3. homework assignment; JAVA, Academic year 2015/2016; FER

Problem 1.

U okviru ovog zadatka pripremamo se za izradu jednostavnog jezičnog procesora. Jezični procesor uobičajeno se sastoji od nekoliko dijelova. Prvi dio je podsustav za izradu leksičke analize. Ulaz ovog podsustava je izvorni tekst programa (dokumenta ili što se već obrađuje) a izlaz je niz *tokena*. Token je leksička jedinica koja grupira jedan ili više uzastopnih znakova iz ulaznog teksta. Primjerice, ako je ulaz izvorni tekst razreda u Javi, tokeni bi bile ključne riječi, identifikatori, cijeli brojevi, decimalni brojevi, simboli, itd. Za tokene pamtimo kojeg su tipa te koju vrijednost predstavljaju. Primjerice, token čiji je tip "ključna riječ" može imati kao vrijednost string "for" ili pak "do" ili "while" ili "new" ili … Token čiji je tip "cijeli broj" može imati kao vrijednost podatak tipa long vrijednosti 358 i slično.

Podsustav koji obavlja sintaksnu analizu konzumira niz tokena koje generira podsustav za leksičku analizu i gradi primjerice sintaksno stablo. Takav će podsustav zaključiti da, ako vidi slijed tokena koji je identifikator (tj. niz slova) pa tokena koji je simbol "=", da se radi o pridjeljivanju vrijednosti varijabli (kao u tekstu "tmp=7", prvi token je tipa identifikator i čuva vrijednost "tmp" a drugi je tipa simbol i čuva vrijednost "="), a ako vidi slijed tokena koji je identifikator pa tokena koji je simbol "(", da se radi o pozivu metode (kao u tekstu "print(x)")

Leksički analizator uobičajeno se izvodi kao *lijeni*: grupiranje znakova odnosno ekstrakciju svakog sljedećeg tokena radi tek kada ga se to eksplicitno zatraži pozivom odgovarajuće metode za dohvat sljedećeg tokena.

Sve razrede i enumeracije u ovom zadatku smjestite u paket `hr.fer.zemris.java.tecaj.hw3.prob1`.
U okviru ovog zadatka potrebno je napraviti jednostavni leksički analizator (razred `Lexer`).

```
public class Lexer {
	private char[] data;      // ulazni tekst
	private Token token;      // trenutni token
	private int currentIndex; // indeks prvog neobrađenog znaka

	// konstruktor prima ulazni tekst koji se tokenizira
	public Lexer(String text) { ... }

	// generira i vraća sljedeći token
	// baca LexerException ako dođe do pogreške
	public Token nextToken() { ... }

	// vraća zadnji generirani token; može se pozivati
	// više puta; ne pokreće generiranje sljedećeg tokena
	public Token getToken() {...}
}
```

Kostur razreda `Token` prikazan je u nastavku.

```
public class Token {
	...

	public Token(TokenType type, Object value) {...}

	public Object getValue() {...}

	public TokenType getType() {...}
}
```

`TokenType` je enumeracija čije su moguće vrijednosti `EOF`, `WORD`, `NUMBER`, `SYMBOL`. `LexerException` je iznimka koja je izvedena iz razreda `RuntimeException`. Vaš je zadatak napisati sve spomenute razrede / enumeracije.

Pravila kojih se lexer pridržava su sljedeća. Tekst se sastoji od niza riječi, brojeva te simbola. Riječ je svaki niz od jednog ili više znakova nad kojima metoda `Character.`*`isLetter`* vraća `true`. Broj je svaki niz od jedne ili više znamenaka, a koji je prikaziv u tipu `Long`. Zabranjeno je u tekstu imati prikazan broj koji ne bi bio prikaziv tipom `Long` (u tom slučaju lexer mora baciti iznimku: ulaz ne valja!). Simbol je svaki pojedinačni znak koji se dobije kada se iz ulaznog teksta uklone sve riječi i brojevi te sve praznine (`'\r'`, `'\n'`, `'\t'`, `' '`). Praznine ne generiraju nikakve tokene (zanemaruju se). Vrijednosti koje su riječi pohranjuju se kao primjerci razreda `String`, brojevi kao primjerci razreda `Long` a simboli kao primjerci razredi `Character`. Token tipa `EOF` generira se kao posljednji token u obradi, nakon što lexer grupira sve znakove iz ulaza i bude ponovno pozvad da obavi daljnje grupiranje. U slučaju da korisnik nakon što lexer vrati token tipa `EOF` opet zatraži generiranje sljedećeg tokena, lexer treba baciti iznimku.

