SJTU SCHOOL OF SOFTWARE

Digital ART Laboratory

(Game Design)

Project Report

SILVER MIRROR REACTION SIMULATION

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1 Introduction

1.1 Objectives

1. Create an VR Gaming environment for the players to do silver mirror reaction freely.
2. Allow the players to see the phenonmenon of each reaction steps as well as the guide for the next step-to-do.
3. Produce and Dissolve different amount of deposit according to the players' adding amount of reagents.
3. Ensure the whole reaction is controllable by the players and try best to simulate the real silver mirror reaction tutor.

1.2 Theoretical Background

Silver mirror reaction is made up of three main steps, aiming at revivficating silver compound solution to metal silver. This reaction is widely known to high school students in China because it is included in Chemistry labs of high school education. The three steps of reaction are 1: **$AgNO_3$-$NaOH$ reaction** 2: **silver-ammonia reaction** 3: **silver-creation reaction**, which are detailedly mentioned below.

1.2.1 $AgNO_3$-$NaOH$ reaction

$AgNO_3$ and $NaOH$ solution will react with each other, creating white deposit after being shaked.

The reaction formula for $AgNO_3$-$NaOH$ reaction is

$$2AgNO_3 + 2NaOH == 2NaNO_3 + Ag_2O + H_2O$$

In the simulation of this reaction step, we prepare two $AgNO_3$ solution with different concentration :2% and 4% for the player to choose and one 2% $NaOH$ solution. The player can first drop one kind of $AgNO_3$ solution into the tube and then $NaOH$ solution into the tube according to the menu board. To speak of, the amount of adding reagants can be controlled by the player himself or herself.

1.2.2 silver-ammonia reaction

Silver-ammonia solution is the reactant of $AgOH$-NH_3H_2O reaction, a transparency solution. In this step, silver-ammonia reaction represents the reaction between NH_3H_2O and $Ag(OH)_2$ deposit. This reaction will create silver-ammonia solution, resulting in the dissolution of white deposit.

The reaction formula for NH_3H_2O-silver-ammonia reaction is

$$AgOH + NH_3H_2O == Ag(NH3)_2OH + H_2O$$

In the simulation of this reaction step, we prepare 2% NH_3H_2O solution for the player to continue the silver mirror reaction. As soon as the player drop the enough amount of NH_3H_2O solution into the tube, the remaining deposit in the tube will dissolve, or it will remain. Therefore, to ensure the full dissolution of deposit, the player can continue adding NH_3H_2O solution until he or she sees the deposit dissolving.

1.2.3 silver-creation reaction

Silver-creation reaction represents the reaction between silver-ammonia and $C_6H_{12}O_6$ solution. This reaction will revivficate metal silver under the environment of hot water. The player can see shinning silver in the tube if he or she add $C_6H_{12}O_6$ solution into silver-ammonia solution

The reaction formula for NH_3H_2O-silver-ammonia reaction is

$$CH_2OH(CHOH)_4CHO+2[Ag(NH3)_2]OH == H_2O+2Ag+3NH3+CH_2OH(CHOH)_4COONH_4$$

In the simulation of this reaction step, we prepare 2% $C_6H_{12}O_6$ solution for the player to continue the silver mirror reaction. As long as the player drop some amount of $C_6H_{12}O_6$ solution into the tube, he or she can put the tube into hot-water container and thus see the silver mirror phenomenon.

1.3 Virtual Experimental Setup

The Virtual experimental setups in VR simulation are shown in Figure 1. It consists of a set of breakers with solution name it contain as tag under the breakers, a menu borad for the player to check the progress of reaction steps, a formula board to check the chemical formula, a tube holder, a test tube and a pipette.

Figure 1. Virtual Experimental Setup

The detailed setup table is listed as below.

