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corso B

## Word Quizzle

a project authored by

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### Abstract

This year networking course's final at Università di Pisa consisted of implementing a client-server application by the name of Word Quizzle. Word Quizzle is a competitive multiplayer game where the matches take place between two players whose objective is to correctly translate, from the Italian language to the English language, the highest number of words submitted by the server in the given time. In this report I will describe my proposed solution consisting of what I think is a scalable server architecture obtained by pairing an iterative task dispatching with a concurrent task execution. Firstly, I will describe the problem in a more detailed way, particularly focusing on the various complications that I encountered and the corresponding solutions that I came up with. I will then describe in detail my version of Word Quizzle, spanning from the data structures that I found appropriate to use in each class implementation to the inter class communication and, last but not least, how I took care of the thread concurrency. Finally, I will conclude this report by making a list of all the things I could have done better and all the aspects where I think there's room for improvement.

### Problem Definition

Word Quizzle can be seen as a miniature social network, a user can create his own account providing the nickname and the password, log in with the freshly created account, make some friends and challenge them to a fierce translation match. In order to achieve all of this many things need to be taken care of, the first of which is the **persistence** of the users' data. Who wants to play a game for hours just to see all of his progress vanish when the server restarts? No one perhaps. To address this issue and to ensure that, among all the other important things to preserve such as nicknames and passwords, the hard earned score of the

users remains unaltered between server's restarts I used the Google-backed library Gson. I made this choice after checking out many other Java JSON libraries such as JSON.Simple and Jackson, although not being the fastest of the three nor the best optimized I found Gson to be the easiest to use and above all it was the only one that allowed me to serialize and deserialize the ConcurrentHashMap that I use to store users' data with just one line of code. In this case I preferred simplicity over performance, nevertheless, I used an hashmap because of its high retrieval efficiency, to know more check the concurrency section.

After persistency, the next thing that I had to take care of was the overall **scalability** of the architecture. I wanted to provide a performance close to that of a multi threaded system but with a much more lower cost in terms of cpu power and still obtaining a better performance than a single threaded server using a Selector. What I came up with is an architecture that uses a Selector to perform **task dispatching**, i.e. accepting clients requests, and then feeds them to a ThreadPoolExecutor which then performs **task execution**, I provided the threadpool with a core pool of four threads, as the majority of the mid-end and low-end cpus have two cores with four threads, and an unbound LinkedBlockingQueue in order to ensure the acceptance of all submitted tasks. This approach allows the thread on which the server's main method runs to solely handle the parsing of the clients requests thus delegating the real execution of the tasks to the threadpool. For every client request the server's selector has to read from the client's socket the parameters of the request, it then has to create the appropriate task and finally it has to send the task to the threadpool, forgetting about it, the threadpool then takes care of executing it and also to communicate the result to the client. The main problem that rose was the following: the match task takes much more time to complete than the other tasks, this posed the risk of saturating the threadpool. I solved the problem by allowing the threadpool's maximumPoolSize to be parsed from command line, allowing the server owner to set it **on his needs**, and by coding a reasonable small keepAliveTime in order to ensure

the possibility for a thread to be recycled. Given the fact that, in the end, I adopted the selector-threadpool solution the next implementation's detail worth mentioning is how I handled the client-server communication. Due to the presence of the Selector I provided the server with **non blocking** sockets using Java NIO. Talking about the client though, I didn't see any particular reason at all to justify the use of non blocking sockets, on the contrary, it seemed to me a more correct client's behavior to block and wait for the server response so I provided the client with **blocking** sockets, I also liked more the idea of a *well behaved* client that waits for its current request to be executed before sending another one. Following the given requirements I ensured that most if not all of the client-server communication happens on the main TCP connection, which is the one associated with the socket that gets created upon accepting the incoming client's connection on the server's master socket, except for the client-server match communication, which instead takes place on two other TCP connections, set up by both clients with the server upon the acceptance of the match invitation by one of the two contestant clients. I would like to conclude this section by stating that I was initially not satisfied with the fact that my application was only able to function on the loop-back address so I came up with what I think is a pretty decent solution to make it work on the LAN of the host that runs the server program, in a way that allows the clients to dynamically discover the server's local IP address. To know more about the implementation check the client's description.

