COMP4910 Senior Design Project 1, Fall 2019
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POF: Performance Optimized Fluids

High Level Design
Design Specifications Document

Revision 1.0
8.12.2019

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Revision History

Revision	Date	Explanation
1.0	12.12.2019	Initial high level design

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1. Introduction

The purpose of the POF system is to research and apply existed methods to simulate fluids and looking for a better way to simulate it. Various methods will be implemented and tested during the research and development of this project. The main goal is making research and sharing our observations of the project results. One of the major project objectives is to reach a more efficient and better performance fluid simulation system but it is not promised because there is no certain way to achieve it and as mentioned, the project is mainly research-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. The project conforms to UML diagrams. Diagrams are describing the project to understand mainly operations of the POF system. Imperceptible parts of the POF system can be changed but the main functioning of the 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 are 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 given later in the third section of this document.

2. POF Computer System High Level Design

2.1. POF System Architecture

The POF system architecture works with NVIDIA Flex as an outsource asset. NVIDIA flex is mandatory because particle positions and AABB data are necessary. The system has a handler between the NVIDIA flex and the POF system. Initially, Flex starts the simulation and creates the particles and AABB. The handler passes data for relevant classes. We have a hash function that uses a hash algorithm to make easier and faster data access. Surface particle recognizer function determines the particles that are on the surface by calculating colour field quantity. Surface particles and their vertices grouped for a specific radius, which is made by group neighbour particle function. Afterward, grouped neighbour particle data send to the marching cubes algorithm and it determines which vertices should be drawn. The last part is triangulation and drawing the particles by the renderer section.