Apparatus	Quantity
breaker	5
breaker_1	2% $AgNO_3$
breaker_2	4% $AgNO_3$
breaker_3	2% $NaOH$
breaker_4	2% NH_3H_2O
breaker_5	2% $C_6H_{12}O_6$
tube	1
pipette	1
tubeholder	1
menu board	1
formula board	1
hot water container	1

Table 1: Table for List of virtual Setups

2 Project Description

2.1 Project Requirement

2.1.1 UI Design

1. Basic chemical lab instruments
2. Lab menu guide to lead the player through the whole silver mirror reaction
3. Allow the player to see the kind and the concentration of reactants and products

2.1.2 Chemical Reaction Process Simulation

1. Establish quantitative calculation of reactants during the reaction process
2. Present the reaction phenomenons with the use of physical simulation and shader
3. Make the amount of reaction reactants and thus final phenomenon controllable by the player

2.1.3 Application

1. Establish complete experimental process, including instruments preparation, experimental environment set-up, experimental operation, phenonmenon observation and so on.
2. (Extra Points) Establish deposit creation and dissolution with Particle System
3. (Extra Points) Establish fluid effect with Physical function.

2.2 Expected Established Goals

2.2.1 UI Design

1. Basic chemical lab instruments for the player to operate.
2. Variable Lab menu guide at each step of reaction to lead the player through the whole silver mirror reaction.
3. Allow the player to see the kind and the concentration of reactants in the instrument when holding a certain instrument.

2.2.2 Chemical Reaction Process Simulation

1. Calculate the amount of reactants with the use of calculating the particle collision.
2. Establish quantitative calculation of reactants during the reaction process according to the recorded amount of reactants and get the amount of products according to the calculation.
3. Present the reaction phenomenons of deposit creation and dissolution with particle system and Create different amount of deposit according to the player's adding amount of reactants.

2.2.3 Reaction Phenonmenon Presentation

1. After adding certain amount of reactants, the liquid amount in the test tube increases
2. After doing $AgNO_3$-$NaOH$ reaction step and shaking the tube, white deposit with calculated amount creates in the tube.
3. After doing silver-ammonia reaction step, white deposit decreases according to the player's adding amount of NH_3H_2O solution.
4. After doing silver-creation reaction step and putting the tube into hot-water container, shinny silver shader can be seen in the tube according to the amount of liquid in the tube.

2.3 Established Contents

2.3.1 UI Design

1. Basic chemical lab instruments for the player to operate: **a set of breakers with different,a hot-water container, a tube holder, a test tube and a pipette.**
2. Variable Lab menu guide at each step of reaction to lead the player through the whole silver mirror reaction: **four key step tutor guide when players complete the previous steps**
3. Allow the player to see the kind and the concentration of reactants in the instrument when holding a certain instrument: **UI Text occurs besides the container or pipette whenever the player is holding a certain instrument**

2.3.2 Chemical Reaction Process Simulation

1. Calculate the amount of reactants with the use of calculating the particle collision: **Use OnParticleCollison to adjust the recorded amount of reactants and presented amount of liquid in the tube**

2. Establish quantitative calculation of reactants during the reaction process according to the recorded amount of reactants and get the amount of products according to the calculation: **Use various kind of judging condition to calucate different amounts of products result**

3. Present the reaction phenomenons of deposit creation and dissolution with particle system and Create different amount of deposit according to the player's adding amount of reactants: **Use calculated amount of deposit to control the height of deposit-effect particle system**

2.3.3 Reaction Phenonmenon Presentation

1. After adding certain amount of reactants, the liquid amount in the test tube increases: **Use OnParticleCollison to trigger the change of height of liquid cylinder**

2. After doing $AgNO_3$-$NaOH$ reaction step and shaking the tube, white deposit with calculated amount creates in the tube: **Use proper additon of reactants and tube-shaking as triggering condition to play the particle system**

3. After doing silver-ammonia reaction step, white deposit decreases according to the player's adding amount of NH_3H_2O solution: **Use proper additon of reactants as triggering condition and use the amount of NH_3H_2O to control the stop of particle system**

4. After doing silver-creation reaction step and putting the tube into hot-water container, shinny silver shader can be seen in the tube according to the amount of liquid in the tube: **Use tube collison with container as triggering condition, and change the shader of different objects according to the minimum height of tube liquid and container liquid**

3 Methodology

In the Methodology part, each key function in the reaction and its establishing methods are mentioned below.

3.1 Collison of instruments

To establish the goal that each instrument can collide with each other like real-life instruments, we need to give each breaker, pipette, test tube and container mesh Collider properties, since they are not ruglar objects . Therefore, we need to bind Mesh Collider an Rigid Body to these objects with properties "Convex" and "Use Gravity" checked.

