GALWAY-MAYO INSTITUTE OF TECHNOLOGY

Department of Computer Science & Applied Physics

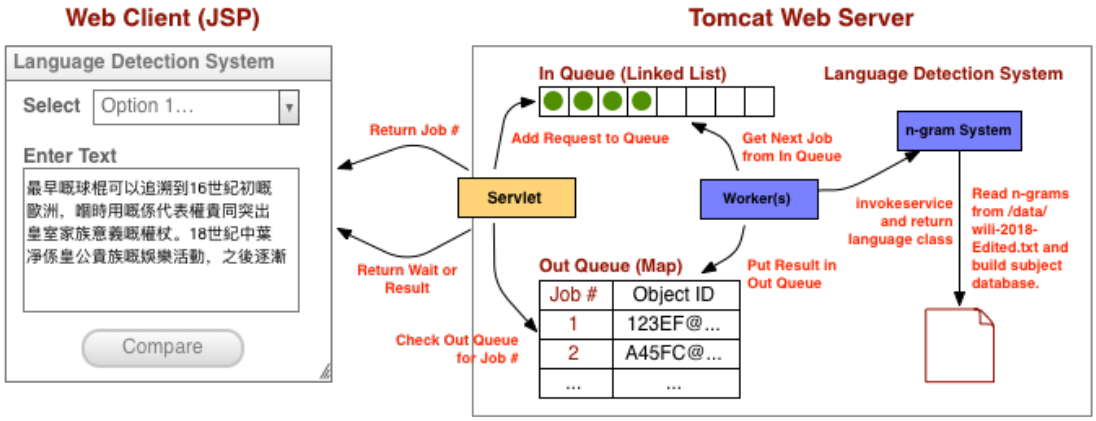
B.Sc. Software Development – Object-Oriented Design Principles & Patterns (2019)
ASSIGNMENT DESCRIPTION & SCHEDULE

An Asynchronous Language Detection System

This assignment constitutes 50% of the total marks for this module.

1. Overview

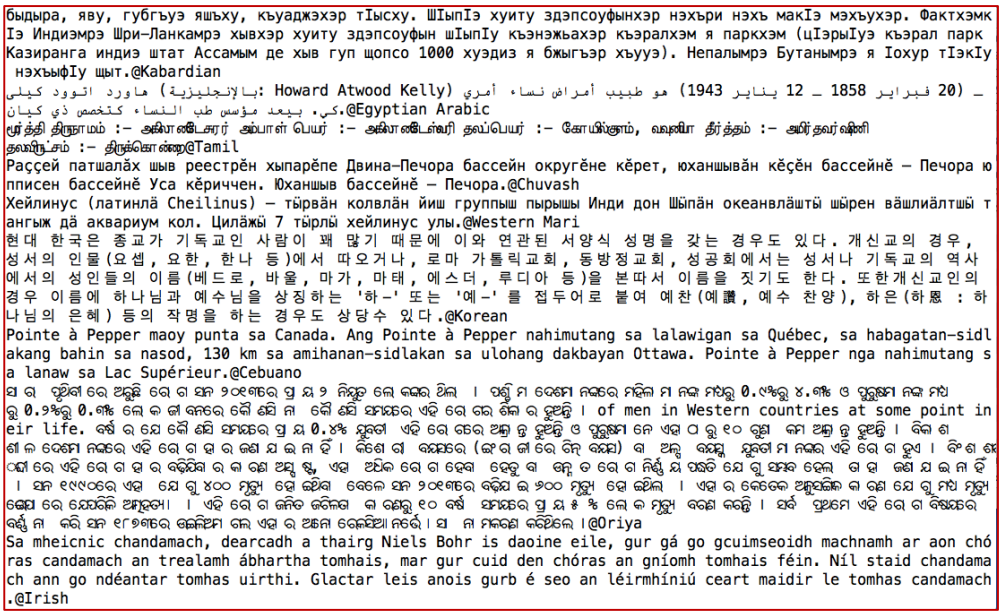
You are required to implement a web-based services capable of identifying the language classification of a submitted body of text. As illustrated below, the system is asynchronous, as the length of time required to dynamically determine a language may be prohibitively expensive for a synchronous mode of messaging. Users should be able to specify some text in a web form that, when submitted, is placed in a message queue. The web clients should periodically poll the web server with a Job# to ask if the language detection task has been completed. A worker process(es) should remove tasks from the queue and make a request on a language detection system that uses *n*-grams to identify a language type. Once completed, the task should be placed in an out-queue (a map) and returned to the client when they next poll the server.