2.2. POF System Structure

2.2.1 Use Case Diagram

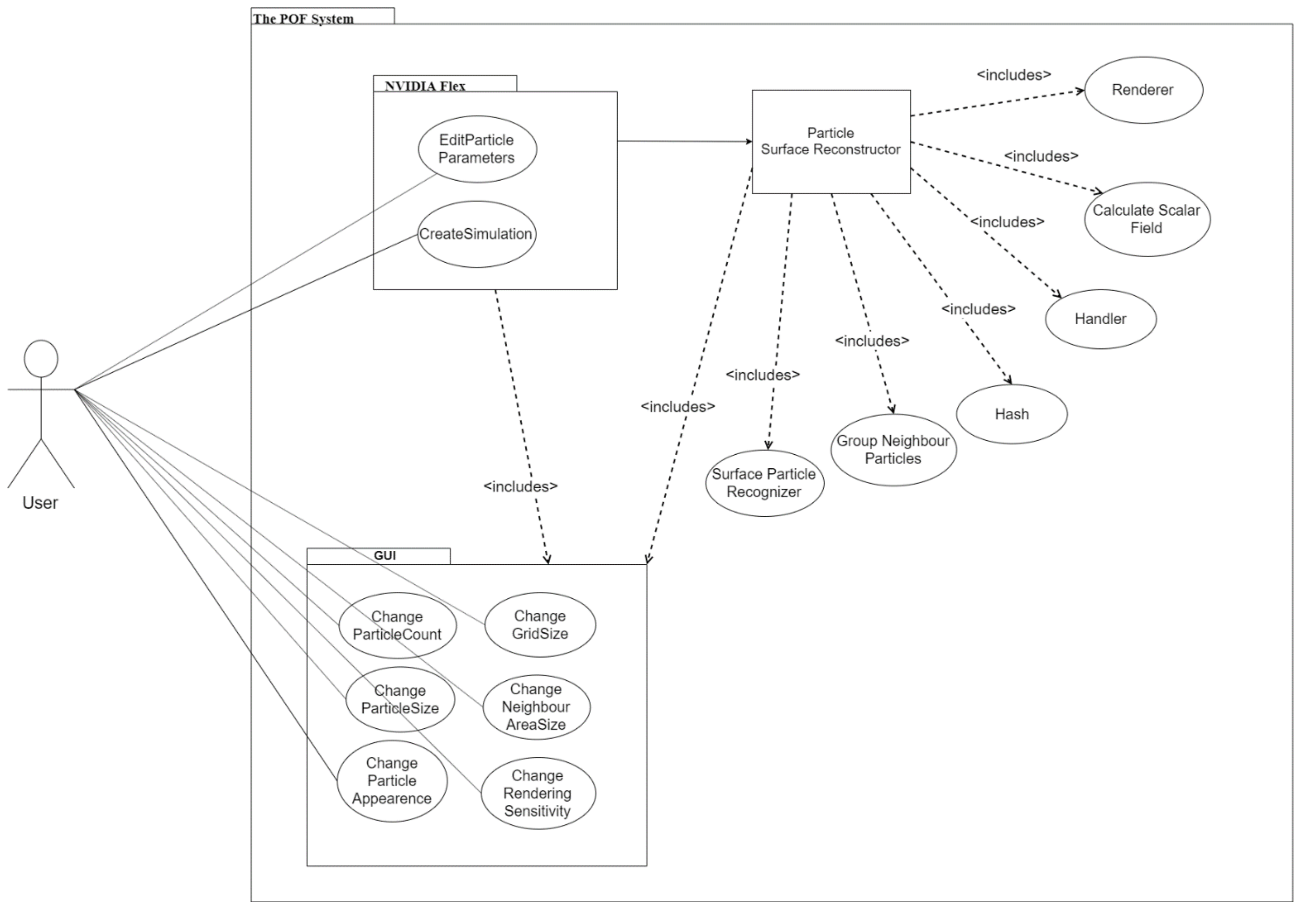
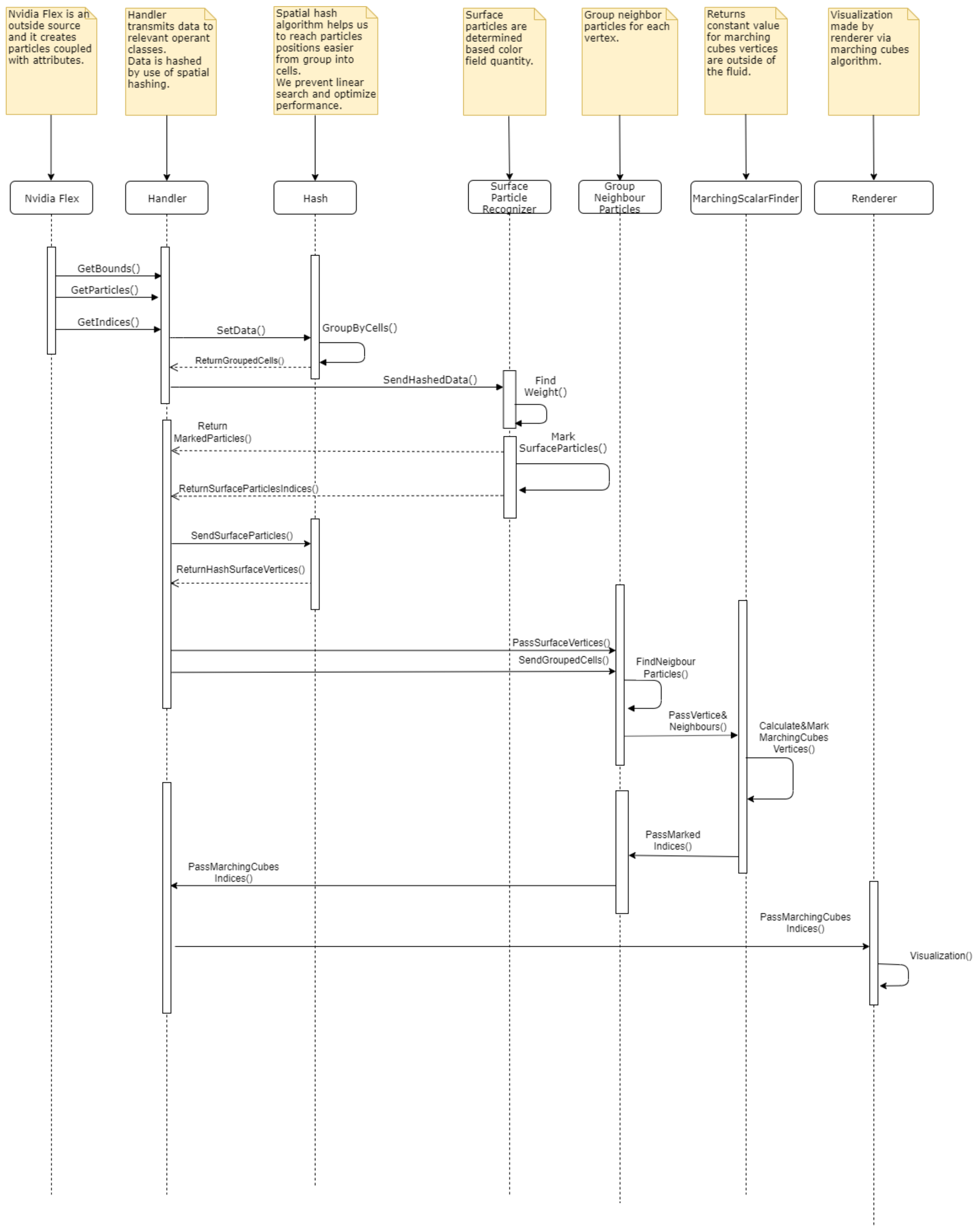


