Designing Objects for Virtual Experiments

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Abstract

As computer technology advanced in the last decades, traditional education has been much influenced by the progress of such computer-assisted learning platform. This paper proposes a virtual experiment environment (V.E.E.) to let students experiment with visual equipment on multimedia computers, which then be formulated as a visualized demonstration platform to process visual learning. Considering the practicum of conventional education, this "learning by doing" design brings the idea of situated learning into computer environment, as the interactions of human cognition are studied and improved in different computer-based learning environment. (Brown, Collins & Duguid, 1989) Furthermore, in order to simulate cooperative work in a real laboratory, the virtual experiment environment should be constructed on the computer network.

Keywords: V.E.E. (Virtual Experiment Environment) , knowledge object, visual object, experiment object

1.Introduction

The development of knowledge in school education always relies much on "doing" or "practicing", which is the most important character in Bobbitt Education Mechanism. (Bobbitt, 1918) That is the reason why practicums are so emphasized in today's school education. But the traditional experiment is always restricted by time and place, students may not practice after school, and also may not do along. As CAI (Computer Assisted Instruction) had been investigated by many psychologists and educators to support traditional education for decades, the role that a computer plays is an intelligent tutor. [Chan95][Tung95][HSHJ96] And on the computer supported network, students can doing experiment along or with other participants. By the development of V.E.E., it is never a dream to doing experiment at any time and anywhere. [CCJH96]

2.The Model of Virtual Experiment

The destination of experiment is to let students obtain knowledge in the process of doing experiment. For the reason, the knowledge which a student possesses from beginning doing experiment to finishing must have some difference. How to get the best learning efficiency in doing experiment is the most important assessment level of the designment of experiment model. To establish the general model of virtual experiment, the analysis of the input and outcomes of experiment has been proceeded as follows.

The outcome O of an experiment is determined by the control parameter P and the nature law in this experiment (actual knowledge K); it can be represented as $O = O(K, P)$. After students learning through the parameter settings and observed outcomes, they can obtain estimated knowledge $\hat{K}$; it can be represented as $\hat{K} = \hat{K}(P, O)$. The best result of experiment is that the estimated knowledge $\hat{K}$ and the actual knowledge K can keep balance. The virtual experiment model can be presented clearly in Figure 1.

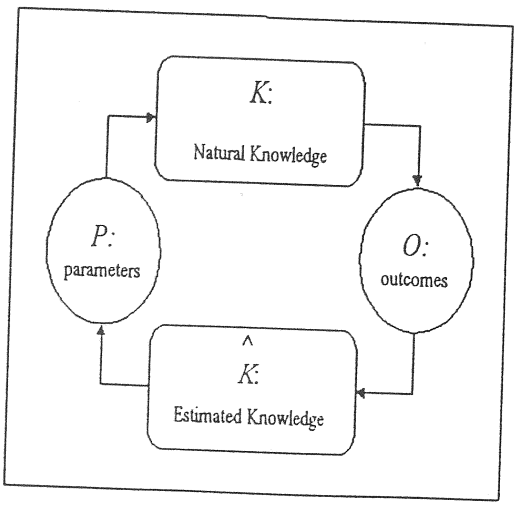


Figure 1. The general model of Virtual Experiment

In the general discussion of curriculum design,

an experiment is designed in one kind of technology to manipulate and prove some pieces of useful knowledge acquired in the classroom. (Gagne, 1968) [Huan91] Therefore, practicum is the course that puts together many learning theories: situated learning, visual learning and cooperative learning. As analyzed, an experiment can be decomposed into five working stages in following, as shown in Figure 2.

1. **Previous Test:** Before an experiment is beginning, it is necessary for keeping the sequence and articulation of the practicum. By the previous test, students can irradiate the goal of practicum, and know how to design and observe from the experiment.

Task Assignment: During the process of an experiment, there would be lots of various tasks to be distributed before an experiment started. A student can learning different knowledge with be different role. Usually, before the experiment is executing in real world, the task should be assigned first. The leader of group will allocate tasks, one student takes responsibility for preparing experiment equipment, one student takes responsibility for recording the result, one or all students processing experiment. But in V.E.E., students' task assignment should be more limpid, because those learners might live in different place, even in different country. As same as the experimental group in real world, the group leader of a virtual group will assign tasks, one designing the experiment scene by equipment objects, one setting the parameters of equipment and environment, and one recording the observational result.