## Project Structure

While defining the structure of my project I tried to maintain a strict but cohesive modularity, isolating as much as possible each of the Word Quizzle application's features on which I then proceeded to shape the classes. I ended up shaping **fifteen classes** in total, the role of which will be carefully described in this section, however, for an even more detailed description of the classes logic it's highly suggested to check the **javadocs**.

### WQServer

It's the server's class, here are declared and instantiated the server's selector and, server's threadpool and all of the class variables such as the match duration and the number of words to submit to the players per match.

### WQClient

This class contains all of the client's logic: it handles the communication with the server and displays the command list on user's request. It also takes care of dynamically finding the WQServer's IP address by broadcasting probing UDP packets on port 9999. A running WQServer, if there's one on the LAN, will eventually respond with it's IP address and its port number. If the exploration takes too long the attempt is aborted.

### WQDatabase

This class provides all the method to manipulate the users' database and it also handles the serialization and the deserialization of it.

## WQUser

It's the class that I used to represent a Word Quizzle user, it's provided with all the necessary fields to model a generic user such as the nickname, the password, the friend list and the score plus all the getters and setters of the case.

## WQWords

This class' purpose is to randomly choose a list of  $n$  words from the italian dictionary text file, where  $n$  is the number of match words set upon the server creation. It also takes care of the translation process, sending GET requests to the mymemory API. If the previously mentioned translation service is not available it alerts the MatchTask class to return an error message to both players. WQWords it's only instantiated during matches.

## ItalianDictionary

Not a class, it's the text file where the WQWords class randomly picks the words.

## WQRegistrationRMI

It's the remote interface that provides the user's registration method. The actual method implementation is in the WQServer class.

## Tasks

The tasks are all runnable classes, they create an instance of a user-requested operation which is executed by the server's thread-pool. All of the tasks are constructed in the WQServer's main thread.

**TaskInterface:** interface all tasks implement, it extends runnable and provides utility methods.

**LoginTask:** is the login operation.

**LogoutTask:** is the logout operation.

**AddFriendTask:** is the add friend operation.

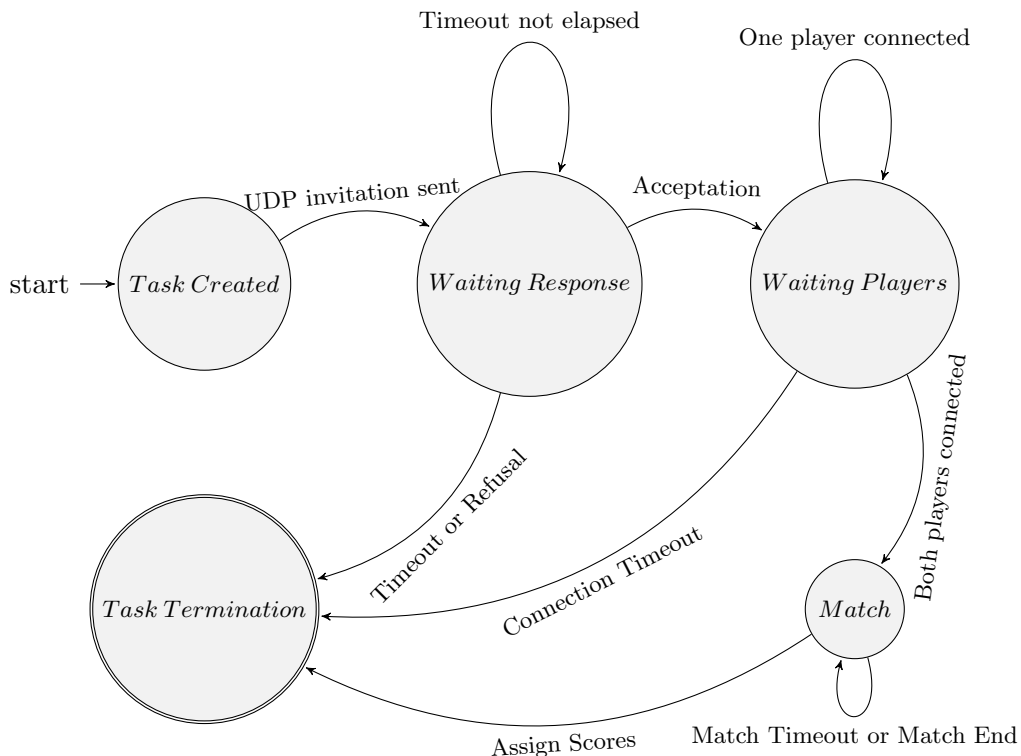
**GetFriendListTask:** prints the user's friend list.