Fig 1: Use case diagram

Title	**Description**
Calculate Scalar Field	Calculates a constant value of a particle in given range.
Change grid size	Interval of grid size of axis aligned bounding box can be changed with this function.
Change neighbor area size	Neighbor particle range of volume can be changed which affects the visualization of particles and changes the shape.
Change particle appearance	Particle color, texture and light settings can be changed with this function.
Change particle count	Particle number in the scene can be edited.
Change particle size	Radius of the particle can be changed with this function. Increase in the particle size will result slow performance compared to less particle size.
Change rendering sensitivity	Rendering sensitivity can be changed with this function. If sensitivity increase, fluid visualization will be more precise however processing time will increase.
Create Simulation	NVIDIA Flex simulation initialize when this function called.
Edit particle parameters	Particle attributes can be edited by 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. Handler manage data transmission.
Hash	Hashes the particle and cell position.
Renderer	Visualize fluid by drawing the given polygons.
Surface Particle Recognizer	Surface particles marked and processed for the necessary calculations in this function.
User	Users can be anyone who has access to the program.

Table 1: Description of the use case diagram

2.2.2 Sequence Diagram



Nvidia Flex is an outside source and it creates particles coupled with attributes.
Handler transmits data to relevant operant classes. Data is hashed by use of spatial hashing.
Spatial hash algorithm helps us to reach particles positions easier from group into cells. We prevent linear search and optimize performance.
Surface particles are determined based color field quantity.
Group neighbor particles for each vertex.
Returns constant value for marching cubes vertices are outside of the fluid.
Visualization made by renderer via marching cubes algorithm.
Nvidia Flex
Handler
Hash
Surface Particle Recognizer
Group Neighbour Particles
MarchingScalarFinder
Renderer
GetBounds()
GetParticles()
GetIndices()
SetData()
GroupByCells()
ReturnGroupedCells()
SendHashedData()
Find Weight()
Return MarkedParticles()
Mark SurfaceParticles()
ReturnSurfaceParticlesIndices()
SendSurfaceParticles()
ReturnHashSurfaceVertices()
PassSurfaceVertices()
SendGroupedCells()
FindNeigbour Particles()
PassVertice& Neighbours()
Calculate&Mark MarchingCubes Vertices()
PassMarked Indices()
PassMarchingCubes Indices()
PassMarchingCubes Indices()
Visualization()

Fig 2: Sequence diagram

Description:

Handler manages data transfer between other sections. If any data have to transmit to another class, Handler executes this operation. NVIDIA flex is an already existed particle-based fluid system that is outsourced and initializes the fluid simulation. Hash applies a special algorithm and makes it easier and faster store and reach it to particle and cell data. Surface particle recognizer finds the surface particles by computing colour field quantity value. Group neighbour particles function finds a particle's neighbours in a specific range. Marching scalar finder function computes a constant value for the particle vertices that outside of the fluid. Renderer makes the triangulation of the specified vertices and draws the fluid for each frame.