2. **Experiment Conduction:** In this stage, by the operating of experiment equipment, many points should be considered. For example, the setting of parameters, the observing of consequence, the realization of nature laws and the acquisition of the results. In the finally, the destination is to simulate an experiment with the natural law(actual knowledge) to produce the simulation outcomes $O = O(K, P)$.

3. **Verification & Discussion:** After the experiment running over, students have to collect the measured data and then to determine their own estimated knowledge $\hat{K} = \hat{K}(P, O)$, and be verified with variables P and O by V.E.E.. If the estimated knowledge is not correct, students must find out what is wrong, and correct these wrong factors, then do it again from the task assignment step.

4. **Comprehension Test:** It checks how much knowledge has been internalized to students through the experiment.

From the preceding steps, students learn estimated knowledge $\hat{K}$. The difference between K and $\hat{K}$ is an interesting problem. When students do experiment by themselves, natural knowledge will transfer to another actual style, and can be learned by students easily. In another way, natural knowledge is represented by the experiment steps, in the process of "doing" and "practicing", students learn how to design an experiment; how to inference the physical formula or other formulas, and how to control and get a correct experimental result. By knowledge inference, any complicated theory can be analyzed and learned facilely.

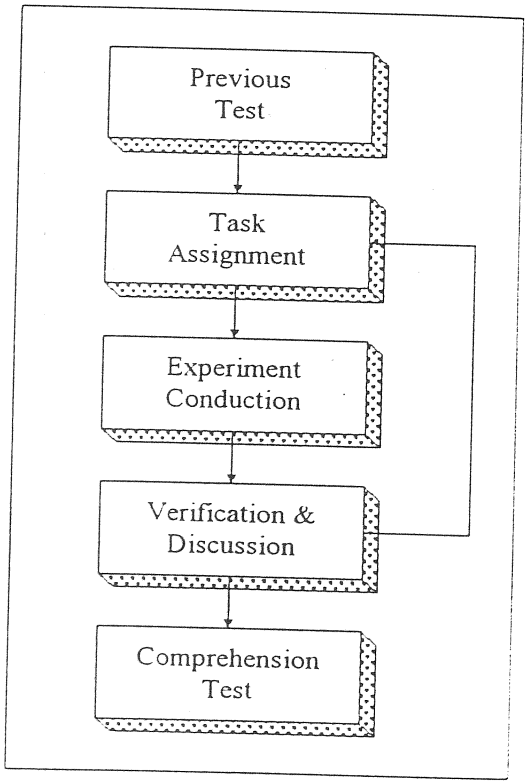


Figure 2. Working Process of Experiment

According aforementioned, it is worth to design the V.E.E. to assist learners to learn knowledge from experiments. The virtual experiment will be analyzed more detail in next section.

3.Analysis of Virtual Experiment

V.E.E. is a laboratory that is established on computer networks to integrate the preceding steps of an experiment. For simulating a real world laboratory, experiment equipment should be created by computer and can be thought as a simulated object in the virtual environment. Every thing in real world has its own characteristic, and it can be simply divided into two part: the visual part and the internal part. The visual part means the object's figure or color, the internal part represents its identity.

The basic object in V.E.E. is virtual experiment equipment, which can be divided into two parts: the visual object and the knowledge object. Both of them are combined to achieve the designated functions of the corresponding equipment in the real world.

Virtual experiment is composed by visual objects and knowledge objects. For example, "Freely Falling Body Motion" is a conversant experiment; when a ball is falling to ground from ten meter height, we observe the ball and measure the value of g, where g is gravity. The ball and ground which are viewable belong to the visual objects; the formula meaning and the measured method belong to the knowledge objects. Incontestably, each experiment object can be divided into several sub-objects, and these objects respectively belong to visual objects and knowledge objects, as shown in Figure 3.

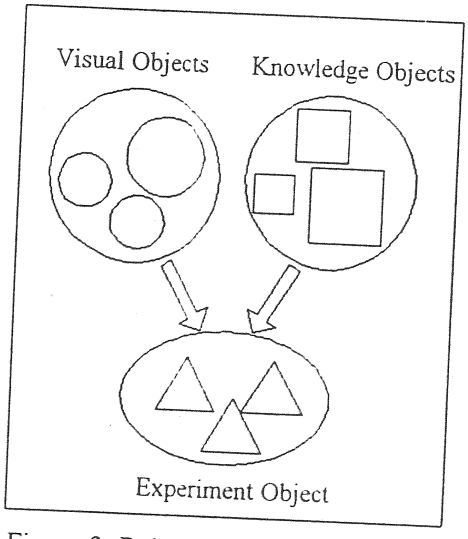


Figure 3. Relationship between Objects

Visual Object

An experiment is represented by several needed visual objects. Every visual objects has its own properties P = (p_1 , p_2 Λ , p_n), and we control their movement by parameters setting(or called properties setting), as shown in Figure 4. For example, a ball in a kinematic experiment has many visual properties such likes volume and color. Therefore, the manipulation of an experimental equipment is through the properties of visual object.