Pretpostavite da je u datoteci zapisan sljedeći tekst.

```
Ovo je 123ica, ab57.
Kraj
```

Za potrebe testiranja, ovaj tekst možemo pohraniti kao `String` varijablu u Javi:

```
String ulaz = "Ovo je 123ica, ab57.\nKraj";
```

Očekivali bismo da uzastopnim pozivima metode `nextToken` nad lexerom koji je inicijaliziran prikazanim tekstom dobijemo sljedeći niz tokena:

```
(WORD, Ovo)
(WORD, je)
(NUMBER, 123)
(WORD, ica)
(SYMBOL, ,)
(WORD, ab)
(NUMBER, 57)
(SYMBOL, .)
(WORD, Kraj)
(EOF, null)
```

U posljednjem prikazanom tokenu vrijednost je `null`-referenca.

Dopušta se uporaba mehanizma escapeanja: ako se u tekstu ispred znaka koji je znamenka nađe znak `\`, ta se znamenka tretira kao slovo. Posljedica je da tako escapeano slovo može biti dio riječi. Evo primjera i ispod njega očekivane tokenizacije. Znak `\` ispred samog sebe također predstavlja ispravnu escape sekvencu koja označava znak `\` tretiran kao slovo. Niti jedna escape sekvenca osim opisanih nije valjana i za njih lexer treba baciti iznimku.

```
\1\2 ab\\\2c\3\4d
```

```
(WORD, 12)
(WORD, ab\2c34d)
(EOF, null)
```

Primjetite da bi, zbog pravila escapeanja string-konstanti u Javi, prethodni ulaz u izvornom kodu izgledao:

```
String ulaz = "\\1\\2 ab\\\\\\2c\\3\\4d";
```

Da biste riješili zadatak, napravite sljedeće.

1. U Eclipse-u, ako već niste, napravite projekt za ovu domaću zadaću.
2. Napravite zadani paket.
3. Napišite enumeraciju `TokenType`.
4. Napišite razred `Token`.
5. Napišite kostur razreda `Lexer`. Neka metode `nextToken` i `getToken` vraćaju `null`.
6. Desni klik na projekt, “Build Path” → Add Libraries → JUnit →JUnit4.
7. Desni klik na projekt, “New” → Source Folder → “`tests/prob1`”.
8. Skinite na Ferku iz repozitorija datoteku `prob1tests.zip`. Sadržaj te datoteke raspakirajte u direktoriju projekta zadaće u napravljenom poddirektoriju `tests/prob1`. Potom u Eclipse-u napravite desni klik na projekt i “Refresh”. Eclipse bi morao prikazati u poddirektoriju `tests/prob1` nove izvorne kodove.

Otvorite u Eclipseu razred `Prob1Test` koji se pojavio pod `tests/prob1` (u paketu `hr.fer.zemris.java.tecaj.hw3.prob1`). Pripremio sam niz JUnit testova koje Eclipse zna pokretati. Svaka metoda koja je u tom razredu označena anotacijom `@Test` predstavlja jedan test. Inicijalno, uz sve sam metode napisao i anotaciju `@Ignore` kojom sustav pri izvođenju testova te testove preskače.

