

**Department of Computer Science**

**Department of Multimedia**

Multimedia - Game Programming

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S19340

**Turn-based multiplayer strategy game**

Engineering thesis

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Table of Contents

[1. Introduction 3](#_Toc75360009)

[2. Project description 4](#_Toc75360010)

[2.1. Definitions 4](#_Toc75360011)

[2.2. Game description 4](#_Toc75360012)

[2.3. Multiplayer aspects 5](#_Toc75360013)

[2.4. Game visuals 5](#_Toc75360014)

[3. Project architecture 6](#_Toc75360015)

[3.1. Overview 6](#_Toc75360016)

[3.2. C# build pipeline 6](#_Toc75360017)

[3.3. Unit testing 8](#_Toc75360018)

[3.4. Database schema 8](#_Toc75360019)

[3.5. Class diagram 8](#_Toc75360020)

[3.6. Deployment 8](#_Toc75360021)

[4. Game state 9](#_Toc75360022)

[4.1. Game state data structure 9](#_Toc75360023)

[4.2. Updating the game state with new move 9](#_Toc75360024)

[4.3. Cycle search algorithm 9](#_Toc75360025)

[4.4. Encircled unit search algorithm 9](#_Toc75360026)

[5. Game rendering 10](#_Toc75360027)

[5.1. Board rendering 10](#_Toc75360028)

[5.2. Captured area rendering 10](#_Toc75360029)

[6. Client-server interaction 11](#_Toc75360030)

[6.1. WebSockets API 11](#_Toc75360031)

[6.2. Making a move 11](#_Toc75360032)

[6.3. Backend server 11](#_Toc75360033)

[6.4. Database 11](#_Toc75360034)

[6.5. WebSockets API 11](#_Toc75360035)

[6.6. Authentication? 11](#_Toc75360036)

[6.7. ELO ranking 11](#_Toc75360037)

[6.8. Matchmaking 11](#_Toc75360038)

[7. Conclusion 12](#_Toc75360039)

[8. Bibliography 12](#_Toc75360040)

## Introduction

Inform about topic -> What is this thesis/diploma about ...

(Don't write it at the beginning (final version)

Explain …

List of goals:

(THIS part is written BEFORE You will start...) -> It defines how You wish to proceed...

(Do not give any answers to your problems)....

#KEYWORDS!!!!

List of technologies

## Project description

### Definitions

Game - …

Turn based game - …

Strategy game - ..

Multiplayer - …

Matchmaking - …

Player ranking - ...

### Game description

Chart, scatter chart

Description automatically generatedThe game is played between 2 players on a rectangular grid, usually 25 by 25 cells, but other sizes are also supported. Each turn a player places his unit (also called “dot”) on a vacant grid cell. All units are the identical and only differentiated by the color, signifying to which player they belong. If, after placement, by connecting player’s adjacent dots (either orthogonally or diagonally) a cycle can be formed that also surrounds one or more opponent’s dots, the player captures the opponent’s units.

Figure 1. Red units captured a blue unit.

Each captured dot grants the player 1 point, as well as effectively “disables” the enemy uint - it can no longer participate in forming cycles needed for capture. The goal of the game is to get more points then your opponent. The game is played until either one of the players resigns or there are no legal moves left.

### Multiplayer aspects

The game should also provide rich multiplayer aspects by having an automatic matchmaking system, where you can queue up to have a game with the next available player.

There also will be a ranking system to give each player a score that would describe their skill level. Ranking would be calculated based on the results of game’s played and updated according to the ELO system[1], similar to the ones used in online chess games. The rankings would also be used to match opponents with the closest skill levels during matchmaking.

### Game visuals

The two players are identified by their color: player 1 - red, player 2 - blue. The dots are rendered on cell grid intersections and match the color of the player who placed them.

Captured areas are denoted by connecting the dots that participated in the enclosure with a line and adding a semi-transparent fill over the enclosed area with a matching color.

Q: Should I include the game screenshots here?

## Project architecture

### Overview

The project can be split among two parts: the game client that uses Unity and is written in C#, and a backend server that maintains the game state. Between them there are several shared classes such as data models describing the game state and the moves made by players. The high level overview of the project structure is presented on Figure 2.

The backend server hosts a WebSocket API that game clients connect to. Choosing WebSockets as a transport layer provides us with an ability for two-way communication: game server can push updates to the clients and clients can send moves made by players. Also this increases the flexibility for the backend deployment as almost all hosting providers support WebSockets.

The backend server has a PostgreSQL database associated with it. It was chosen because relational databases are well supported by mainstream C# data-persistence frameworks, such as Entity Framework.

There’s also an additional test module hosting automated unit-tests for the core data models and algorithms.

Diagram

Description automatically generated

Figure 2. Project overview. TODO: Add the test module.