All kinds of visual objects inherit from one ancestor, called shape, which is an abstract object. It defined several basic elements of visualization in the world. Ball inherit from shape, and ground/wall does, too. Slope can inherit from ground/wall, because the former's properties are more than latter, and their identity is similar. After adding the lacking properties, a new visual object will be created easily. The simply inherit hierarchy of visual object is shown in Figure 5.

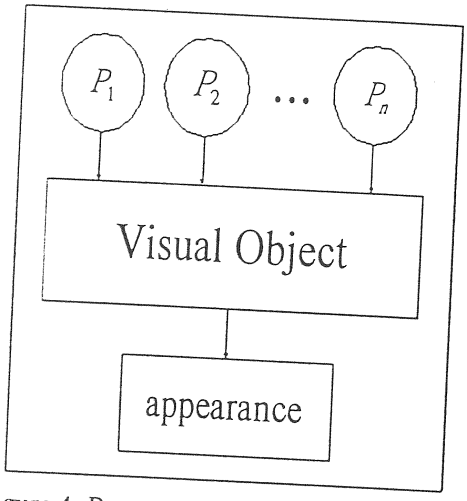


Figure 4. Representation of Visual Object

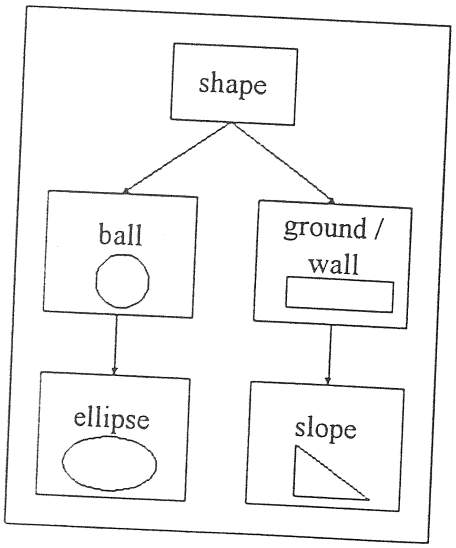


Figure 5. Simply Inherit Hierarchy of Visual Object

Knowledge Object

Naturally, equipment not only has visualized appearance, but its behavior has to follow some nature laws which are treated as some kinds of knowledge objects here. Since any knowledge is learned incrementally, a piece of knowledge can be defined as $K = k_1 + k_2 + \cdots + k_n$. Let Δk indicate those necessary knowledge in an virtual experiment simulating the corresponding real experiment, then all these knowledge pieces can be analyzed as hierarchy of knowledge object, as shown in Figure 6. For example, if a ball is falling from a tree to the ground, it will drop until something stops it, called "Freely Falling Body Motion", which is represented by the formula, velocity $v = gt$ and distance $s = gt^2/2$, where g is gravity, t is the time duration of falling.

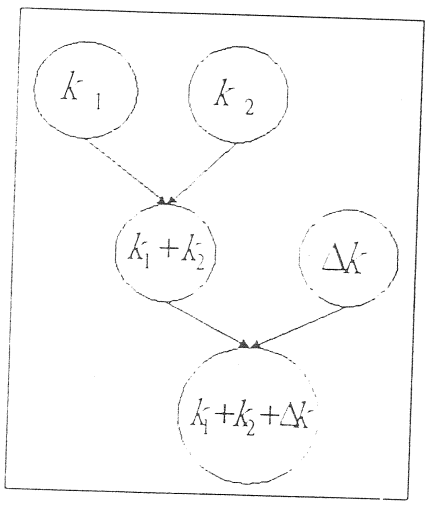


Figure 6. Simple Hierarchy of Knowledge Object

Because the needful knowledge object more complex when the stickiness of experiment is increasing, how to define the knowledge object clearly for raising the reusable identity is the most important work. First, we should know how to infer an experiment. In kinematics, the basic element which construct an experiment usually the divisional time Δt or the divisional distance Δs, now we try to decompose a simple motion. For example, in "Uniform Motion", we find that the basic knowledge object is the time Δt and distance Δs firstly. The Δt means the time which a particle moving linearly from one side to another, and Δs is the distance between two place. By physical formula of Uniform Motion $v = \frac{s_2 - s_1}{t_2 - t_1} = \frac{\Delta s}{\Delta t}$, it is conspicuously that the v should be composed by Δs and Δt, and it means that the knowledge object Δs and the knowledge object Δt construct the knowledge object $\bar{v}$, as shown in Figure 7, and the process of composing is called "knowledge inference".