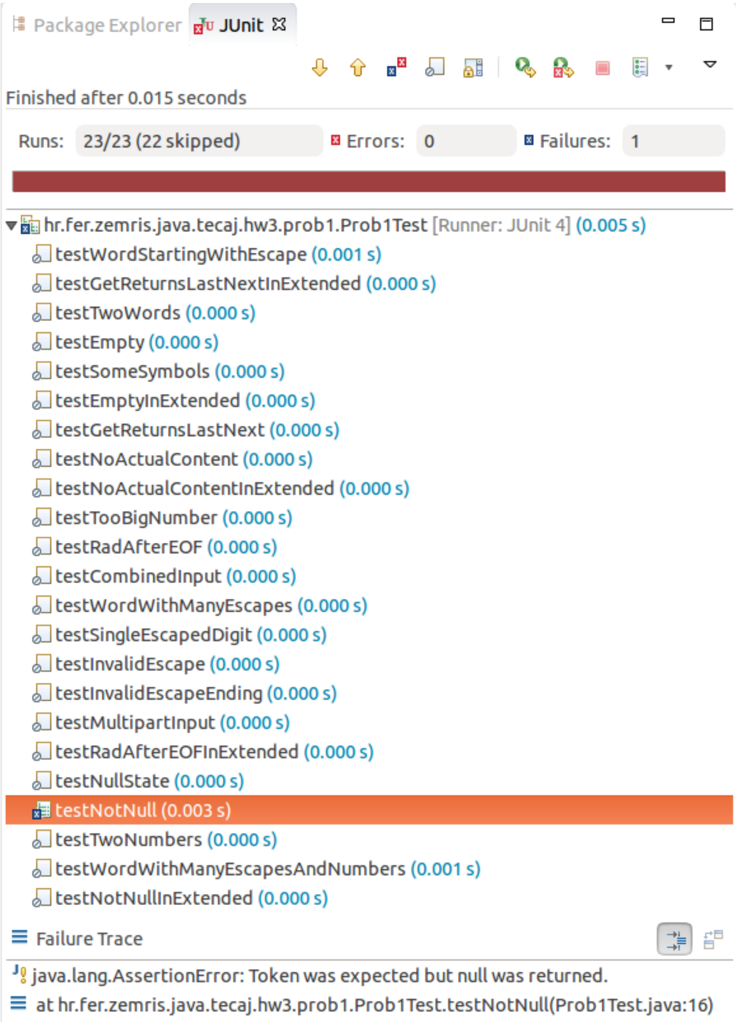
Svaki od testova predstavlja jedan jednostavan primjer uporabe razreda `Lexer` i njegovog očekivanog ponašanja. Testove sam pisao od jednostavnijih prema složenijima. Sama datoteka je podijeljena u dva dijela gdje je čitav drugi dio zakomentiran.

Uz datoteku s testovima bez ikakvih izmjena, pokrenite sve testove (desni klik u Package Exploreru na razred `Prob1Test` pa “Run As” → “JUnit Test”. Na dijelu gdje je bio Package Explorer otvorit će se nova kartica naziva “JUnit” s rezultatima testiranja. Svi testovi bit će označeni kao preskočeni (ali neće biti nikakvih pogrešaka, sve se može prevesti i pokrenuti).

Sada krenite redom: obrišite anotaciju `@Ignore` uz prvi test, snimite datoteku pa pokrenite sve testove.

U prikazanom izvještaju (vidi sliku u nastavku) imat ćete taj test označen kao test koji nije prošao: test stvara `Lexer` s praznim nizom i očekuje da će prvi poziv metode `nextToken` vratiti token; međutim, metoda vraća `null` i test pada. Krenite polako s izradom metode `nextToken` i riješite uočeni problem. Nastavite dalje – napišite tu metodu kako mislite da je dobro i malo po malo omogućavajte daljnje testove i pokrećite ih.

Tek kada riješite sve što je u datoteci s testovima napisano (a da nije zakomentirano – vidjet ćete taj dio, posebno je označen), nastavite dalje s ovim dokumentom.



Ako ste riješili sve testove koji nisu bili zakomentirani (prvi dio datoteke s testovima), sada ste spremni za dalje. Malo ćemo promijeniti pravila igre za lexer.

Ulazna datoteka može se sastojati od različitih dijelova teksta koji se obrađuju u tokene po različitim pravilima. Da ne kompliciramo, radit ćemo s primjerom gdje postoje dvije vrste pravila.

- Tekst se sve do pojave simbola `'#'` obrađuje kako je prethodno pojašnjeno.
- Pojavom simbola `'#'` prelazi se u režim rada u kojem lexer sve uzastopne nizove bilo slova bilo znakova bilo simbola tretira kao jednu riječ; također, ne postoji escapanje odnosno pojava znaka `\` ne predstavlja ništa drugačije u odnosu na pojavu bilo kojeg drugog znaka. U tom dijelu riječi su međusobno razdijeljene prazninama. U ovom režimu lexer nikada ne generira token tipa `NUMBER`. Ovo se područje proteže sve do pojave sljedećeg znaka `'#'` (koje generira token tipa simbol). Izvan tog područja ponovno sve ide po starom – do pojave novog ovakvog područja.