2.2.3 Package Diagram

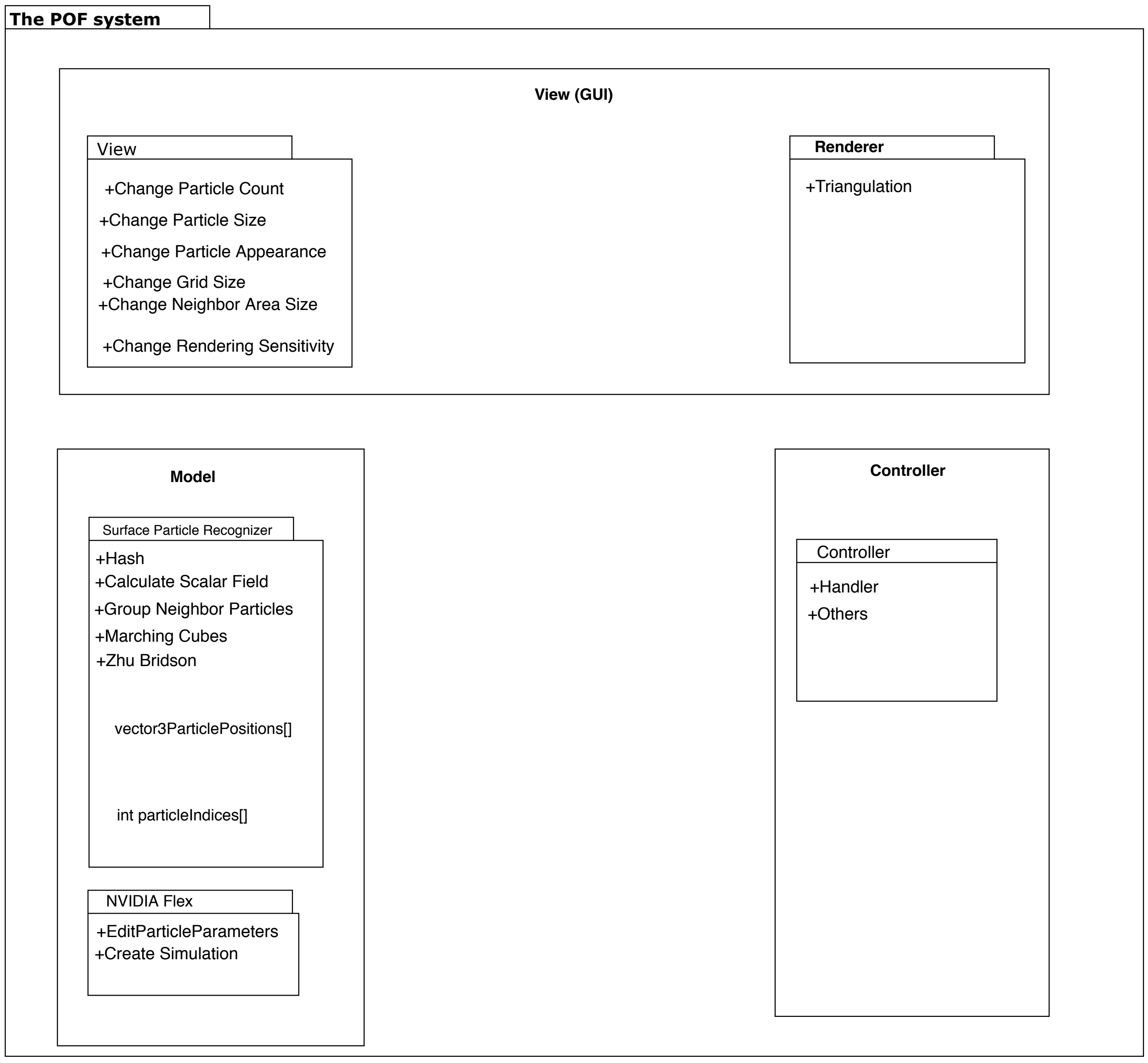


Fig 3: Package diagram

Description:

The package diagram is based on the MVC (model view controller) system. The model section consists of NVIDIA flex and surface particle recognizer. NVIDIA flex creates a simulation and can change hydrodynamic attributes of the particles. A surface particle recognizer is another package in the model section. Hash calculates cell id based on the boundaries of cells. The function of calculating the scalar field returns a constant value of the particle. Group neighbour particles compute the weight of a particle by checking nearby particles in a specific range. The marching cubes algorithm determines which vertices will be triangulated. [ZB05] is needed for reconstructing the surface. The controller part has a handler that controls data transmission and communication between sections. View section can change particle attributes such as particle count, size and appearance. Change grid size affects cell sizes. Change neighbour area size can affect the particle rendering. Changing the rendering sensitivity of the rendering affects the appearance of the POF fluid system directly.

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 system has low performance on this project because it can handle very small amount of particles. The optimal system should be workstation defined in final report [3].