### C# build pipeline

One of the difficulties when sharing code with a Unity project is that Unity does not support multi-assembly builds. Meaning that all C# sources must be a part of a single C# project when compiling the game client. Also, C# project and solution files are auto generated, which means making any manual changes are unfeasible, as they would be lost next time Unity Editor is refreshed.

This poses a challenge, because a usual way to share code between the backend server and a client would be to introduce a third class-library project with shared classes, that two other projects depend upon. Since that’s not possible the only solution is two have two parallel project structures: one for the backend and the second one for the Unity build. The shared sources would be included in both structures and compiled separately.

Unity requires all C# sources to be placed inside “Assets” directory. This also includes the shared classes. This would force us to move away from then canonical project structure where each module resides in a separate directory on the top level. There were numerous attempts to go back to the flat structure utilizing filesystem symlinks. Unfortunately, Unity as well as C# build tools do not have good enough support for them, and often they were not recognized as a link to another directory.

Ultimately the following project structure was settled on:

* Backend project directory.
  + Backend “csproj” file.
  + Backend sources.
* Test project directory.
  + Test “csproj” file.
  + Test sources.
* Unity project directory.
  + Assets directory.
    - Unity assests.
    - Core project directory (shared sources).
      * Core “csproj” file.
  + Unity autogenerated “csproj” file.
  + Unity autogenerated solution file.
* Solution file for the backend and core projects.

### Unit testing

### Diagram Description automatically generatedDatabase schema

Figure 3. Database schema.

### Class diagram

### Deployment

TODO: digital ocean or heroku

## Game state

### Game state data structure

The game state consists of a 2-dimensional array describing each grid cell position as well as a list of captures that were performed during the game.

Each cell state consists of:

* Vacancy flag - whether this cell was claimed by the player.
* Their player that claimed this cell - only in case this cell is claimed.
* Captured flag - whether the dot placed in this cell is captured by the opponent.

Each capture entry in the list includes a player that made the capture as well as the list of grid coordinates of dots that participated in the enclosure of enemy units.

TODO: C# code sninppets.

### Updating the game state with new move

With every move we perform a cycle search to find new enclosed areas. Dots placed on the square grid form an effective graph with their neighbors. A depth-first search algorithm is used to find cycles in this graph. Cycles are also validated to not be composed from multiple larger cycles.

After the cycle is found a variant of flood-fill algorithm is used to select all grid coordinates that are enclosed by this cycle. Then, if any of those contain enemy units, those units are marked captured, and the cycle is added to “captures” list.

### Cycle search algorithm

Depth first search is used to find cycles in the graph. Search is always started from the dot placed on the current move. This optimization can be made because all cycles that were formed without the dot placed on the current move were already discovered when running the algorithm on previous moves.

To implement the algorithm a recursive approach is used with a stack to store a sequence of coordinates being currently processed. First a recursive function is executed on the starting point - the dot placed on the current move. It pushes the coordinates to the stack and then executes itself on all neighbors that can participate in capture. If a valid cycle is found, i.e. we reached the starting point, the sequence of points is stored as one of the cycle candidates. After all of the neighbors have been processed the current position is popped from the stack, and the execution flow is returned to the caller.

If during the execution we reach a neighbor of any point that already in the stack, but not the initial one, we terminate early, because that cycle could have been formed without the initial dot. And hence, was already processed on previous moves.

TODO: Union find algorithm: <https://www.cs.princeton.edu/~rs/AlgsDS07/01UnionFind.pdf>

### Encircled unit search algorithm

A modified version of flood-fill algorithm

## Game rendering

### Board rendering

### Captured area rendering

With sprite-shape controller

## Client-server interaction

### WebSockets API

Rationale for using web sockets.

API reference: JSON RPC

### Making a move

Describe what path a move makes, from being created on the client, registered on the backend and then game state synchronized to the client.

### Backend server

### Database

### WebSockets API

### Authentication?

### ELO ranking

### Matchmaking

Show Your Struggle... and knowledge You had to get...

Theory - There is a knowledge You will have to accumulate... Explain it on Your OWN... (give good statement from where You got this knowledge... footnote.. ...page 47-85)

(You got all the pieces together here)...

Practice

You invoke knowledge form thery presenting Your SOLUTION...

(Always ask 2 questions... Why... and ... where.....)....

You do think about something.... Is it important for my work... for it's explanation...

Choose something for structure... Start general... then go to details/ or do opposite...

------------------------------------------------------------------------------------

## Conclusion

Answer Introduction...

- You where defining problem.. You where defining possible approaches You wish to follow...

Look at ALL YOUR SOLUTION (Main body)... tell what is the result... Summarize effects...

What Do You think about it....

Future improvements

------------------------------------------------------------------------------------

## Bibliography

1. [*"About the USCF"*](http://www.uschess.org/about/about.php). United States Chess Federation http://www.uschess.org/index.php/About-USCF/*. Retrieved 2008-11-10*.