A suite of resources for the project are available on Moodle, including a set of stubs for the Tomcat web application. These include the web form, a refresh script and a handler for the form data. The code is fully-commented and shows how to read environmental variables from the Tomcat *web.xml* deployment descriptor and wire together the different server-side components required for the project. The message queuing system can be implemented using a pair of maps from the *Java Collections Framework*. Do not use *RabbitMQ* or any other micro-services. You should treat the language detection system as a likely candidate for a messaging façade.

An edited version of the ***WiLI benchmark dataset*** is also provided, consisting of 117,500 lines of text in 235 languages, with the text and language name delimited by an '@' symbol. A smaller subset consisting of 11,750 lines of text is also available. As shown below, each

character of text can be represented by a Unicode UTF-16 number and by a **char** type in Java.



A technique for detecting the language of a text is described below under the section "***Using n-grams for Classifying Text***".

The stubs for the Tomcat application that have been provided on Moodle should be sufficient for all the client functionality. Please do not waste your time adding styling "bells and whistles" to the web client. Additional marks will only be given for programming extras. Your objective is to implement the required features and then extend, modify and refactor your code to create an elegant application design. You should aim to accomplish the following in your application:

- Group together cohesive elements into methods, types and packages.
- Loosely-couple together all programme elements to the maximum extent possible.
- Create a reusable set of abstractions that are defined by interfaces and base classes.
- Encapsulate at method, type, package and module level.
- Apply creational, structural and behavioural design patterns throughout the application where appropriate.

You are free to asset-strip any online resources for text, images and functionality provided that you modify any code used and cite the source both in the README and inline as a code comment above the relevant section of the programme. You are not free to re-use whole components and will only be given marks for work that you have undertaken yourself. Please pay particular attention to how your application must be packaged and submitted and the scoring rubric provided. Marks will only be awarded for features described in the scoring rubric.

2. Deployment and Delivery

- ***The project must be submitted by midnight on Sunday 6th January 2020***. Before submitting the assignment, you should review and test it from a command prompt on ***a different computer*** to the one that you used to program the assignment.
- The project must be submitted as a Zip archive ***(not a 7z, rar or WinRar file)*** using the Moodle upload utility. You can find the area to upload the project under the "*An Asynchronous Language Detection System (50%) Assignment Upload*" heading of Moodle. Only the contents of the submitted Zip will be considered. ***Do not add comments to the Moodle assignment upload form.***

- The name of the Zip archive should be <*id*>.zip where <*id*> is your GMIT student number.
- You must use the **package name ie.gmit.sw** for the assignment.
- The Zip archive should have the following structure (do NOT submit the assignment as an Eclipse project):

Marks	Category
ngrams.jar	A **Web Application Archive containing** the resources shown under Tomcat Web Application. All environmental variables should be declared in the file WEB-INF/web.xml. You can create the WAR file with the following command from inside the "ngrams" folder: jar –cf ngrams.war *
src	A directory that contains the packaged **source code** for your application.
README.txt	A text file detailing the main **features** of your application. Marks will only be given for features that are described in the README.
design.png	A UML **class diagram** of your API design. The UML diagram should only show the relationships between the key classes in your design. Do not show private methods or attributes in your class diagram. You can create high quality UML diagrams online at **www.draw.io**.
docs	A directory containing the **JavaDocs** for your application. You can generate JavaDocs using Ant or with the following command from inside the "src" folder of the Eclipse project: **javadoc -d [*path to javadoc destination directory*] ie.gmit.sw** Make sure that you read the JavaDoc tutorial provided on Moodle and comment your source code correctly using the JavaDoc standard.

3. Marking Scheme

Marks for the project will be applied using the following criteria:

Element	Marks	Description
Structure	12	*All-or-nothing.* The packaging and deployment are both correct. The WAR file deploys perfectly without any manual intervention and access the text resource at **/data/wili-2018-Edited.txt**.
README	8	All **features and their design rationale** are fully documented. The README should clearly document where and why any design patterns have been used.
UML	8	Class diagram correctly shows all the **important structures and relationships** between types.
JavaDocs	7	All classes are fully commented using the **JavaDoc** standard and generated docs are available in the *docs* directory.
Message Queue	10	In and out **queues** work correctly and allow status updates using pull notification.
Language Detection	30	The file at **/data/wili-2018-Edited.txt** is processed into *n*-grams and the ***Out-of-Place*** metric used to determine the language of a query text.
Cohesion	10	There is very high **cohesion** between packages, types and methods.
Coupling	10	The API design promotes **loose coupling** at every level.
Extras	5	Only **relevant extras** that have been fully documented in the README.