**GetScoreTask:** prints the user's score.

**GetScoreBoardTask:** prints the user's scoreboard.

**MatchTask:** sets a translation match between two users. This is the most worthy task to pay attention to. I will explain its functioning with the help of a finite state machine. Also checking the **javadocs** is highly recommended.

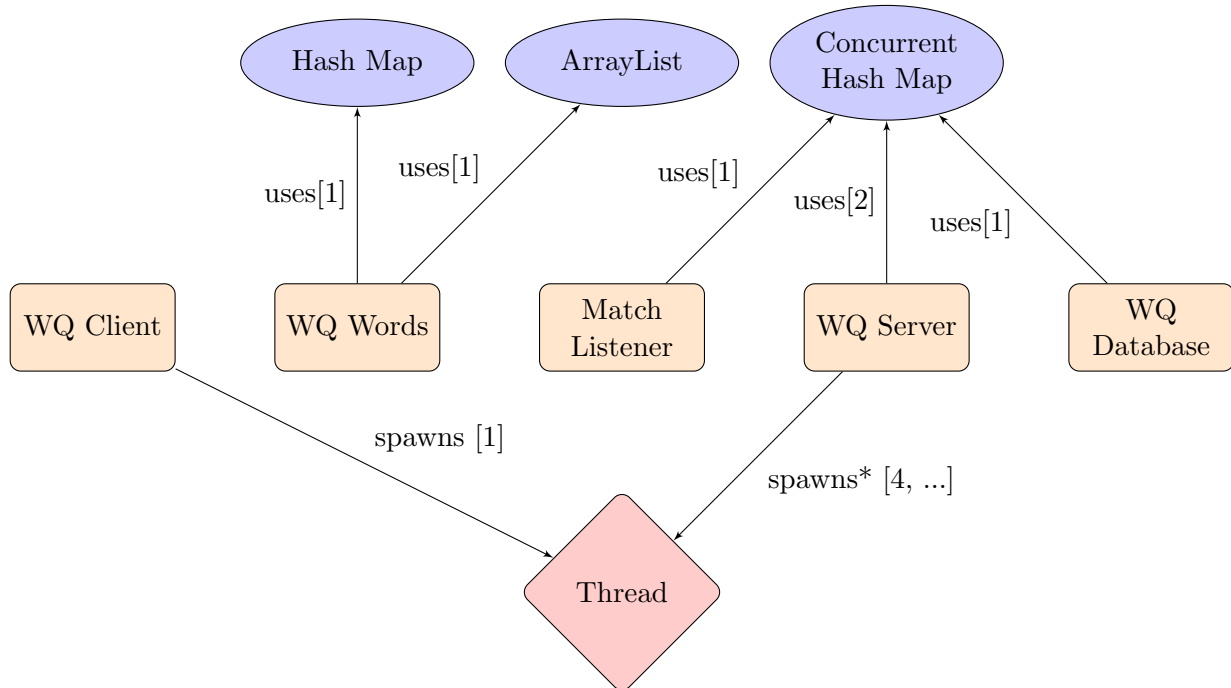
Match Task Finite State Machine



## Concurrency and Data Structures

I think it's a good idea to group the dissertations of both thread concurrency and data structures used because the two topics are strictly correlated. Firstly I will provide a brief explanation with some diagrams. The ellipses represent the

data structures, the rectangles with rounded corners represent the project's classes, and the diamond shape represent a thread instance. The labels on the relations edges indicate the arity of the relation.



As can be easily seen in the diagram above, the WQClient class spawns **two** threads: one is the thread on which the class main method runs and the other one executes the MatchListener class `run()` method, constantly listening for match invitations, which upon arrival are inserted in a ConcurrentHashMap, where the keys are the users' nicknames and the values are the UDP datagram invitations. WQServer also spawns some threads though indirectly, the number varies from **four** to the threadpool's `maxPoolSize`, which is parsed by command line. The class also uses two ConcurrentHashMap one for keeping trace of online users while the other is used as a book address to send match invitations. Another class that makes good use of the ConcurrentHashMap is WQDatabase, in fact, the database itself is nothing more than that. Finally let's talk about WQWords, i.e. the class that provides the words and their translations, it uses an HashMap whose keys are the words and whose values are an ArrayList con-