3. POF System Detailed Design:

3.1 Activity Diagram of Zhu & Bridson

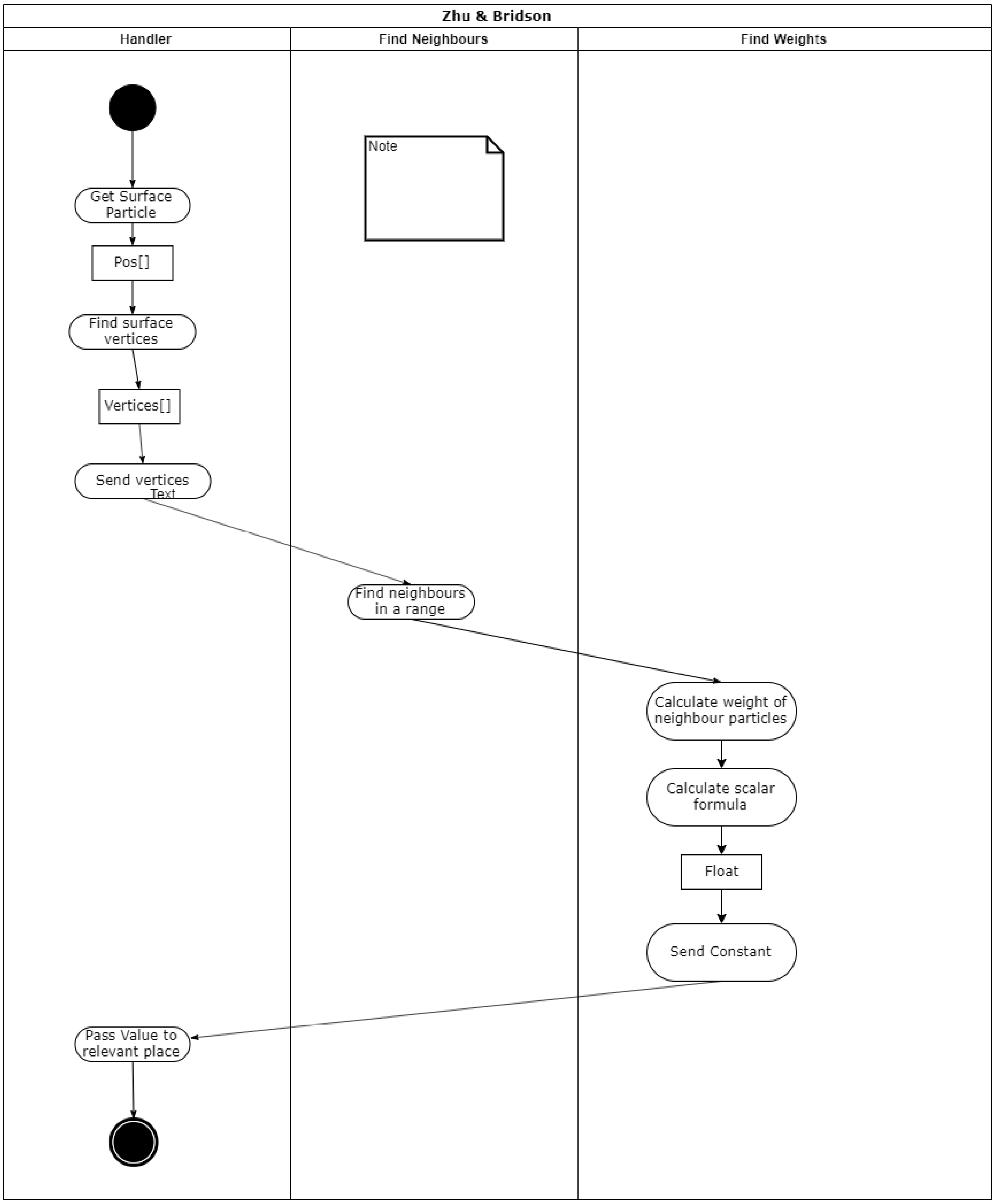


Fig 4: Zhu&Bridson Activity diagram

Description: Handler gets the surface particle from relevant sections. The handler receives the surface vertices and sends it to find neighbours section which is responsible to find neighbours of the particle in a specific range. Find neighbours pass neighbour particle data to find weight section. Find weight calculates the weight of the neighbour particles of a specific particle. Weight is used for calculating a scalar value. Find weight send constant value to the handler. Handler knows where to send specific data.