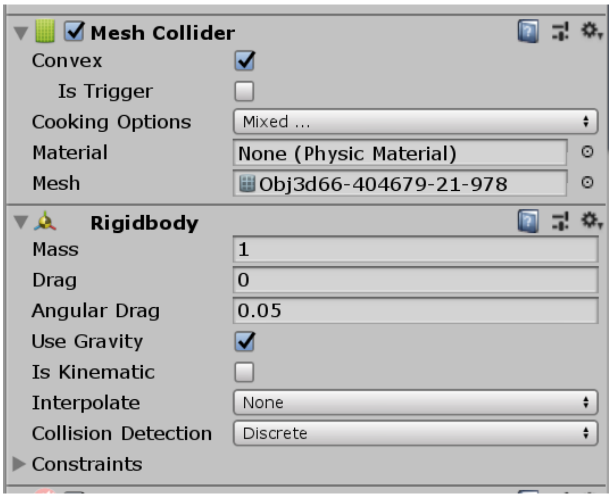

Figure 2. Mesh Collider and Rigidbody Properties

Besides, If we don't want to grab sth but just want see it collide with other objects, for example, we only want the tube-hoding function of tube container. For this, instead of setting it as Gravity, we bind it with Mesh Collider with "Convex" properties checked and add several invisible box collider to the tube container as sub-objects to controll the position of tube.

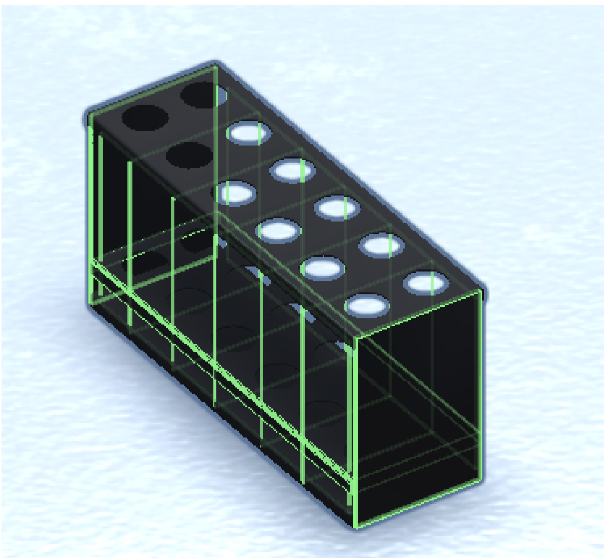

Figure 3. Construction of collider in the tube container

3.2 Drawing different solution with pipette

For the establishment of this functin, in order to draw different reactants, we bind an invisible cube with the pipette to collide with liquid. Therefore, we can use script to controll the change of tag of our particle system of pipette. When the collision cube collides with the liquid, the tag of pip plane changes according to the tag of that liquid.Since pip plane is used for emission of "dropping liquid", emitting particle's tag can also be changed.

Figure 3. Tag of pip plane after touching $C_6H_{12}O_6$ solution

3.3 Dropping solution into tube from pipette

For the establishment of dropping liquid into the tube, we use Touchpad to controll the start and the stop of the particle system.

Therefore, we use EventArgs to handle the change of events. The established code of this part is mentioned as below

```
private void Left_touchpadPressed(object sender, ControllerInteractionEventArgs e)
{
    LeftTouchPadMode = !LeftTouchPadMode;
}

private void Right_touchpadPressed(object sender, ControllerInteractionEventArgs e)
{
    RightTouchPadMode = !RightTouchPadMode;
}
```

Figure 4. Change of Touchpad tag

```
//determine whether pipette is grabbed or not
if (rightGrab.GetGrabbedObject() == pip ){

    //Debug.Log("right hand GRAB");
    Debug.Log(RightTouchPadMode);

    if (RightTouchPadMode)
    {
        Debug.Log("start right hand drop");
        liquid.GetComponent<ParticleSystem>().Play();
    }
    else
    {
        Debug.Log("stop right hand drop");
        liquid.GetComponent<ParticleSystem>().Stop();
    }

}
```

Figure 5. Controll of Particle System

3.4 Rise of Liquid surface

In order to controll the rise of liquid surface in the tube, we divide the process into two parts.

First is to use the collision of particles to record the amount of certain reactants.We judge the tag of dropping particles to clarify the kind of reactants and record the amount of reactants according to the number of particles for later quantative calculation.