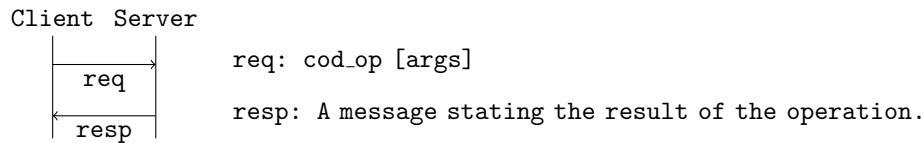
taining all of the translations. For a more detailed description it's highly suggested to check the **javadocs**. Let's dive now in the concurrency discussion, I would like to begin by making a list of all the possible race conditions that I spotted:

1. The insertion of a user in the database.
2. The adding of a friend by a user.
3. The serialization of the database.
4. The updating of a user's score.
5. The insertion of a user among the online users and his UDP match address in the book address upon the completion of the login operation.
6. The removal of a user from the online users and his UDP match address from the book address upon the completion of the logout operation.

All of the race conditions above have been taken care of by using a ConcurrentHashMap and by declaring the method that perform the serialization of the database as synchronized, as the database must be serialized upon each modification. I conducted extensive tests and never had a problem related to concurrency. To my knowledge there are not any unchecked race conditions.

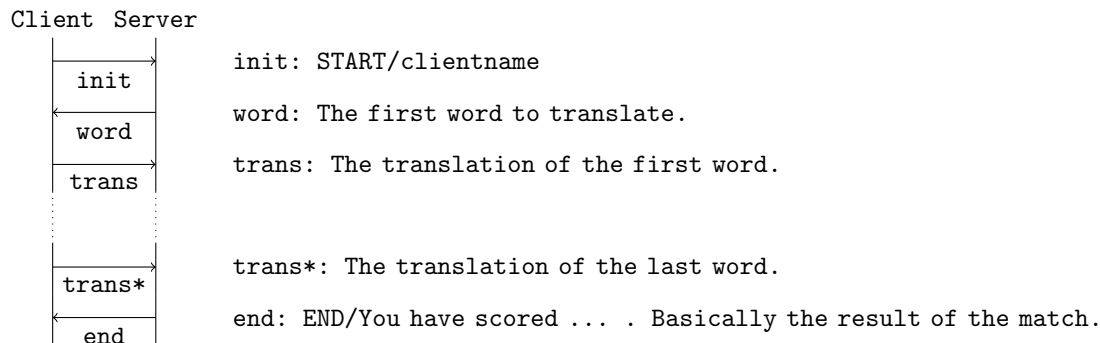
## Client-Server Communication Protocol

In this section I will briefly illustrate all of the possible client-server interactions with the aid of an interaction diagram to provide an overall description of the **communication protocol**'s functioning.



E.g. for the **login** operation the format of **req** would be: 0 username password UDP\_port\_number.

I'll provide a similar scheme to illustrate the protocol used for the client-server communication during **matches**.



## Compilation and Execution

To compile the project on **Linux distributions** simply run the following commands in the project folder:

```
javac -cp ./:lib/gson-2.8.6.jar WQClient.java
javac -cp ./:lib/gson-2.8.6.jar WQServer.java
```

To run the server on **Linux distributions** simply run the following command:

```
java -cp ./:lib/gson-2.8.6.jar WQServer.java <TCP_port> <UDP_port> <match_timer>
<invitation_timer> <num_words>
```

To run the client on **Linux distributions** simply run the following command:

```
java -cp ./:lib/gson-2.8.6.jar WQClient.java
```

Both **WQClient** and **WQServer** programs take **--help** as argument in order to provide the user with an useful command list.

To **stop** the client use the **quit** command and to stop the server feel free to use **ctrl + c**.

## Self-critique

I am overall very satisfied with what I achieved, nevertheless I do not fear to admit that there are certain things that I could have done better, among which:

- I could have made the threadpool fixed size, thus emphasizing the crux of my architecture, by keeping the status of the clients' requests in a data structure, such a `ConcurrentHashMap` where the keys are the nicknames and the values are the operations, and by implementing only three tasks: a read task, a write task, and a cleanup tasks, for the tasks that need a timeout. Although it sounds very exciting it's also very mind bending.
- A thing I'm not satisfied at all with is the server termination. There is plentiful of fancier ways to stop a while cycle than **ctrl + c**. Still this is a very minor rant.
- I could have used a factory class to create the tasks, although it would have been only a style exercise, in the end, I would have liked more my work.