Da bismo omogućili pozivatelju za kontrolira u kojem je stanju lexer odnosno po kojim pravilima radi, definirajte novu enumeraciju `LexerState` koja ima konstante `BASIC` (predstavlja osnovni način obrade) te `EXTENDED` (predstavlja prošireni način obrade – naše drugo područje).

Potom proširite razred `Lexer` tako da mu dodate metodu:

```
public void setState(LexerState state) {…}
```

kojom pozivatelj izvana može postaviti željeni način grupiranja (te ako još što trebate zbog toga – učinite to). Inicijalno, lexer se mora konstruirati u stanju `BASIC`.

Kako sada vanjski klijent koristi Lexer? Ideja je jednostavna: sve dok lexer ne vrati token tipa simbol sadržaja '#', pozivatelj konzumira tokene u skladu s njihovom semantikom. Kad dobije token tipa simbol sadržaja '#', pozivatelj lexer prebaci u drugo stanje pozivom upravo dodane metode `setState`. Nastavlja konzumirati tokene koje proizvodi lexer ali oni se sada stvaraju po drugim pravilima. Kad ponovno dobije token tipa simbol sadržaja '#', pozivatelj lexer vrati u prvo stanje pozivom metode `setState` i nastavi dalje konzumirati tokene. Ovaj mehanizam trebat ćete i u sljedećem zadatku u kojem ćete u različitim područjima potencijalno generirati i različite skupove tokena te raditi escapeanje po različitim pravilima.

Kad ste to napravili, sada odkomentirajte drugi dio testova, omogućavajte ih jednog po jednog i prepravite implementaciju tako da sve proradi odnosno da svi testovi prođu.

Problem 2.

Now you are ready for something more useful which you will actually use in one of the following homeworks in second part of semester.

We will write two hierarchies of classes: *nodes* and *elements*. Place the classes into packages `hr.fer.zemris.java.custom.scripting.elems` and `hr.fer.zemris.java.custom.scripting.nodes` respectively. *Nodes* will be used for representation of structured documents. *Elements* will be used to for the representation of expressions.

`Element` hierarchy

`Element` – base class having only a single public function: `String asText();` which for this class returns an empty String.

`ElementVariable` – inherits `Element`, and has a single read-only[1] `String` property: `name`. Override `asText()` to return the value of `name` property.

`ElementConstantInteger` – inherits `Element` and has single read-only `int` property: `value`. Override `asText()` to return string representation of `value` property.

`ElementConstantDouble` – inherits `Element` and has single read-only `double` property: `value`. Override `asText()` to return string representation of `value` property.

`ElementString` – inherits `Element` and has single read-only `String` property: `value`. Override `asText()` to return `value` property.

`ElementFunction` – inherits `Element` and has single read-only `String` property: `name`. Override `asText()` to return `name` property.

`ElementOperator` – inherits `Element` and has single read-only `String` property: `symbol`. Override `asText()` to return `symbol` property.

`Node` hierarchy

`Node` – base class for all graph nodes.

`TextNode` – a node representing a piece of textual data. It inherits from `Node` class.

`DocumentNode` – a node representing an entire document. It inherits from `Node` class.

`ForLoopNode` – a node representing a single for-loop construct. It inherits from `Node` class.

`EchoNode` – a node representing a command which generates some textual output dynamically. It inherits from `Node` class.

Lets assume that we work with following text document:

---

1 If class has property Prop, this means that it has private instance variable of the same name and the public getter method (getProp()) and the public setter method (setProp(value)). If property is read-only, no setter is provided. If property is write-only, no getter is provided. For read-only properties, use constructor to initialize it.