Second, we also use collision of particles to controll the height of liquid cylinder in our test tube. For each partile, if it touch the invisible collision plane we set, we will change the corresponding height and tranform of liquid cylinder to reach the effect of the rise of liquid surface visually.

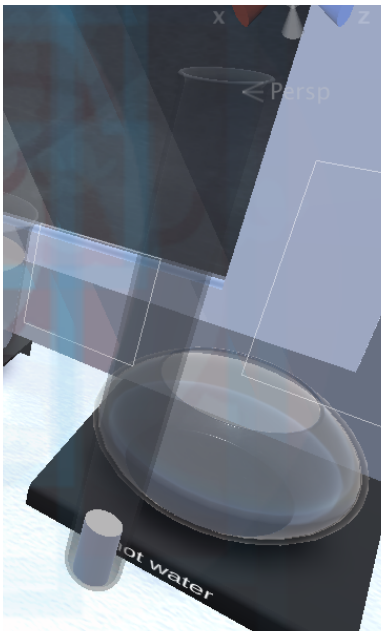

Figure 6. Rise of Liquid Surface in Tube

3.5 Judgement of shake of tube

Since shake of the tube is an essential trigger condition of creating the deposit phenomenon, we need to judge whether the tube is shaked before presentsing the creation of deposit phenomenon.

Therefore, in order to establish this objective, we judge the shaking count with the arguments of rotation angle. If the shaking count is more than 150, we regard it as completion of shaking part.

3.6 Creation of Deposit

In Deposit Part, we use Particle System to simulate the creation of Deposit. We set a height-controllable Particle-Emission plane to create particles.

Besides, to controll the trigger condition of particle system's play action, we use shake tag and amount of reactants as arguments to judge the play of particle system.

Moreover, to keep the amount of deposit more like in the real chemical reaction, we calculate the amount of deposit with the amount of reactants to adjust the height of particle emission plane.

The result of deposit is shown as below.

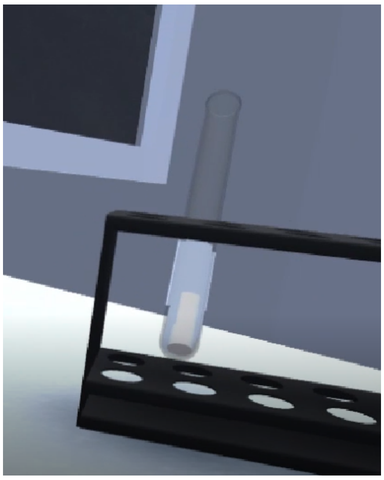

Figure 7. Creation of Deposit in Tube

3.7 Disolution of Deposit

In this part, we also use Particle System to simulate the dissolution of Deposit.

We use the amount of $AgNO_3$, $NaOH$ and NH_3H_2O as trigger condition, and calculate the remaining amount of deposit according to the adding amount NH_3H_2O.

As the same time, we use the calculated amount of remaining deposit to control the dissolution of deposit. As long as we add enough amount of NH_3H_2O solution, particle system will stop, thus resulting in the dissolution of deposit.

```
if ((collider_script.NH3H2O> 0)  && (collider_script.NaOH > 0) && (collider_script.AgNO3_2 > 0 || collider_script.AgNO3_4 > 0
{
    if (collider_script.D2 >0)
    {

        //If there is deposit remaining
        if (collider_script.D2 > 0.0f)
        {
            //D2 is relative with 0.05D height
            if (Deposit.transform.localPosition.z > collider_script.D2 * 0.05f - 2.56f) //这里4是对应沉淀上升高度4
            {
                Deposit.GetComponent<Transform>().localPosition -= new Vector3(0.0f, 0.0f, Time.deltaTime * 0.1F);
                IsKeepParticleSystem = 1;
                IsChangeHeightParticleSystem = 1;
            }
            else
            {
                IsKeepParticleSystem = 1;
                IsDisableParticleSystem = 0;
                IsChangeHeightParticleSystem = 0;
                //at this else time, the deposit is arriving at the ideal height
            }
        }
```

Figure 8. Dissolution of Deposit in Tube

3.8 Creation of silver

In order to show shinny silver effect, we use shader to simulate the visual effect. We add normal shader attribute to the code according to Reference Document provided by Digital Art Laborary[1] and adjust the code to get a better silver shader effect. Besides, we adjust the gloss and diffusion arguments to get a better visual effect.