3.2 Activity Diagram of Surface Recognizer

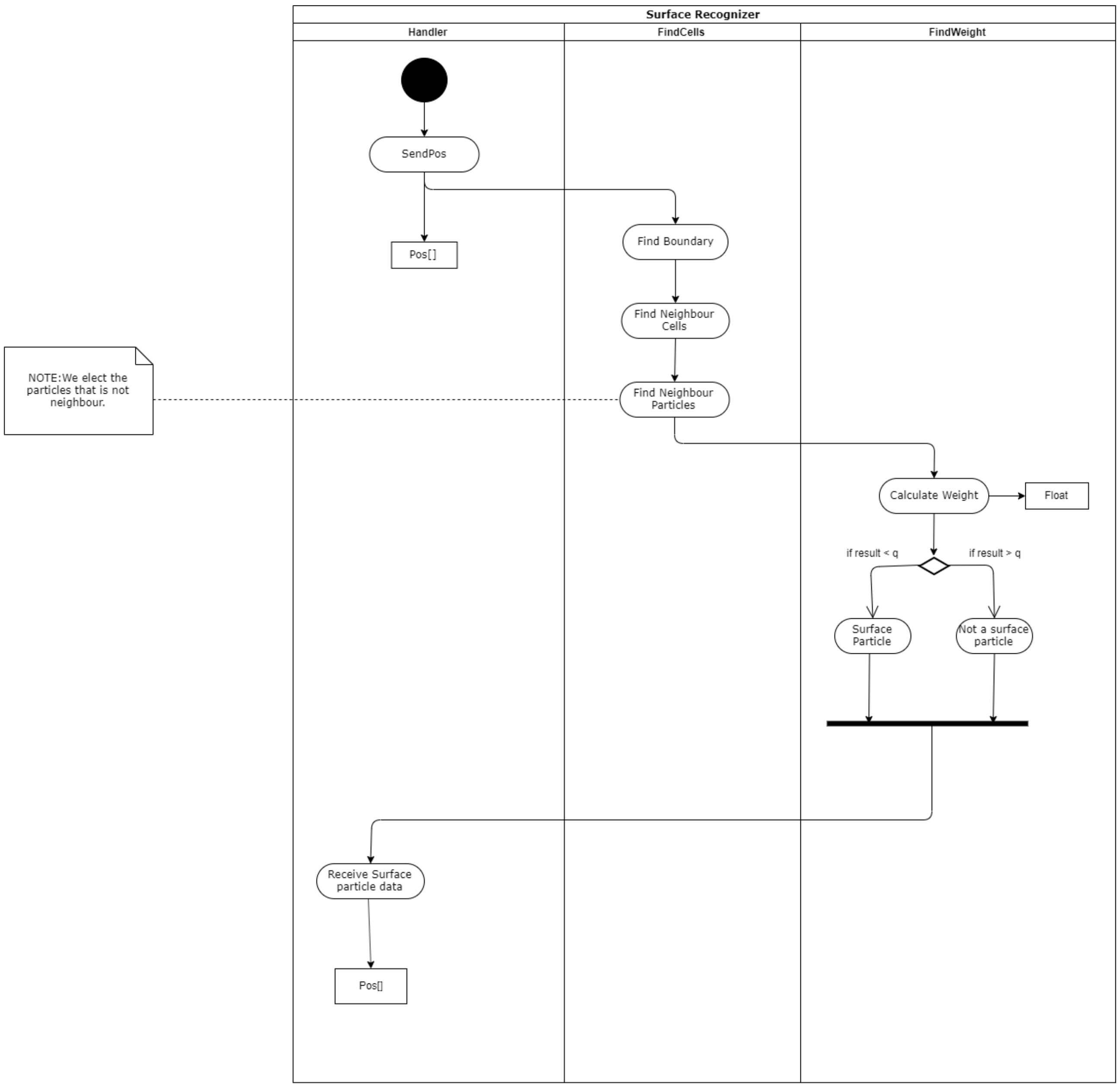


Fig 5: Surface recognizer activity diagram

Description: Handler sends position data of the particle to find cell function. Find neighbour cells find boundaries and neighbour cells. After that, find cells computes the neighbour particles and elect the particles that are not neighbour with each other and passes the data to find weight section. Find weight section calculates the weight and if weight is smaller than specific constant value ‘q’, (This constant called kernel can be changed for better results in the future implementations of the project.) particle marked as a surface particle. If weight is bigger than a constant value, the particle is not a surface particle. Marked particles are sent to the Handler.

