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**COMP4910 Senior Design Project 1, Fall 2019**

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**POF: Performance Optimized Fluids**

**High Level Design**

**Design Specifications Document**

**Revision 2.0**

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# Revision History

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| --- | --- | --- |
| **Revision** | **Date** | **Explanation** |
| 1.0 | 12.12.2019 | Initial high-level design. |
| 1.1 | 2.2.2020 | - Introduction part has been revised.  - POF system architecture part has been revised and sentences were made more descriptive. |
| 1.2 | 9.2.2020 | - Sequence, use case, package diagrams have been updated. |
| 1.3 | 15.2.2020 | - Activity diagrams have been updated. |
| 1.4 | 21.2.2020 | - High-level design section elaborated. |
| 1.5 | 26.2.2020 | - Descriptions have updated for the new diagrams. |
| 2.0 | 4.3.2020 | - Testing Design section elaborated. |

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# 1. Introduction

The purpose of the Performance Optimized Fluid (POF) system is to research and apply existed methods to simulate fluids and looking for a better way to represent it. Numerous algorithms will be implemented and tested during the research and development of this project. The main goal is to research and discuss the advantages and disadvantages of methods. One of the project objectives is to reach a more efficient and better performance fluid simulation system. However, indicated features are not guaranteed to improve performance. The project goal is visualizing the particle-based fluid system differently by benefiting from specific algorithms. The system expected to work more efficiently as a result of the implementation of the algorithms in the research papers. The project is exceedingly research and development based.

The design is based on The POF system Requirements Specification Document, Revision 2.0 [1]

This design process conforms to the Requirements Specification Document and its diagrams. Diagrams are describing the project to understand mainly operations of the POF system. Imperceptible parts of the POF system can be changed. However, the general operands of the POF system will remain the same as before. If any change occurs during the development of the POF system, this document and diagrams will be changed.

The system architecture and overall high-level structure of the POF system have given in the second section. Detailed design of all system functions and the user interface in terms of are methods of all classes will be explained later in the third section of this document.

# 2. POF System High Level Design

This section describes the POF system with high-level design. The high-level design section mentions about the POF system architecture and structure in different headings. Besides, the system environment explains the system constraints for the execution of the POF system. In the high-level design, activity diagrams testing design section have elaborated.

# *2.1. POF System Architecture*

The POF system architecture works with NVIDIA Flex which works as an outsource asset. Utilization of NVIDIA flex is mandatory because particle positions and AABB data are necessary to initialize. Initialization of fluid simulation data cannot be randomized. The system has a handler which acts as a communicator between NVIDIA flex and the POF system. Initially, NVIDIA Flex starts the fluid simulation and creates the particles and AABB. The Handler transmits necessary data to relevant classes. We have a hash system section that uses a hash algorithm to reach data quicker which keeps away us from linear search. Surface particle recognizer section determines the particles that are on the surface by calculating colour field quantity. Surface particles and its vertices grouped for a specific radius which is made by group neighbour particle function. Afterwards, grouped neighbour particle data send to the marching cubes algorithm [4]. Marching cubes section determines which vertices must be drawn. Lastly, the Marching cubes section intercommunicates with triangulation section which draws the given vertices.

# *2.2. POF System Structure*

In this section, the POF system structure has described with UML diagrams. Use case, sequence and package diagrams have drawn in this section.

***2.2.1 Use Case Diagram***

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**Fig 1:** Use case diagram

|  |  |
| --- | --- |
| **Title** | **Description** |
| **Calculate Scalar Field** | Calculates a constant value of a particle in a given range. |
| **Change grid size** | Interval of grid size of axis-aligned bounding box can change with this function. |
| **Change neighbour area size** | Neighbour particle range of volume can be changed. It affects the visualization of particles and changes the shape. |
| **Change particle appearance** | Particle colour, texture and light settings can be changed with this function. |
| **Change particle number** | Changes the particle number in the scene. |
| **Change particle size** | This function changes the radiusof the particle. Excessively disproportionate sizes compared to the scene can result in bugs and anomalies in physics behaviour of the particles |
| **Change rendering sensitivity** | User can change the rendering sensitivitywith this function. If the sensitivity increase, fluid visualization will be more precise as a result. However, the processing time will increase. |
| **Create Simulation** | NVIDIA Flex simulation initialize when this function called. |
| **Edit particle parameters** | Particle attributes can edit by a user from GUI. Parameters can be maximum particle number, particle size, friction, adhesion etc. |
| **Group Neighbour Particles** | Neighbour particles are grouped by looking a specific range. |
| **Handler** | Handler transmits data between layers and relevant classes. The Handler manages data transmission. |
| **Hash Model** | Structure class for Hash system. |
| **Hash System** | This function hashes the particle's position and cell position that particle belongs to. |
| **IMarching** | Interface class for Marching and Marching Cubes classes. |
| **Marching** | Analyze the cube for vertices and convert edges to triangles from the prewritten table. |
| **Marching Cubes** | Applies the Marching cubes algorithm on a single cube. |
| **Marching Cubes Scalar Calculator** | It is an application of Zhu et al. [ZB05]. |
| **Particle** | It represents the particles which used by both NVIDIA Flex and Particle Surface Reconstructor. |
| **Renderer** | Visualize fluid by drawing the given polygons. |
| **Situational Surface Calculator** | This section calculates and return the value. |
| **Surface Particle Recognizer** | Surface particles marked andprocessed for the necessary calculations in this function. |
| **User** | User can be anyone who has access to the program. |

