing its argument */
    throw new MissingOperandException(exp, func + "[ ]");
} catch (FunctionNotFoundException e) {
    /* Throw an Exception if an extracted function name is unsupported */
    throw new FunctionNotFoundException(exp, func);
} catch (ExpressionParserException e) {
    /* Pass on any Exceptions encountered while evaluating the argument */
    throw e;
} catch (Exception e) {
    /* Pass on any other Exceptions as ExpressionParserExceptions */
    throw new ExpressionParserException(exp);
}
/* Adjust the number spacing before passing the expression back to the evaluator */
exp = adjustNumberSpacing(exp);
return exp.trim();
}

/**
 * Substitutes all binary expressions involving arithmetic operators with their result.
 * Operations are performed following the BODMAS rule. The resultant parsed String

```

```

* is free of all operators, thus containing only numbers.
* See {@link com.github.sahasatvik.math.MathParser#solveBinaryOperation(double, String, double)}
* for a list of supported operators. See {@link #operators}, which defines the order of
* operations.
*
* @param exp          the expression to be parsed
* @return             the expression such that all arithmetic operations
*                    have been carried out
* @throws com.github.sahasatvik.math.MissingOperandException
*                    thrown if a binary operator is missing an operand
* @see    com.github.sahasatvik.math.MathParser#solveBinaryOperation(double, String, double)
* @since  1.0
*/

```

```

protected String parseOperators (String exp) throws MissingOperandException {
    int leftIndex, rightIndex;

    try {
        /*
         * This code addresses a small problem in directly implementing BODMAS.
         * Expressions like (1 - 2 + 3) will mistakenly evaluate to (-4) if the addition
         * is done first, disregarding the minus sign before the (2).
         * Eliminate this problem by changing all instances of subtraction to addition
         * of the second operand's negative form. Thus, the minus sign acting as an operator
         * now becomes part of the number itself, and all ambiguity disappears.
         */
        while (exp.matches("(.*)" + numberRegex + "\\s+-\\s+" + numberRegex + "(.*)")) {
            exp = exp.replaceAll(numberRegex + "\\s+-\\s+" + numberRegex, " $1 + -($6) ");
            exp = parseParenthesis(exp);
        }
    } catch (Exception e) {
        /* Something went seriously wrong - the expressions in the 'try' block were valid */
        System.out.print("You should never see this message. If you do, please inform the author.");
        e.printStackTrace();
    }

    /* Split the expression into a stack of operators and operands */
    String[] stack = exp.split("\\s+");

    /* Loop through all supported operators (in order) */
    for (String op : operators) {
        /* Loop through the stack, searching for a match with the operator */
        for (int i = 0; i < stack.length; i++) {
            if (stack[i].equals(op)) {
                leftIndex = rightIndex = i;
                /* Keep on searching before the operator until a valid operand is found */
            }
        }
    }
}

```

```

        while (leftIndex >= 0 && !isNumber(stack[leftIndex]))
            leftIndex--;
        /* Keep on searching after the operator until a valid operand is found */
        while (rightIndex < stack.length && !isNumber(stack[rightIndex]))
            rightIndex++;
        try {
            /* Get the operands */
            double left = Double.parseDouble(stack[leftIndex]);
            double right = Double.parseDouble(stack[rightIndex]);
            /*
             * Pass the operands and the operator to an operator solver,
             * then replace the operator with the result. Also remove the
             * operands.
             */
            stack[i] = "" + solveBinaryOperation(left, op, right);
            stack[leftIndex] = stack[rightIndex] = "";
        } catch (Exception e) {
            /* Throw an Exception if there is a missing operand */
            throw new MissingOperandException(exp, op);
        }
    }

    }
    exp = "";

    /* Recombine the stack into the solved expression */
    for (String s : stack) {
        exp += s;
    }
    return exp.trim();
}

/**
 * Adjusts the spacings between numbers, variables, functions, operators, etc in an expression.
 * Each number will be enclosed within a 'buffer' of spaces. Instances of signed numbers
 * immediately following another number will be interpreted as their sum.
 * (<code>    1  -1</code> is simply <code>1 + -1</code>)
 *
 * @param exp    the expression to be parsed
 * @return       the expression with adjusted spacing
 * @since 1.0
 */
protected static String adjustNumberSpacing (String exp) {
    /* Make sure numbers are all spaced out from other symbols */
    exp = exp.replaceAll(numberRegex, " $0 ");
}

```

```

        /* Make sure the sign in signed numbers is also considered during addition/subtraction */
        exp = exp.replaceAll(numberRegex + "\\s+" + signedNumberRegex, " $1 + $6 ");
        return exp;
    }