3.3 Activity Diagram of Marching Cubes

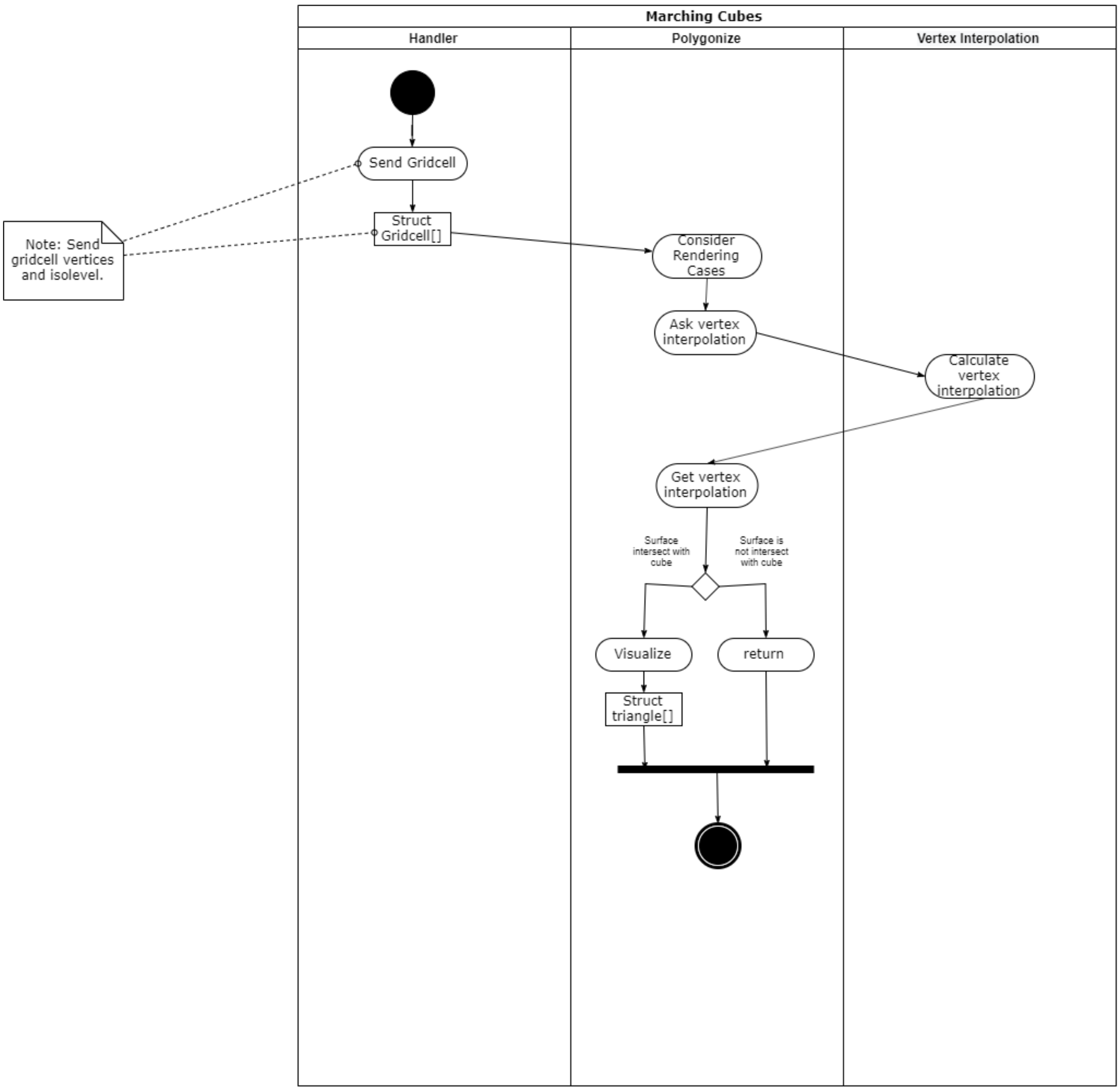


Fig 6: Marching cubes activity diagram

Description: Handler sends grid cell (Cell is a structure consisting of vertices and iso-level) to polygonize function. Polygonise consider rendering by looking cases (There are 16 cases predefined). After that, vertex interpolation calculates a value and returns to polygonize function. If the surface intersects with the cube, the vertex will be visualized. If the surface does not intersect with the cube, the vertex will not be drawn.