Moreover, to establish the correct silver mirror phenomenon, we use tube and container's collision as comparing condition to judge the actual size of simulated silver mirror. Then we judge the height of liquid in the tube and in the hot-water container to decide the height of silver mirror. As long as we judge the right silver-creation condition, we change the shader of cylinder in the tube to present silver mirror phenomenon

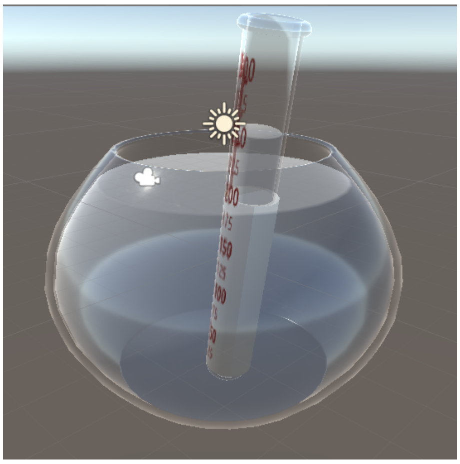

Figure 9. Creation of silver

3.9 Grab of instruments

In order to combine our Unity Game with VRTK to simulate a virtual experimental environment for players, we allow players to grab objects with the button of trigger. Players can grab a certain instruments by contiuning pressing trigger button. As long as the player releases the trigger buttom, this instrument will fall down and collide with table or ground.

The VRTK Interactable Object script is also provided by Digital Art Laborary[2]. We use this script to bind each object and shank and set it as below to fulfill our grabbing goal.

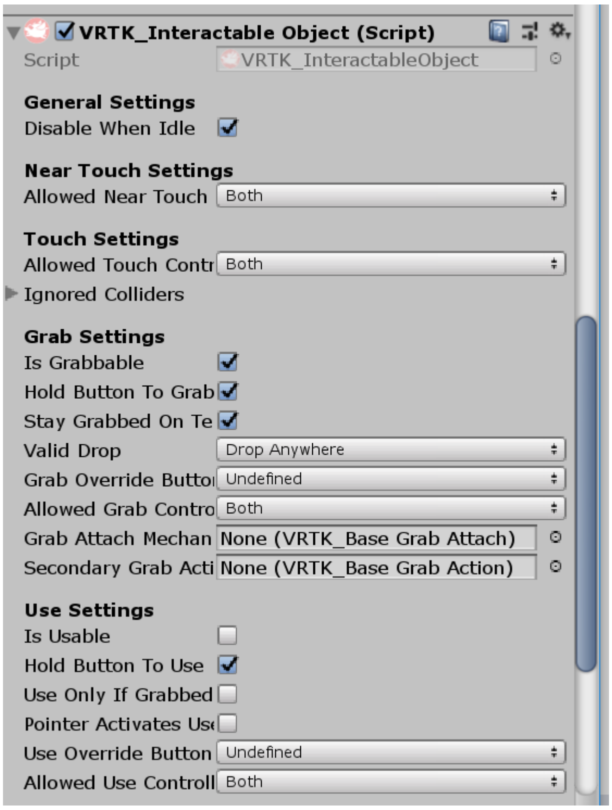

Figure 10. Setting of VRTK Interactable Object script

3.10 UI presentation of instruments

To guide the player with more information about the reactants, we use TextMeshPro to bind corresponding UI text along each grabbable objects. As long as this object is grabbed, corresponding UI part will show.