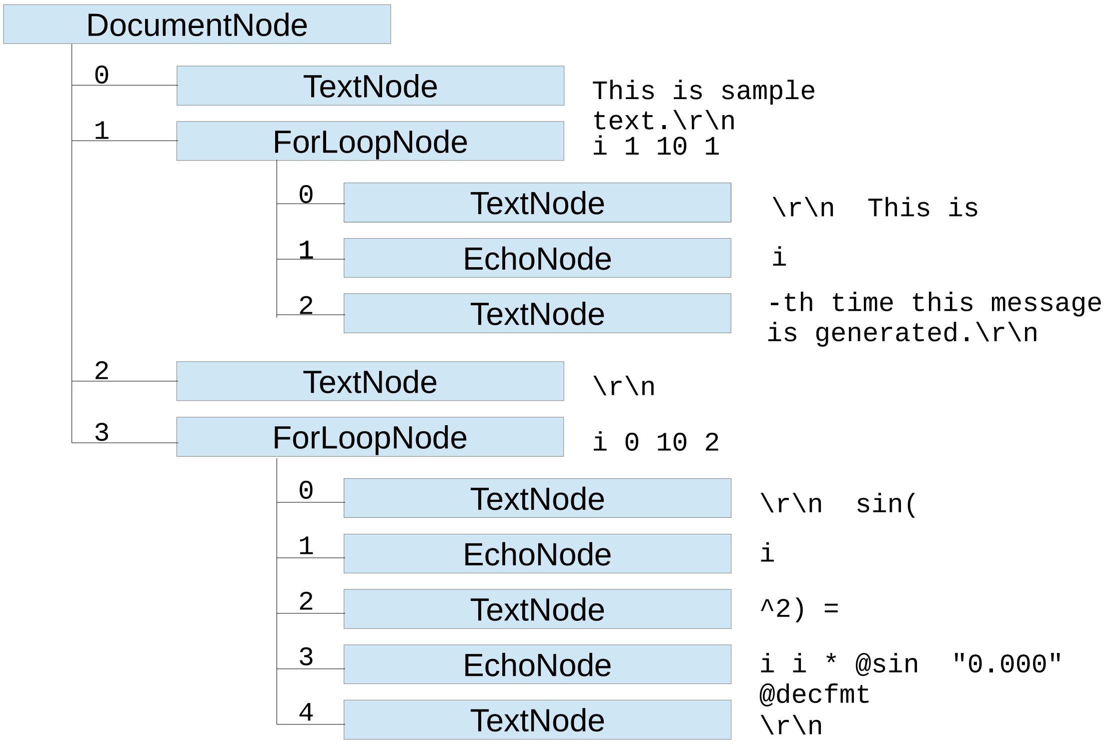
```
This is sample text.
{$ FOR i 1 10 1 $}
  This is {$= i $}-th time this message is generated.
{$END$}
{$FOR i 0 10 2 $}
  sin({$=i$}^2) = {$= i i * @sin  "0.000" @decfmt $}
{$END$}
```

This document consists of tags (bounded by `{$` and `$}`) and rest of the text. Reading from top to bottom we have:

text	`This is sample text.\r\n`	1
tag	`{$ FOR i 1 10 1 $}`	2
text	`\r\n  This is`	3
tag	`{$= i $}`	4
text	`-th time this message is generated.\r\n`	5
tag	`{$END$}`	6
text	`\r\n`	7
tag	`{$FOR i 0 10 2 $}`	8
text	`\r\n  sin(`	9
tag	`{$=i$}`	10
text	`^2) =`	11
tag	`{$= i i * @sin  "0.000" @decfmt $}`	12
text	`\r\n`	13
tag	`{$END$}`	14

Observe that spaces in tags are ignorable; `{$END$}` means the same as `{$ END     $}`. Each tag has its name. The name of `{$ FOR … $}` tag is `FOR`, and the name of `{$= … $}` tag is `=`. Tag names are case-insensitive. This means that you can write `{$ FOR … $}` or `{$ For … $}` or `{$ foR … $}` or similar. A one or more spaces (tabs, enters or spaces – we will treat them equally) can be included before tag name, so all of the following is also OK: `{$FOR … $}` or `{$ FOR … $}` or `{$       FOR … $}`. `=`-tag is an empty tag – it has no content so it does not need closing tag. `FOR`-tag, however, is not an empty tag. Its has content and an accompanying `END`-tag must be present to close it. For example, the content of the `FOR`-tag opened in the line 2 in above table comprises two texts and a tag given in lines 3, 4 and 5. Since `END`-tag is only here to help us close nonempty tags, it will not have its own representation.

The document model built from this document looks as follows.



Class `Node` defines methods:

`void addChildNode(Node child);` – adds given `child` to an internally managed collection of children; use an instance of `ArrayIndexedCollection` class for this. However, create this collection only when actually needed (i.e. create an instance of the collection on demand → on first call of `addChildNode`).