3.4 Activity Diagram of Hasher

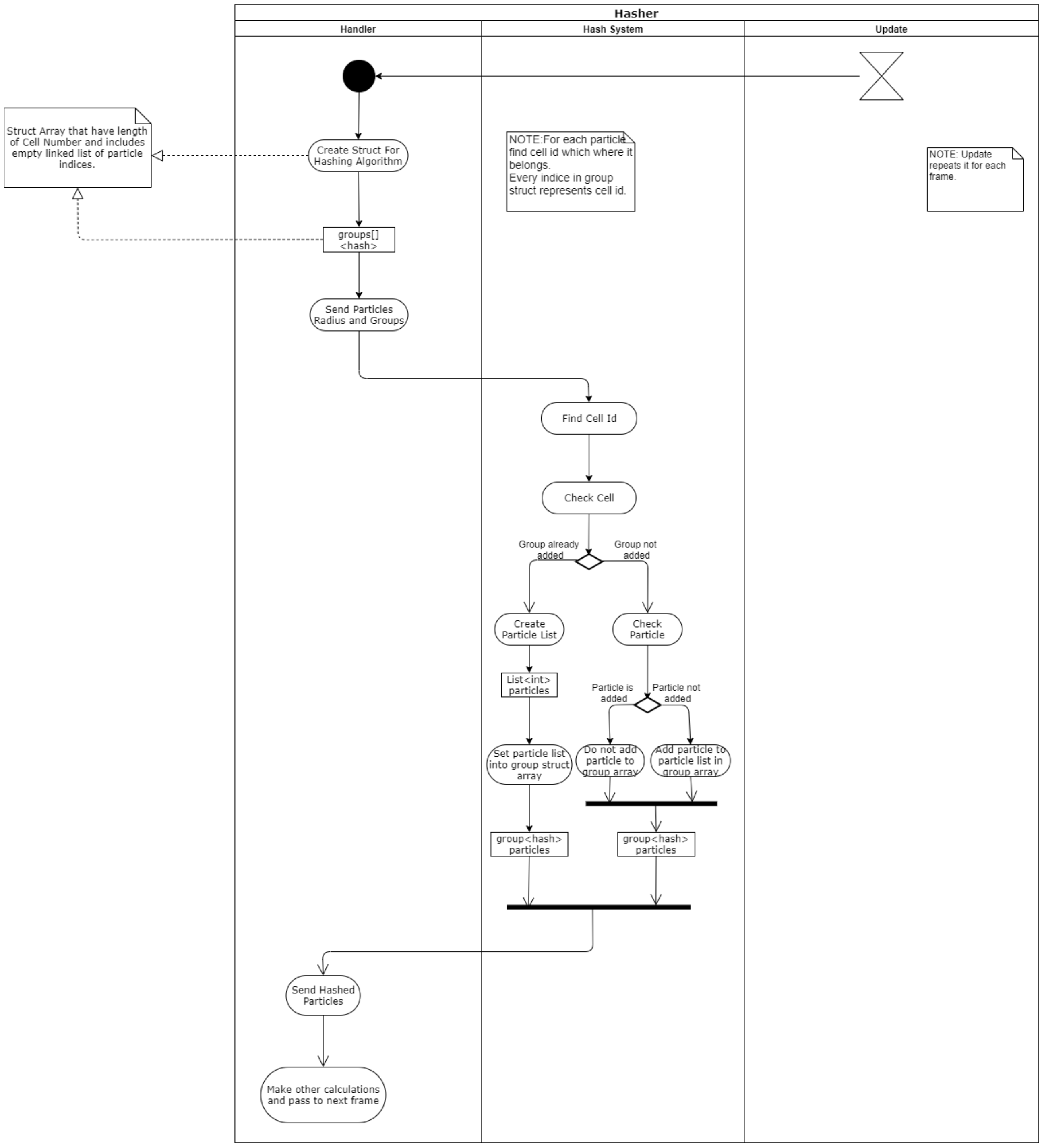

Hasher
Handler
Hash System
Update
Struct Array that have length of Cell Number and includes empty linked list of particle indices.
Create Struct For Hashing Algorithm
groups[] <hash>
Send Particles Radius and Groups
NOTE:For each particle find cell id which where it belongs. Every indice in group struct represents cell id.
NOTE: Update repeats it for each frame.
Find Cell Id
Check Cell
Group already added
Group not added
Create Particle List
Check Particle
List<int> particles
Particle is added
Particle not added
Set particle list into group struct array
Do not add particle to group array
Add particle to particle list in group array
group<hash> particles
group<hash> particles
Send Hashed Particles
Make other calculations and pass to next frame

Fig 7: Hasher activity diagram

Description: Handler sends particle radius and groups to the hash system. Hash system finds the cell that particle includes and checks the cell. If the group already added, the hash system creates a particle list and sets it into the group array and sends hashed particles to the handler. If the group is not added, add the particle to particle list in group array and send hashed particles to the handler.

4. Testing Design

Since our project is heavily research-based, the testing design is not handled smoothly in the earlier stages of our project. We will implement various methods mentioned in research papers on our project. The Unity 3D game engine will be used to test results. The best methods will be determined according to the test results. The main standards are performance and efficiency. Memory and CPU usage is important. NVIDIA flex communicates with the GPU for the efficiency of the simulation. Detailed comparison tables will be sketched and elaborated in the second future.

Table of figures

References

1. Requirement Specification Document revision 2.0 (RSD 2.0)

2. Use case and sequence diagrams in RSD 2.0

3. Final Report revision 1.0

4. **[ZB05]** Zhu, Y., & Bridson, R. (2005). Animating sand as a fluid. (New York, NY, USA, 2005) *ACM Trans. Graph., 24*, 965-972.
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Other references to additional documents, like other internal organizational documents,software project management documents, software design tool documents, etc.
References to additional bibliographic sources, like professional books, textbooks, handbooks, patents, standards, technical reports, journal/conference papers, etc.