You should treat this assignment as a project specification. Any deviation from the requirements will result in some or all marks not being earned for a category. Each of the categories above will be scored using the following criteria:

Range	Expectation
0–39%	Not delivering on basic expectations. Programme does not meet the minimum requirements.
40-60%	Meets basic expectations.
61–70%	Tending to exceed expectations. Additional functionality added.
80-90%	Exceeding expectations. Any mark over 70% requires evidence of independent learning and cross-fertilization of ideas, i.e. your project must implement a set of features using advanced concepts not covered in depth during the module.
90-100%	Exemplary. Your assignment can be used as a teaching aid with little or no editing.

Using n-grams for Classifying Text

An *n*-gram, also called a shingle, *l*-mer or *k*-mer is a contiguous substring of text of size *n*. Their use is an example of a ***divide-and-conquer*** technique and *n*-grams have been applied to a wide variety of computing problems including text similarity measurement, text subject determination and language classification.

Consider the text "*object oriented programming is good fun for me*". This string can be decomposed into the following set of 5-grams: {"*objec*", "*t_ori*", "*ented*", "*_prog*", "*rammi*", "*ng_is*", "*_good*", "*_fun_*", "*for_m*", "*e____*"}. A set of *n*-grams can be formed from discrete "chunks" of non-overlapping characters or by tiling across a string using a fixed offset. For example, using an offset of 1, the following set of 5-grams will be formed: {"*objec*", "*bject*", "*ject_*", "*ect_o*" , "*ct_or*" , "*t_ori*"…}. Note that spaces are included in the *n*-gram set of a text and that the total number of possible *n*-grams in an *n*-spectrum is $\sum^n$, where $\sum$ is the number of symbols in the alphabet for the text, e.g. the full *n*-spectrum for 5-gram lower-case words in English has 26^5 = 11,881,376 elements. In practical terms, an *n*-spectrum will not be fully realized, as the vast majority of *n*-gram combinations will not be present in text. It should also be clear that the frequency of a 2-gram appearing in a text will be much greater than that of a 5-gram. For example, if we only include lower-case characters in English, each character will appear with a probability of 1/26 = 0.038. A 2-gram will therefore occur with a probability of 0.038 * 0.038 = 0.001444 and a 5-gram with a probability of 0.038 * 0.038 * 0.038 * 0.038 * 0.038 = $0.038^5 = 7.92\text{x}10^{-8}$.

Empirical evidence shows that the most frequently occurring ~300 *n*-grams are highly correlated to a language, with the next 300-400 *n*-grams more correlated to the subject that a text relates to. Moreover, only ~400 characters of text are required to generated a sufficient set of *n*-grams to allow a language to be identified correctly. Naturally, these observations will vary somewhat from language to language, but they do provide an effective heuristic for language detection.

The following set of steps can be used to build a ***subject database*** to determine the language classification of a text. Although there are 235 languages in the WiLI benchmark dataset, it is probably worth while creating a *Language* enum for this purpose.

- Generate 235 maps capable of relating an *n*-gram to its frequency of occurrence in a specific language.
- For each line of text in the *WiLI benchmark dataset*.
    - Split the line into its text and language tokens using the '@' symbol.
    - Set the current map to point to that denoted by the language token.
    - For each 1-gram, 2-gram, 3-gram and 4-gram in the text.
        - Insert the *n*-gram into the map with a frequency of 1 or increment the frequency if the *n*-gram already exists in the map.

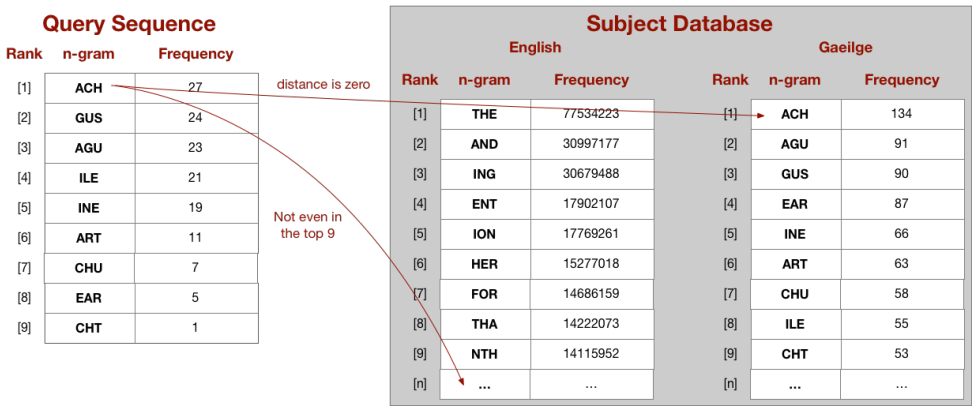
- Sort each of the maps in descending order of occurrence frequency. Only the top ~300 *n*-grams need to be retained.