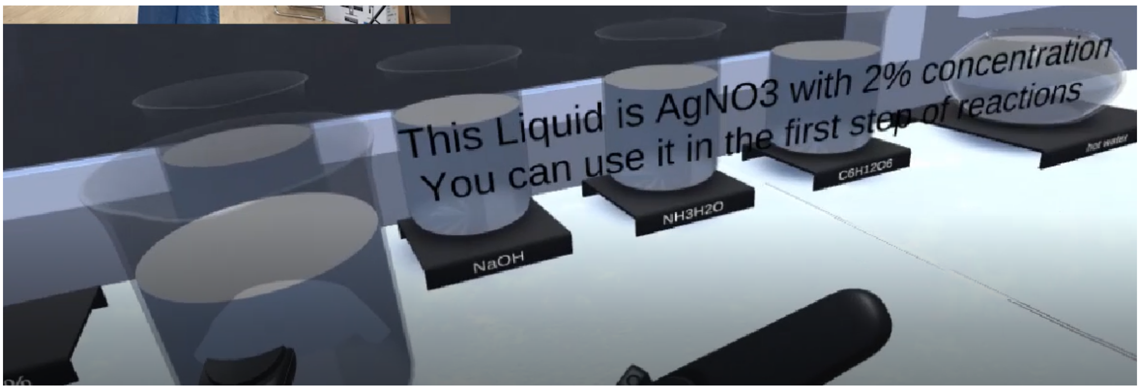

Figure 11. The UI text results

3.11 Menu Board Guide

To better guide the player how to do silver mirror reaction in a correct order of step, we provide players with an auto-changable menu board. This menu board will adjust its content according to imported signal of previous reaction tag. As long as the player finish the following steps, this menu board will present fresh content, leading the player to do the following steps.

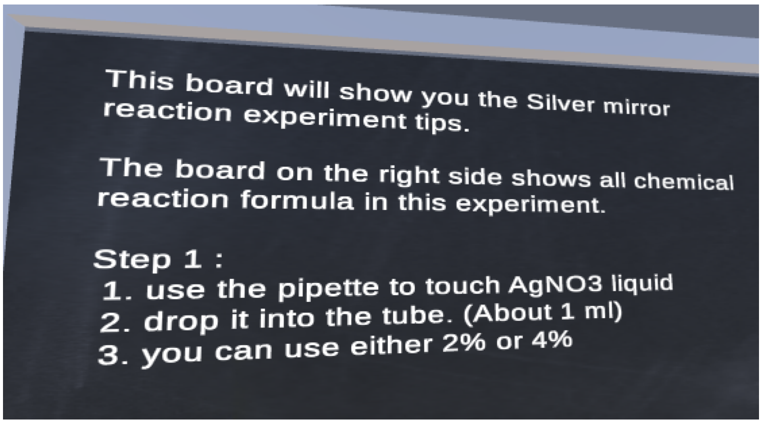

Figure 11. The Menu Board

4 Conclusion and Expectations

4.1 Conclusion

Our Environment Simulation of Virtual Experiment of Silver Mirror Reaction is based on Experiment of Silver Mirror Reaction, aiming at providing users with an interesting and vivid simulation tutoring experience.

In this Virtual Experimental Environment, we provide players with a set of breakers with solution name it contain as tag under the breakers, a tube holder, a test tube and a pipette to operate and a menu borad for the player to check the progress of reaction steps, a formula board to check the chemical formula.In this lab, players can freely controlthe amount of reactants to get a different result phenomenon at each step of reactions.

For our established results:

UI Design

1. Basic chemical lab instruments for the player to operate
2. Variable guide Lab menu
3. Seeable kind and the concentration of reactants

Chemical Reaction Process Simulation

1. Correct recorded reactant amount and calculated products amount
2. Depoist Creation and Dissolution according to the amount of deposit.
3. Lifelike changable deposit creation and dissolution

Reaction Phenonmenon Presentation

1. Visual increase of liquid height when liquid dropping-in
2. Presentation of Particle System to simulate the deposit
3. Lifelike controllable silver mirror phenomenon

4.2 Expectation

Since we have one expected functions, but kind of out of time to establish them, which are using physical fluid to simulate the flowing liquid. We might complete it after learning more corresponding knowledge.

Beside, more controllable UI guide can be added to decrease users' difficulty to do this reaction.

5 Reference

1. Unity Technologies.*Unity 5.X from Introduction to Profiency* China, Chinese Rewailway Press
2. http://dalab.se.sjtu.edu.cn/gp/hw3doc/doc.html
3. https://blog.csdn.net/wolf96/article/details/41826127
4. https://www.bilibili.com/video/av41430698/
5. https://www.jianshu.com/p/9d6b73cc077f
6. https://blog.csdn.net/nt_xs_j/article/details/88037568
7. https://blog.csdn.net/qq_34552886/article/details/70176692
8. https://blog.csdn.net/Ber_gen/article/details/51446437

7 Appendix