Experiment Object

As mentioned previous, experiment object is constructed by visual objects and knowledge objects, and V.E.E. involves experiment objects and tools. The major inducement which prompt us to constitute experiment object is the close relationship between visual object and knowledge object.

Visual object merely represent the sight of experiment. Maybe someone will misdoubt about the behavior of visual object, and what way it should be conformed. Effectively, visual objects are coerced by knowledge objects. If there are many visual objects on the platform of virtual experiment, but does not have any knowledge object, the visual objects would loss their meaning, and the platform become a nonsense screen. But if there are only knowledge objects in virtual experiment, students can not select experimental equipment to design the experiment, even they can not see anything. Specifically, a completely virtual experiment environment can not be formed. Therefore, lacking one of them will make the experiment nonsensically.

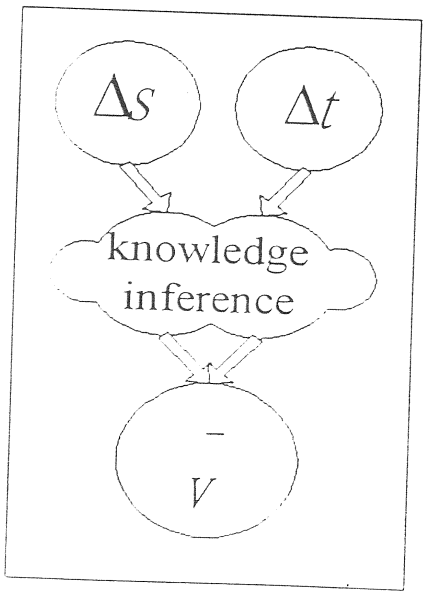


Figure 7 Knowledge Inference of Knowledge Object

In kinematics, physical theory is the kernel,

and the knowledge objects just play this important role. For example, in "Freely Falling Body Motion", we regard it as an experiment object which is composed by visual objects and knowledge objects in V.E.E.. From the viewpoint of visualization, the simplest style of this experiment, is constructed by a ball and ground, as shown in Figure 8, which means that we need only two kinds of visual objects, ball and ground. From the viewpoint of knowledge, the conception of Freely Falling Body Motion is uniformly accelerated knowledge object, as shown in Figure 8, and it is inherited from instantaneous velocity knowledge object.

By necessary objects were equipped in V.E.E., any experiment, call Experiment Object, can be created through the inheritance from both visual objects and knowledge objects. For developing our virtual system, it is worth to research the designment of virtual experiment. It will describe at the next section.

4.Design of Virtual Experiment

The original idea of V.E.E. is that students can use it to do experiment through the computer network, so that virtual experiments can be processed as in real laboratory. Besides, there are many experiments such like "Kepler's Law of Planet Motion", can not be achieved in conventional laboratory, but it can be materialize in V.E.E.. In this section, how to develop and design the V.E.E. system is the major task.

From the preceding analysis, visual object is just like the equipment in experiment, and has its own properties. For convenience to designing, the visual object is called "component" in our system, and it have many properties setting fields. And the component will be represented on the experiment platform according to the property setting.

The rules of component designing conform to the analysis model in previous. In Figure 5, the basic component in V.E.E. is "shape", and all components are inherited form it. Actually, shape is an abstract class, the ball and ground/wall are objects which are inherited form it.

Now, we will explain the inherited solution in our system. Each component has its own properties. When we want to create a new component, the first task we should do is to induce its properties, then we compare these properties with other existent ones. Trying to find out the closest one, and then defining an object which inherit from it, finally, add the lacking properties on it. The reason why ellipse component inherit from ball in Figure 5, is because that the latter is the most similar one to the former.

For designing knowledge objects, completely understanding about the meaning of experiment is the most important. Basically, knowledge object takes responsibility for calculating some necessary value, or we can consider it as a calculating unit. The goal of each experiment is to obtain some specific result, like $\bar{v}$. For the reason, the way of knowledge inference decide the success or failing in experiment.