    /**
     * Finds the index of a matching closing bracket in a String, given the index of the
     * opening one. This method can also be given any characters as opening and closing brackets.
     * Nesting of brackets has also been dealt with.
     *
     * @param str          the String containing the brackets
     * @param pos          the index of the opening bracket
     * @param open         the character to be recognized as an opening bracket
     * @param close        the character to be recognized as a closing bracket
     * @return             the index of the matching closing bracket
     * @throws com.github.sahasatvik.math.UnmatchedBracketsException
     *                   thrown if the specified opening bracket is unclosed
     *
     * @since 1.0
     */
    protected static int indexOfMatchingBracket (String str, int pos, char open, char close)
        throws UnmatchedBracketsException {
        int tmp = pos;
        /* Loop through the String, forward from the position of the opening bracket */
        while (++pos < str.length()) {
            /* Exit the loop as soon as a closing bracket is found */
            if (str.charAt(pos) == close)
                return pos;
            /*
             * If another opening bracket is found, it becomes clear that bracketed expressions
             * have been nested. Thus, the next closing bracket will not match the bracket
             * we have targeted. In order to return the correct bracket, simply skip everything
             * within the nested portion. This is done by calling
             * indexOfMatchingBracket(String, int, char, char) recursively.
             */
            if (str.charAt(pos) == open)
                pos = indexOfMatchingBracket(str, pos, open, close);
        }
        if (pos >= str.length()) {
            /* Throw an Exception if a matching bracket is not present */
            throw new UnmatchedBracketsException(str, tmp);
        }
        return pos;
    }
}

```

```

// src/com/github/sahasatvik/math/FunctionNotFoundException.java

package com.github.sahasatvik.math;

/**
 * Exception thrown when an unparsable function is passed to ExpressionParser.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParserException
 * @since 1.0
 */

public class FunctionNotFoundException extends ExpressionParserException {
    private String func;

    /**
     * Constructor of FunctionNotFoundException. This constructor accepts the
     * invalid expression as well as the unrecognized function name.
     *
     * @param faultyExpression the expression which could not be parsed
     * @param func the unrecognized function name
     */

    public FunctionNotFoundException (String faultyExpression, String func) {
        super(faultyExpression);
        this.func = func;
    }

    /**
     * Constructor of FunctionNotFoundException. This constructor accepts only
     * the unrecognized function name.
     *
     * @param func the unrecognized function name
     * @since 1.0
     */

    public FunctionNotFoundException (String func) {
        this("", func);
    }

    /**
     * Gets the unrecognized function name.
     */

```

the unrecognized function name

```
*      @return  
*      @since 1.0  
*/
```

```
public String getFunc () {  
    return func;  
}
```

```
}
```

```
// src/com/github/sahasatvik/math/MathParser.java
```

```
package com.github.sahasatvik.math;
```

```
/**
```

```
 * MathParser contains methods for solving simple operations involving  
 * arithmetic operators and functions.  
 * These methods can be accessed by subclasses of MathParser.  
 *
```

```
 *      @author      Satvik Saha  
 *      @version     1.0, 16/10/2016  
 *      @since       1.0  
 */
```

```
public class MathParser {
```

```
    /**
```

```
     * Checks whether the String passed to it can be parsed as a number.
```

```
     *
```

```
     *      @param  str          the String to be tested  
     *      @return         true if the String can be parsed as a number  
     *      @since  1.0  
     */
```

```
    protected static boolean isNumber (String str) {
```

```
        try {
```

```
            /* Return true only if parseDouble(String) doesn't complain! */
```

```
            Double.parseDouble(str);
```

```
            return true;
```

```
        } catch (Exception e) {
```

```
            return false;
```

```
        }
```

```
    }
```

```
    /**
```

```
     * Calculates the factorial of a number.
```

```
     *
```

```
     *      @param  x          the number whose factorial is to be calculated  
     *      @return         the factorial of the number passed  
     *      @since  1.0  
     */
```

```
    protected static double factorial (double x) {
```

```
        /* Special cases! */
```

```
        if (x < 2)
```

```

        return 1;
    double n = 1;
    while (x > 0)
        n *= x--;
    return n;
}

/**
 * Solves and returns the result of a simple binary expression.
 * Only the following operators are supported : <pre>{@code
 *      ^      -      power
 *      /      -      division
 *      *      -      multiplication
 *      +      -      addition
 *      -      -      subtraction}</pre>
 *
 *      @param a          the operand on the left
 *      @param op         the operator
 *      @param b          the operand on the right
 *      @return           the result on evaluating the expression
 *      @since 1.0
 */

protected static double solveBinaryOperation (double a, String op, double b) {
    double result = 0.0;
    /*
     * Match the operator against a list of supported ones, then
     * perform the appropriate operation.
     */
    if (op.equals("^")) {
        result = Math.pow(a, b);
    } else if (op.equals("%")) {
        result = a % b;
    } else if (op.equals("/")) {
        result = a / b;
    } else if (op.equals("*")) {
        result = a * b;
    } else if (op.equals("+")) {
        result = a + b;
    } else if (op.equals("-")) {
        result = a - b;
    }
    return result;
}