**Table 1:** Description of the use case diagram

***2.2.2 Sequence Diagram***

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**Fig 2:** Sequence diagram

**Description:**Handler manages data transfer between other sections. If any data must transmit to another class, Handler executes this operation. The handler receives the bounds, particles and indices from NVIDIA flex. Handler sends this information to the hash system. Hash systems ask Particle Finder to find the id of the particle and adds to the hash model and acknowledges the handler. Handler sends the hash model to the surface recognizer. Surface recognizer processes the data and asks to the particle finder to find neighbour particles of a specific particle. Surface recognizer sends the data to the situational surface calculator which is responsible to calculate and return weight. The handler receives the neighbour particles and sends it to the marching cubes scalar calculator which finds the surface vertices. Particle finder receives the surface vertices and finds the vertices of the neighbour particles. Marching cubes scalar calculator receives the data from particle finder and sends to the situational surface calculator and it calculates the weight and returns the value. Marching cubes receives the marching cubes constant value which is calculated and send from the marching cubes scalar calculator. Marching cubes mark the vertices to be drawn. The Marching class starts to visualize by triangles.

# *2.3. POF System Environment*

The POF system environment constraints:

|  |
| --- |
| D3D11 capable graphics card |
| NVIDIA: GeForce Game Ready Driver 372.90 or above. |
| AMD: Radeon Software Version 16.9.1 or above. |
| Microsoft Visual Studio 2013 or above. |
| G++ 4.6.3 or higher |
| CUDA 8.0.44 or higher |
| DirectX 11/12 SDK |
| Windows 7 (64-bit) or higher. |
| Unity 3D 2017.3 version or higher |

The main project made on the system:

|  |  |
| --- | --- |
| Operating System | Windows 10 (64-bit) |
| Processor | Intel Core i7-4700 HQ CPU |
| Memory | 16 GB RAM – DDR3L-1600 MHz |
| GPU | NVIDIA GeForce GTX850M 4GB DDR3 |

This computer system has satisfying performance only small number of particles on this project because it can handle a very small number of particles. The optimal fluid simulation computer system mentioned in the final report [3].

# 3. POF System Detailed Design

This section describes the small parts of the POF system. Detailed design has a class diagram for the overall structure. The functionality of these small parts is explained in activity diagrams.

***3.1 POF system class diagram***

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**Fig 3:** Class diagram

***Description:*** NVIDIA flex is an eternal package which it is accessed by Handler. Handler makes the communication and organizes the data transmission as you can see from the relations. Consecutive actions are described in the sequence diagram. Visualization part is consisting of Marching, Marching cubes and IMarching classes. IMarching is an interface class for the other two class. Marching cubes analyse the cube situation according to the Marching cubes algorithm [WH87]. Marching class draws the triangles and applies the algorithm for a cube. The situational surface calculator and particle finder is a class that made calculations and returns values for other classes. Marching cubes scalar calculator is an application of Zhu et al. [ZB05]. It calculates and returns a scalar value for being used in the marching cubes algorithm. Surface recognizer receives the calculated valued from other classes and decides the surface particles.

***3.2 Subclasses of the POF system***

This section includes subclasses of activity diagrams.

***3.2.1 Activity Diagram of Marching Cubes Scalar Calculator***

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**Fig 4:** Activity diagram of Marching Cubes Scalar Calculator

**Description:**The handler sends the particles, bounds, groups and radius. Particle finder class receives and set data. Particle finder class is responsible for find neighbours of the particle in a specific radius. Particle finder marks for the surface vertices in every surface particle. Neighbour particles are sent to the situational surface calculator. Weight is calculated and the vertices that will be drawn are marked in according to the algorithm [ZB05]. Surface Particles are added to the list and return to the Handler.

***3.1.2 Activity Diagram of Surface Recognizer***

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**Fig 5:** Activity diagram of surface recognizer

**Description:** Handlersends data of the particle, bounds, groups and radius to find boundary function. Find boundary searches neighbour boundary cells for every particle and then find neighbour particles process starts. Find weightx function is calculates the weight and return a value. Find weightx section calculates the weight and if weight is smaller than specific constant value ‘q’ [8], Under favor of this calculation, we can decide the surface particles. If weight is bigger than a constant value, the particle is not a surface particle. Marked particles are sent to the Handler.

***3.1.3 Activity Diagram of Marching Cubes***

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**Fig 6:** Activity diagram of marching cubes

**Description:**Handler sends a grid cell (Cell is a structure consisting of vertices and iso-level) to polygonise function [4]. Marching analyses the cube situation by looking cases in [WH87]. There are 256 cases, but it is downgraded to 15 configurations predefined. After that, Marching Cubes finds the surface vertices and marks it. Then, edges that intersected by the surface is found. If the surface does not intersect with the cube, the vertex will not be drawn. Triangles are created by gathering three edges. Finally, the drawing process starts, and triangles are visualized.

***3.1.4 Activity Diagram of Hash System***

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**Fig 7:** Activity diagram of Hash System

**Description:**Handler sends particles, radius and groups to the hash system. Hash system finds the cell id and checks if it is empty. If empty, particle list is created, and the particle list has added. If not empty, checks if particle added. If the particle is not added, the particle is added to the particle list array. Final check occurs for the particles that are on the cell boundary. If the particle is on the boundary, the particle is added to the previous cell. If not, particle remains in the same cell. Hashed cells are sent to the handler and process ends.

# 4. Testing Design

Considering our project is predominantly research and development based, scientific papers and algorithm methods research takes a lot of time. Because of these reasons testing and design changes deferred to the later stages of our project. In this section, we have made integration test design and prove that our code generally works.

//Unity debug problem ve bundan dolayı görsel olarak bulmaya çalışmalar.

***4.1 Hash System***

***4.2 Cell System***

***4.3 Surface Recognition***

The comparison tables with details will be added in final report.

# References

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