`int numberOfChildren();` – returns a number of (direct) children. For example, in above example, instance of `DocumentNode` would return 4.

`Node getChild(int index);` – returns selected child or throws an appropriate exception if the index is invalid.

All other node-classes inherit from `Node` class.
Class `TextNode` defines single additional read-only String property `text`.

Class `ForLoopNode` defines several additional read-only properties:

- property `variable` (of type `ElementVariable`)
- property `startExpression` (of type `Element`)
- property `endExpression` (of type `Element`)
- property `stepExpression` (of type `Element`, which can be `null`)

Class `EchoNode` defines a single additional read-only `Element[]` property `elements`.

As you can see, `ForLoopNode` and `EchoNode` work with instances of `Element` (sub)class. Lets take a look on =-tag from our example:

```
{$= i i * @sin  "0.000" @decfmt $}
```

Arguments (parameters) of this tag are:

- two times `ElementVariable` with `name="i"`
- once `ElementOperator` with `symbol="*"`
- once `ElementFunction` with `name="sin"`
- once `ElementString` with `value="0.000"`
- once `ElementFunction` with `name="decfmt"`

Implement a parser for described structured document format. Implement it as a class `SmartScriptParser` and put it in the package `hr.fer.zemris.java.custom.scripting.parser.` For this parser implement appropriate lexer and put it in the package `hr.fer.zemris.java.custom.scripting.lexer`.
The parser should have a single constructor which accepts a string that contains document body. In this constructor, parser should create an instance of lexer and initialize it with obtained text. The parser should use lexer for production of tokens. The constructor should delegate actual parsing to separate method (in the same class). This will allow us to later add different constructors that will retrieve documents by various means and delegate the parsing to the same method. Create a class `SmartScriptParserException` (derive it from `RuntimeException`) and place it in the same package as `SmartScriptParser`. If any exception occurs during parsing, parser should catch it and rethrow an instance of this exception.

<u>Important</u>
Problem 1 in this homework was an illustration of lexer creation. Here you are creating a separate lexer with different token types, different set of rules for character grouping (see below for some specification) etc. You are expected to place all relevant classes and enums in new package (as defined above). Your parser must use this lexer and not perform character grouping by itself. Take some time to think about:

- how many different token types we need here, in order to be able to create simple parser;
- how many states do we need in lexer?

Please observe that tag `ForLoopNode` can have three or four parameters (as specified by user): first it must have one `ElementVariable` and after that two or three `Elements` of type variable, number or string. If user specifies something which does not obeys this rule, throw an exception. Here are several good examples:

```
{$ FOR i -1 10 1 $}
{$ FOR sco_re "-1" 10 "1" $}
{$ FOR year 1 last_year $}
```

and here are several bad examples (for which an exception should be thrown):

```
{$ FOR 3 1 10 1 $}
{$ FOR * "1" -10 "1" $}
{$ FOR year @sin 10 $}
{$ FOR year 1 10 "1" "10" $}
{$ FOR year $}
{$ FOR year 1 10 1 3 $}
```

Valid variable name starts by letter and after follows zero or more letters, digits or underscores. If name is not valid, it is invalid. This variable names are valid: `A7_bb`, `counter`, `tmp_34`; these are not: `_a21`, `32`, `3s_ee` etc.

Valid function name starts with `@` after which follows a letter and after than can follow zero or more letters, digits or underscores. If function name is not valid, it is invalid.

Valid operators are + (plus), - (minus), * (multiplication), / (division), ^ (power).

Valid tag names are “=”, or variable name. So = is valid tag name (but not valid variable name).

In lexer, when deciding what to do with minus sign, treat it as a symbol if immediately after it there is no digit. Only when immediately after it (no spaces between) a digit follows (lexer can check this!), treat it as part of negative number.

In strings (*and only in strings*!) parser must accept following escaping:
`\\` sequence treat as a single string character `\`
`\"` treat as a single string character `"` (and not the end of the string)
`\n`, `\r` and `\t` have its usual meaning (ascii 10, 13 and 9).
Every other sequence which starts with `\` should be treated as invalid and throw an exception.
For example, `"Some \\ test X"` should be interpreted as string with value `Some \ test X`. Another example: `"Joe \"Long\" Smith"` represents a single string with value `Joe "Long" Smith`.

