Design of Virtual Chemical Experiment Platform Based on Unity3D

Aoyu Wang¹ and Aoshuang Dong¹
1 School of software, Northeastern University, Shenyang, China
Email: 121424559@qq.com

Abstract. The problem we are trying to solve in this paper is how to determine whether the operation sequence is correct and how to achieve undo and redo when we design the virtual chemistry experiment platform in Unity3d. The approach we adopt to solve the problem is we mainly use the design idea of directed acyclic graph to solve the problem of judging operation sequence. We use command pattern and stack data structure to achieve the methods of undo and redo. By solving the above problems, we have successfully implemented the sequence of judgment and the methods of undo and redo in Unity3d. The methods implemented in this paper are not only applicable to the virtual chemistry experiment platform, but also play a role in other systems need them.

1. Introduction
Virtual reality technology, called VR for short. VR has good human-computer interaction. Users can be fully immersed in the virtual world. VR has a wide range of applications in all fields.

In this paper, our goal was to use Unity3D engine to design and implement a chemical experiment virtual simulation platform. Users can simulate dangerous chemical experiments. The platform greatly improve the safety of the experiments.

2. Used Technology

2.1. Unity3D
Unity3D is a powerful cross-platform, integrated 3D engine [1]. Unity3D makes it easy to create and publish powerful cross-platform capabilities across multiple platforms including Windows, Mac, Wii, iPhone, Windows phone 8 and Android. Unity3D engine in the VR, AR is also widely used [2].

2.2. Directed Acyclic Graph
The graph is a way to show the relationship between points. A graph consists of edges and vertices [5]. If you specify a direction for each edge of a graph, the resulting graph is called a directed graph and its edges are also called directed edges. If a directed graph can’t be returned from a certain vertex point through several edges, the graph is a directed acyclic graph (DAG graph).

2.3. Stack
A stack, which is a linear list of insertions and deletions all performed at the same end of the table. One end of an element that is allowed to insert and delete is called the top of the stack and the other end is called the bottom of the stack. Stack has the feature that is FILO-First-In / Last-Out.
2.4. Command Pattern
The purpose of the command pattern is to encapsulate a request into an object so that you can parameterize the customer with different requests [3]. The command pattern divides the responsibility of issuing the order and the responsibility of executing the order into different objects. So the requesting does not have to know the interface of receiving, even not to know how the request was received, when the operation was performed, when it was executed and how it was executed. Command pattern reduces the coupling between user and command receiver. It is easy to expand the method. When we need some new commands, we needn’t modify the whole system [10].

3. Design of Virtual Chemical Experiment Platform
The chemical experiment virtual simulation platform is based on the C / S architecture [9]. We presented it to the user content by the mobile VR device [4]. Users can log in with a given account and password. Users can interact with the system by gazing the objects. When users choose different experimental apparatus, the system will give different feedback. In real life the operation of chemical experiment is in sequence [8]. If the operation is improper it will be dangerous. If we operate it incorrectly [6], the experiment will fail. Based on the above two points we solves the chemical experiment operation of the orderly representation and experimental operation of the undo and redo by using Unity3d engine [7].

4. Expression of Experimental Process Activity
4.1. The Structure of Acyclic Directed Graph
In this paper we take a thermite reaction as an example.
- Pour iron oxide and aluminum powder on the filter
- Take two filter paper folded into a funnel
- Subtract the bottom of one funnel and moisten it with water
- Put the funnel on the iron stand
- Pour into a mixture
- Place Magnesium bar
- Pour into potassium chlorate
- Light the Magnesium bar

According to the sequence of the eight steps, we designed an acyclic directed graph that is shown in figure 1. These points correspond to 1 to 8 in figure 1. The vertices represent the operations to be performed and the directed edges represent the predecessor and successor relationships between the operations. It is not allowed for the user to start operations from 8th node.

![Figure 1. Directed acyclic graph](image)

4.2. Directed Acyclic Graph Precursor Storage Node
In one step we often focus on the state of predecessor node. So we only need to store the state of predecessor node. We design a class called ChemistryGraph and attach this class to the object that we operate. Add a variable ChemistryGraph parents. So we can access a reference to the ChemistryGraph class at the predecessor node.
4.3. Directed Acyclic Graph Operation Relationship

We designed the storage method of acyclic directed graph and the method of finding the predecessor node through the current node. In this case the current node needs to be used to determine whether the current operation can be performed, that is, whether the operation of the precursor node has occurred. Add a variable bool isReady to the ChemistryGraph class. The variable represents whether the current operation has occurred. The current node accesses the isReady variable of the predecessor node by traversing the parents array. If all state is true the current operation can be performed otherwise the current operation can’t be performed. The node without parent nodes in the graph whose isReady variable is true and parents variable is null.

4.4. ChemistryGraph Class Core Code

The CurrentOperation method is used to determine whether the operation of the current node can be performed. Set Parents variable and isReady variable as public variables to make changes in Unity's properties panel easy.

```csharp
public class ChemistryGraph : MonoBehaviour {
    public chemistryGraph[] parents;
    public bool isReady;

    public bool CurrentOperation() {
        if (parents == null)
            return true;

        for (int i = 0; i < parents.Length; i++)
            if (!parents[i].isReady)
                return false;

        return true;
    }
}
```

5. Implementation of Command Pattern

5.1. The Command Class Design

Now we design the base class of command class. As we know all command class inherits the base class. Each command should have forward and reverse operations, that is, redo and undo operations. In the base class, we defined the private variables of type ChemistryGraph to facilitate the inspection of the successor operation is completed. We defined two virtual methods do and undo so that the subclasses can override the do and undo methods.

5.2. Storage Structure

We create and maintain two stacks, one called commands and one called redoCommands. The commands stack stored the current operation has been performed and the redoCommands stack store the revoked command as shown in figure 2.

![Figure 2. The operation of stack](image-url)
5.3. How to Use
When the user to carry out an operation the operation command will be put into the command stack to save. When user need to revoke the command the top-of-stack command from the commands stack will be popped and execute the redo method of the command. After execution, put the command into the redoCommands stack to save. When the user needs to redo, the command will be popped and execute the command do method. So the command will be put again into the commands stack. When a new command is generated, the redoCommands stack will be cleared. Specific operations as shown in the figure 2.

6. The Experimental Results
Now let’s start the experiment. The user inputs the account and password to enter the system. User can select the thermite reaction. According to the prompts user can select the correct experimental equipment. If the user select a wrong operation the chemical effect will not be performed as shown in the figure 3.

![Figure 3. The experiment result A](image)

In order to test the effect of undo we set the funnel and evaporating dish in this experiment and set to undo the operation when the A button is pressed. The operation of placing the evaporating dish is undo and it can be observed that the evaporating dish has been placed in the original position as shown in the figure 4.

![Figure 4. The experiment result B](image)

User performs the operation step by step, each operation corresponds to a different performance in the system, and finally experiment will be completed as shown in the figure 5.
7. Conclusion
Based on the Unity3D engine and the thermite reaction this paper solved the two core problems of system construction. Firstly, how to determine the sequence of occurrence of experimental steps. The second is how to undo and redo the experimental operation. For the first problem, this paper uses the acyclic digraph combined with the characteristics of the object in Unity3D to achieve the control of the sequence of experimental operations. For the second problem, this paper uses the command pattern, designed a base class for the operation of the command and two stack structures to achieve the methods of undo and redo. Determining the sequence in which events occur, undoing, and redoing are common in many different systems. So the approach that the paper proposed is generally applicable in Unity 3D.

8. References
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