In V.E.E., knowledge objects are incarnated by using Dynamic Linking Library. Each experiment object has its own script which is designed first, and when the system is running, experiment object will be executed step by step according to the script. Sometimes when specific values need to be calculated, the system will call the relational knowledge objects to solve it. Actually, the knowledge objects also exist in virtual environment. It provides the same function as it is in experiment object.

Virtual environment plays the administrator role in V.E.E.. It controls the action of all objects, environment parameters, and collision detection between visual objects. For keeping the interaction of objects, the message transfer between objects and environment is the most important issue.

There is a detector in virtual environment which takes responsibility for reconnoitering the action of objects. When V.E.E. is running, it can detect the position and situation of all components, especially attend about the happening of objects collision. All visual objects contain the same property respectively, which also called "detector", detecting any visual object within the specific range. Once our system is running, the property "detector" of visual object will start to detect, and if the distance between any two objects is reducing the range, all of them send messages to the detector in environment. Then the detector continually detecting until the collision is happened.

Another task of detector is sending the

position and situation of component to virtual environment sustaining, and then the administrator can allocate the data to the correct processors. The behavior of visual objects which are controlled by knowledge objects are also represented by this way.

For example, doing "Collision Motion" in V.E.E., how can the detector detect that the ball A is closing to the ball B, and what happen when the ball A collides with the ball B, as shown in Figure 9, within the properties rectangle, D means the property "detector" in visual objects. D can get the range between ball A and ball B in real time, and once when the range induce into a specific value, it will send message to environment detector. The black arrowheads represent the message transfer way between the detector in object property and in environment.

After the design of virtual experiment, and the architecture of V.E.E. then can be constructed on the Internet as shown as Figure 10. A simple example system will be introduced through this architecture and those objects, knowledge objects, visual objects and experiment objects, in the next section. And we will explore the merit and drawback of V.E.E..

5.Example System and Discussion

Our example system is developed as Figure 11 shown. And the experiment object is Freely Falling Body Motion. User must login the system first, and in confirmation of connecting the network, it means that user is in multi-user mode. After login successfully, user can select one interesting experiment group and join the group. Each group needs three users, and one of them is group leader.

The group leader is decided with the priority of login time by system. If user become the member of group, he/she must pass the previous test before doing experiment. And then, the leader will assign tasks. Every user in V.E.E. takes responsibility for different tasks. One of the task is arranging the experiment equipment, other setting the initial values of properties and environment parameters, and the other designing the observant items in Watch Form.

After completely the preparing undertaking, the experiment is ready. When the leader press the "run" button, the component on "Soft Lab Platform" as shown in Figure 11, will move according to the set values. And users can see the experiment results which are shown on Watch Form.

At the ending of execution, record the results and verify if the results are correctly. If every thing is successfully, the latest step is passing the comprehension test. If the results are not right, do the experiment again from the task assignment step.

The best advantage in V.E.E. is that it can extend without limit. It is also the best merit in Object-Oriented Analysis. Everything is object, and every object is independent individually. When we need any object, it can be plug-in. The system with Object-Oriented Design increase not only the expansibility, but also the latest quiddity in our system.

In Object-Oriented Analysis, "reuse" is a greatly idea. V.E.E. is inevitably to develop with "reuse". In preceding, we can get knowledge objects ΔS and Δt. They can be reused if we want to create a new knowledge object. For example, in "Uniformly Accelerated Motion" $a = \frac{V_t - V_{t_0}}{t - t_0} = \lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t} = const$, we find out that the precedent knowledge objects ΔS and Δt can be reused. The first solution is computing the "Instantaneous Velocity" by ΔS and Δt with formula $v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t}$, then calculating V_t and V_{t_0} at time t and t_0. Eventually, knowledge object a can be created.

The reuse model can be used not only in knowledge objects, but in visual objects and experiment objects. If we feel that the experiment is not enough or not suitable for our requirement, we can add the new experiment object or replace it.

6.Conclusion

Learning through the experiment model is the emphasis of education today. To assist students obtain the actual knowledge K in the process of experiment at anywhere and anytime, the V.E.E. system is designed to achieve the goal.

Using Object-Oriented Analysis, V.E.E. is

decomposed into several objects. The major constructions are experiment objects, and they can be divided into visual objects and knowledge objects again. The former impact our viewability, and the latter effect the estimated knowledge $\hat{K}$ we obtained.