The language of the ***query text*** can be determined using the following steps:

- Generate a single map that relates an *n*-gram to its frequency of occurrence.
- Parse the first ~400 characters from the text into a query sequence.
- For each 1-gram, 2-gram, 3-gram and 4-gram in the text.
    - Insert the *n*-gram into the map with a frequency of 1 or increment the frequency if the *n*-gram already exists in the map.
- Sort the map in descending order of occurrence frequency.
- Compute a **distance measure** for the map compared to all 235 maps in the subject database and output the score for each map.
- Output the language of the map with the highest score as the language classification.

Computing a Distance Metric

The ***distance measure*** can be computed using a wide variety of different approaches. In this assignment, we will use the ***Out-of-Place Measure*** as a distance metric. For each *n*-gram, the ***Out-of-Place*** distance measure if computed as $d(n\text{-gram}) = R_s(n\text{-gram}) - R_q(n\text{-gram})$, *where* $R_s(n\text{-gram})$ *is the rank of an n-gram in a subject database and* $R_q(n\text{-gram})$ *is the rank of the same n-gram in the query database*. The sum of all the ***Out-of-Place*** values for all *n*-grams is the distance measure of the document for that language. Consider the following example:



The ***Out-of-Place*** distance between just the first 9 elements in the query map and each of the subject maps is **d**("ACH") + **d**("GUS") + **d**("AGU") + **d**("ILE") + **d**("INE") + **d**("ART") + **d**("CHU") + **d**("EAR") + **d**("CHT"). As none of the first 9 query elements match any of the first 9 English *n*-grams, the distance value will be relatively large. However, for Gaeilge, the distance is (1 - 1) + (3 - 2) + (2 - 3) + (8 - 4) + (5 - 5) + (6 - 6) + (7 - 7) + (4 - 8) + (9 - 9) = 0, indicating that the query text is written in the Irish language.

Computational Overhead of n-gram Mapping

We can compute the set of *n*-grams and their frequency in a text by relating each *n*-gram to an integer value in a map. A naïve implementation of this will declare the map as *Map<String, Integer>*. The problem with this approach is that each String key in the map has a minimum memory usage (Java 7) of 8 * (((***length*** * 2) + 45) / 8). The String "JOHN" will therefore consume 53 bytes of memory! A better approach is to declare the map as *Map<Integer, Integer>*, using the *hashCode()* method of each *n*-gram String as a key, allowing the key to be represented more efficiently as a fixed-length 32-bit integer that can be manipulated in a number of different ways. This approach does have the disadvantage of permitting two different strings to have the same hash code and, although hash-collisions will be rare, they will undoubtedly occur when using large data sets.

If we limit the maximum length of an *n*-gram to 4, we can compress a String into a 64-bit long and declare the map as *Map<Long, Integer>*. This is shown below where each 16-bit Unicode value can be "packed" into a bit vector for a 64-bit long.

char[]	'J'	'O'	'H'	'N'
Decimal	74	79	72	78
Binary	0000000001001010	0000000001001111	0000000001001000	0000000001001110
	16 bits	16 bits	16 bits	16 bits

= 20829487583723598L = 64 bit long

The following method illustrates how the process is implemented in Java. The << operator shifts the bits in the long 16 places to the left to accommodate a UTF-16 Unicode character. The pipe, "|", symbol is bitwise OR. You should alter the *if* statement to allow a 1-gram to be used.

```
public long encode(String s) throws Exception{ //
     if (s.length() < 2 || s.length() > 4) throw new Exception("Can only encode n-grams with 2, 3, or 4 characters");

     long sequence = 0x0000000000000000L; //Set all 64 bits to zero
     for (int i = 0; i < s.length(); i++){ //Loop over the String
          sequence <<= 16; //Shift bits left by 16 bits
          sequence |= s.charAt(i); //Bitwise OR. Sets the first (right-most) bits to the Unicode binary value

     }
     return sequence; //return the chars encoded as a long!
}
```