In document text (i.e. outside of tags) parser must accept only the following two escaping:
`\\` treat as `\`
`\{` treat as `{`
Every other sequence which starts with `\` should throw an exception.

For example, document whose content is following:

```
Example \{$=1$}. Now actually write one {$=1$}
```

should be parsed into only three nodes:

```
DocumentNode
  *
  *- TextNode with value Example {$=1$}. Now actually write one
  *- EchoNode with one element
```

Implementation hint. As help for tree construction use `ObjectStack` from your previous homework – copy in this homework all needed files (but nothing more) so that this code could compile on reviewers computers later. At the beginning, push `DocumentNode` to stack. Then, for each empty tag or text node create that tag/node and add it as a child of `Node` that was last pushed on the stack. If you encounter a non-empty tag (i.e. `FOR`-tag), create it, add it as a child of `Node` that was last pushed on the stack and than push this `FOR`-node to the stack. Now all nodes following will be added as children of this `FOR`-node; the exception is `{$END$}`; when you encounter it, simple pop one entry from the stack. If stack remains empty, there is error in document – it contains more `{$END$}`-s than opened non-empty tags, so throw an exception.

During the tag construction, you do not have to consider whether the provided tags are meaningful. For example, in tag:

```
{$= i i * @sin  "0.000" @decfmt $}
```

you do not have to think about is it OK that after two variables `i` comes the `*`-operator. You task for now is just to build the accurate document model which represents the document **as provided by the user**. At some later time we will consider whether that which user gave us is actually legal or not.

Developed parser should be used as illustrated by the following scriptlet:

```
String docBody = "....";
SmartScriptParser parser = null;
try {
  parser = new SmartScriptParser(docBody);
} catch(SmartScriptParserException e) {
  System.out.println("Unable to parse document!");
  System.exit(-1);
} catch(Exception e) {
  System.out.println("If this line ever executes, you have failed this class!");
  System.exit(-1);
}
DocumentNode document = parser.getDocumentNode();
String originalDocumentBody = createOriginalDocumentBody(document);
System.out.println(originalDocumentBody); // should write something like original
                                          // content of docBody
```

Create a main program named `SmartScriptTester` and place it in package `hr.fer.zemris.java.hw3`. In the `main` method put the above-shown scriptlet. Let this program accepts a single command-line argument: path to document. You can read the content of this file by following code:

```
import java.nio.file.Files;
import java.nio.charset.StandardCharsets;
import java.nio.file.Paths;
String docBody = new String(
                  Files.readAllBytes(Paths.get(filepath)),
                  StandardCharsets.UTF_8
);
```

In your project create directory examples and place inside at least `doc1.txt` which contains the example given in this document. You are free to add more examples.

Implement all needed methods in order to ensure that the program works.

The method `createOriginalDocumentBody` does not have to reproduce the exact original documents, since this is impossible: after the parsing is done you have lost the information how the elements were separated (by one or more spaces, tabs, etc. and similar). But it must reproduce something which will after parsing again result with the same document model! So this is the actual test:

```
String docBody = "....";
SmartScriptParser parser = new SmartScriptParser(docBody);
DocumentNode document = parser.getDocumentNode();
String originalDocumentBody = createOriginalDocumentBody(document);
SmartScriptParser parser2 = new SmartScriptParser(originalDocumentBody);
DocumentNode document2 = parser2.getDocumentNode();
// now document and document2 should be structurally identical trees
```

Very important: you *do not have to* develop an engine that will “execute” this document (iterate for-loop for specified number of iterations etc). All you have to do at this point is write a piece of code that will produce a document tree model.

Please note. You can consult with your peers and exchange ideas about this homework *before* you start actual coding. Once you open you IDE and start coding, consultations with others (except with me) will be regarded as cheating. You can not use any of preexisting code or libraries for this homework (whether it is yours old code or someones else). Additionally, for this homework you can not use any of Java Collection Framework classes or its derivatives. Document your code!

In order to solve this homework, create a blank Eclipse Java Project and write your code inside. You must name your project's main directory (which is usually also the project name) `HW03-`*yourJMBAG*; for example, if your JMBAG is 0012345678, the project name and the directory name must be `HW03-0012345678`. Once you are done, export the project as a ZIP archive and upload this archive to Ferko before the deadline. Do not forget to lock your upload or upload will not be accepted. Deadline is April 1st 2016. at 08:00 AM.