The V.E.E. is develop on the base of experiment object hierarchy, and must be consistent with the practicum stages in the curriculum design.

The advantage of V.E.E. is emphatic about the reusability of experiment objects. Since each experiment object is independently constructed with both visual object and knowledge objects, its reusability could be largely incremental. Another worth of this V.E.E. is that it can simulate those experiments which are difficult or even impossible to be implemented in the real world, suck as Kepler's Planet Motion.

Although V.E.E. is a computer networks system, we hope it can be develop on WWW in the near future. And there will more benefit form it.

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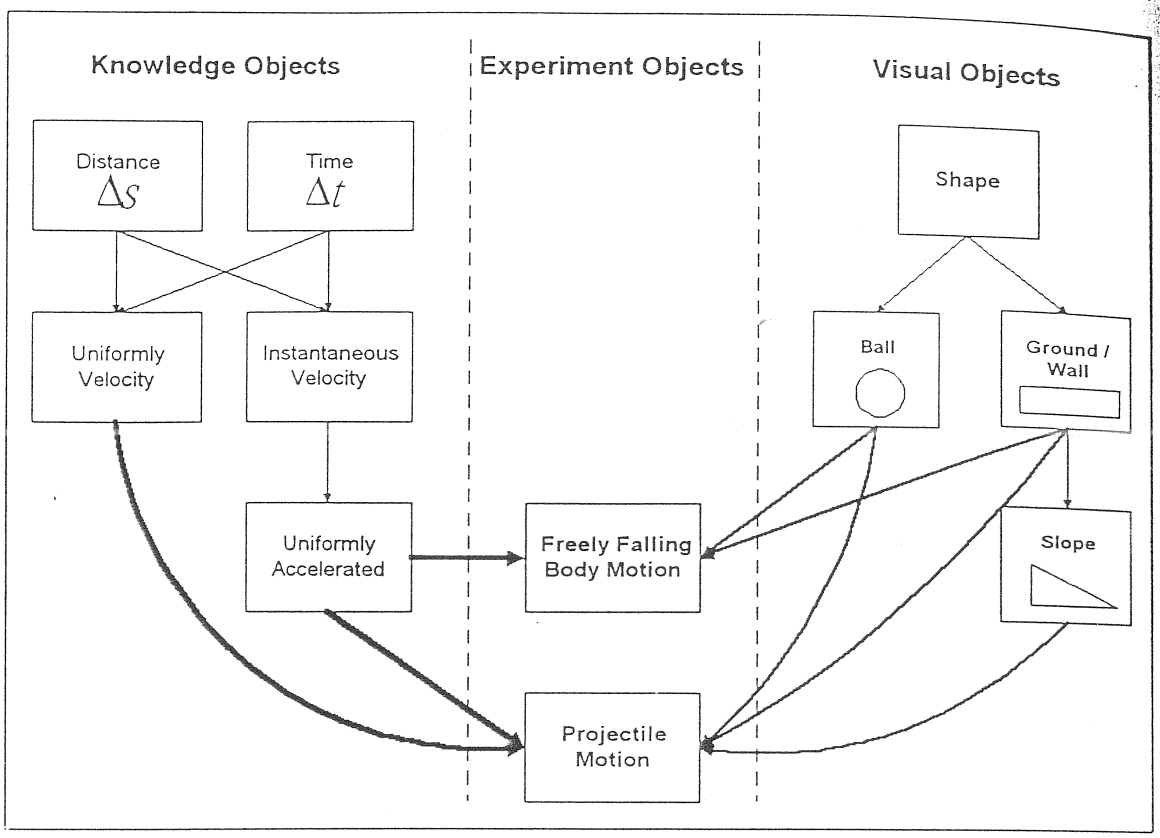