/**

```



```

* Solves and returns the result of an expression involving a function
* with only one operand.
* Only the following function names are supported : <pre>{@code
*     abs      -      absolute value
*     fct      -      factorial
*     exp      -      exponentiation
*     log      -      logarithm (base 'e')
*     rad      -      convert degrees to radians
*     deg      -      convert radians to degrees
*     sin      \
*     cos      |
*     tan      \      standard trigonometric
*     sec      /      functions
*     csc      |
*     ctn      /}</pre>
*
*     @param func          the function name
*     @param x             the operand
*     @return              the result on evaluating the expression
*     @throws com.github.sahasatvik.math.FunctionNotFoundException
*                        thrown when func is not recognized
*
*     @since 1.0
*/

```

```

protected static double solveUnaryFunction (String func, double x)
                                throws FunctionNotFoundException {
    double result = 0.0;
    /*
     * Math the function name against supported ones, then
     * perform the appropriate operation.
     */
    if (func.equals("sin")) {
        result = Math.sin(x);
    } else if (func.equals("cos")) {
        result = Math.cos(x);
    } else if (func.equals("tan")) {
        result = Math.tan(x);
    } else if (func.equals("csc")) {
        result = 1.0/Math.sin(x);
    } else if (func.equals("sec")) {
        result = 1.0/Math.cos(x);
    } else if (func.equals("ctn")) {
        result = 1.0/Math.tan(x);
    } else if (func.equals("rad")) {
        result = Math.toRadians(x);
    } else if (func.equals("deg")) {

```

```

        result = Math.toDegrees(x);
    } else if (func.equals("fct")) {
        result = factorial(x);
    } else if (func.equals("abs")) {
        result = Math.abs(x);
    } else if (func.equals("exp")) {
        result = Math.exp(x);
    } else if (func.equals("log")) {
        result = Math.log(x);
    } else {
        /*
         * Throw an Exception if the function name does not
         * match any supported one.
         */
        throw new FunctionNotFoundException(func + "[]");
    }
    return result;
}
}

```

```
// src/com/github/sahasatvik/math/MissingOperandException.java

package com.github.sahasatvik.math;

/**
 * Exception thrown when an expression passed to ExpressionParser has a missing
 * operand.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParserException
 * @since 1.0
 */

public class MissingOperandException extends ExpressionParserException {
    private String op;

    /**
     * Constructor of MissingOperandException.
     *
     * @param faultyExpression the expression which could not be parsed
     * @param op the operator which is missing an operand
     * @since 1.0
     */

    public MissingOperandException (String faultyExpression, String op) {
        super(faultyExpression);
        this.op = op;
    }

    /**
     * Gets the operator which is missing an operand.
     *
     * @return the operator which is missing an operand
     * @since 1.0
     */

    public String getOperator () {
        return op;
    }
}
```

```
// src/com/github/sahasatvik/math/NullExpressionException.java

package com.github.sahasatvik.math;

/**
 * Exception thrown when an expression passed to ExpressionParser is empty.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParserException
 * @since 1.0
 */

public class NullExpressionException extends ExpressionParserException {

    /**
     * Constructor of NullExpressionException.
     *
     * @since 1.0
     */

    public NullExpressionException () {
        super("");
    }
}
```

```
// src/com/github/sahasatvik/math/UnmatchedBracketsException.java

package com.github.sahasatvik.math;

/**
 * Exception thrown when an expression passed to ExpressionParser has unmatched
 * brackets.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParserException
 * @since 1.0
 */

public class UnmatchedBracketsException extends ExpressionParserException {
    private int pos;

    /**
     * Constructor of UnmatchedBracketsException.
     *
     * @param faultyExpression the expression which could not be parsed
     * @param pos the index of the unmatched bracket
     * @since 1.0
     */

    public UnmatchedBracketsException (String faultyExpression, int pos) {
        super(faultyExpression);
        this.pos = pos;
    }

    /**
     * Gets the index of the unmatched bracket.
     *
     * @return the index of the unmatched bracket
     * @since 1.0
     */

    public int getIndexOfBracket () {
        return pos;
    }
}
```

```

// src/com/github/sahasatvik/math/VariableNotFoundException.java

package com.github.sahasatvik.math;

/**
 * Exception thrown when an unrecognized variable is passed to ExpressionParser.
 *
 * @author Satvik Saha
 * @version 1.0, 16/10/2016
 * @see com.github.sahasatvik.math.ExpressionParserException
 * @since 1.0
 */

public class VariableNotFoundException extends ExpressionParserException {
    private String var;

    /**
     * Constructor of VariableNotFoundException. This constructor accepts the
     * invalid expression as well as the unrecognized variable.
     *
     * @param faultyExpression the expression which could not be parsed
     * @param var the unrecognized variable
     * @since 1.0
     */

    public VariableNotFoundException (String faultyExpression, String var) {
        super(faultyExpression);
        this.var = var;
    }

    /**
     * Constructor of VariableNotFoundException. This Constructor accepts only
     * the unrecognized variable.
     *
     * @param var the unrecognized variable
     * @since 1.0
     */

    public VariableNotFoundException (String var) {
        this("", var);
    }

    /**
     * Gets the unrecognized variable.
     *

```

the unrecognized variable

```
*      @return
*      @since 1.0
*/
public String getVar () {
    return var;
}
```