Figure 8 Experiment Object Hierarchy

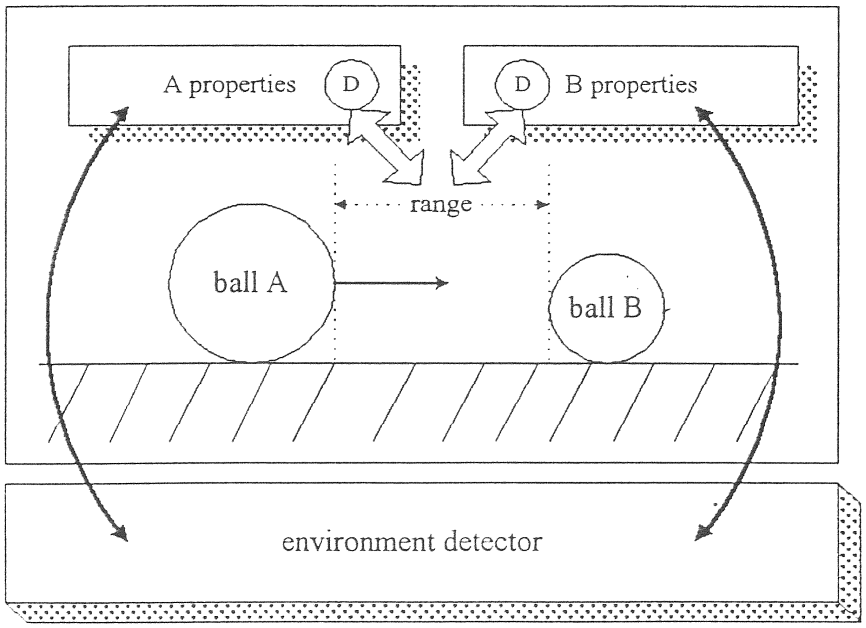


Figure 9. Representation of Collision Model

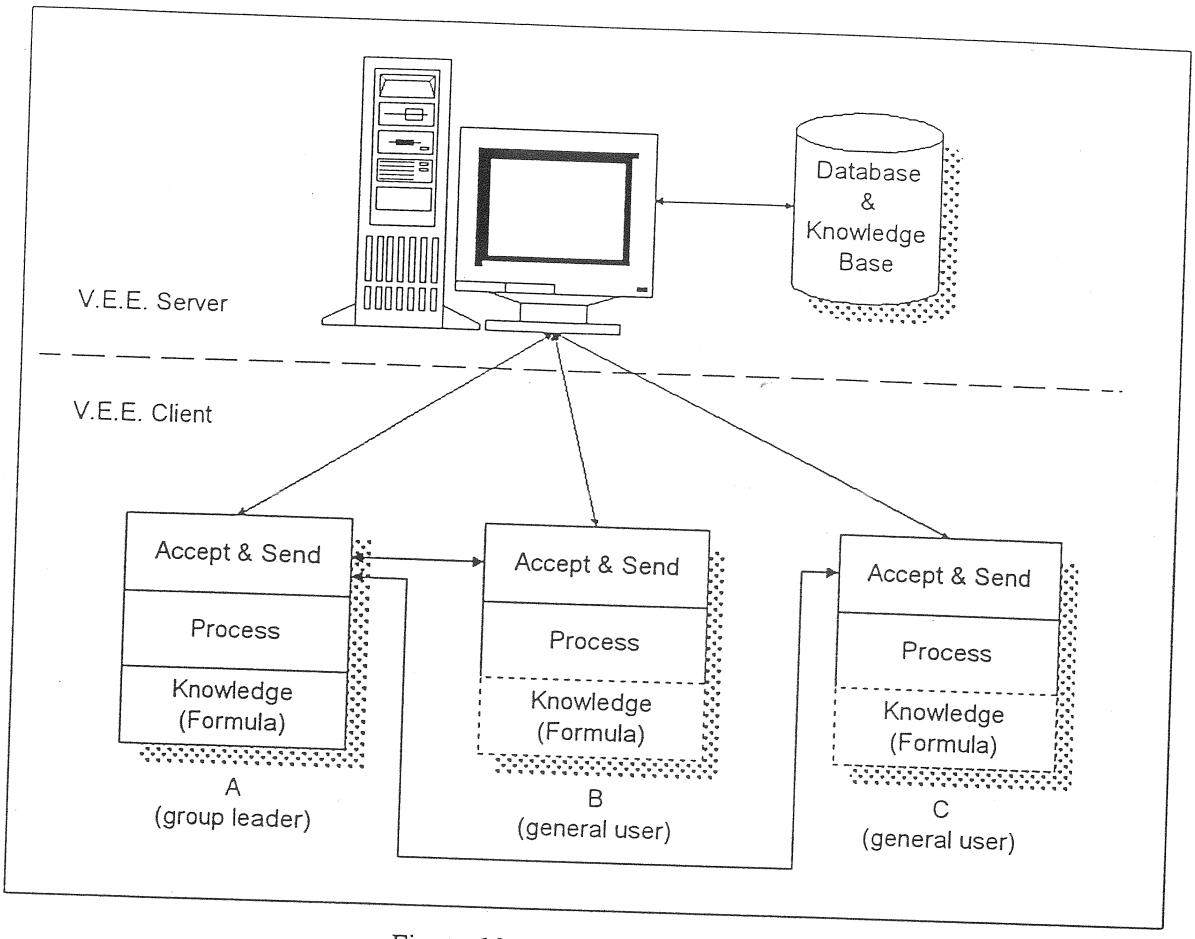


Figure 10. Architecture of V.E.E.

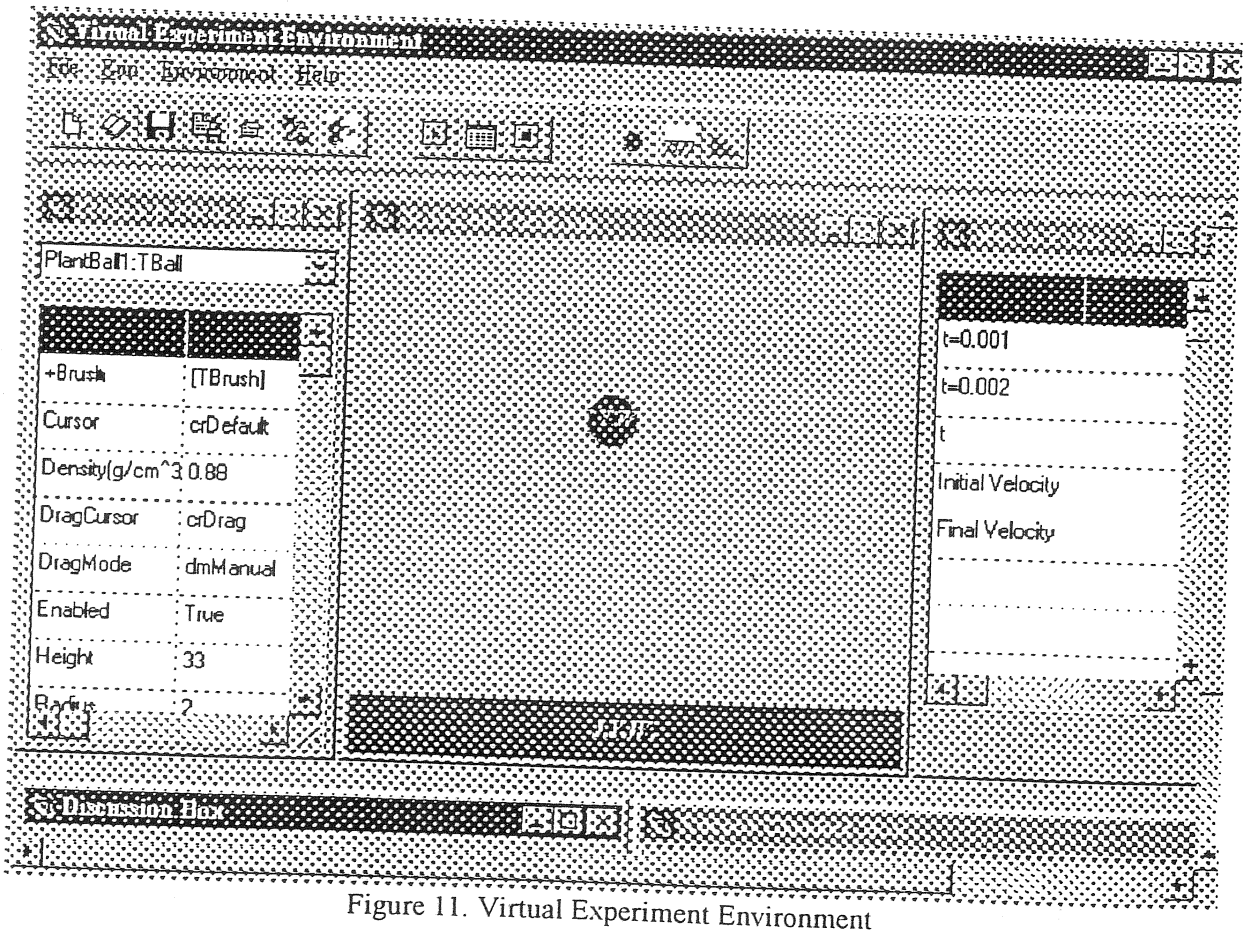


Figure 11. Virtual Experiment Environment