Tablet VR-Learning System: Chemical Laboratory Experience System

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***Abstract*—Education builds culture of human for many years. The method of education has been developed from oral communication and textbook to broadcasting and e-learning. According to development, children have become to be free for place, time and teacher who gives some advice. On the other hand, the opportunities that children contact with real things and experience is getting decrease. Generally speaking, experience is important for the education such as physical education, art and also science. In addition, it is usually difficult to have a good environment for experience at a self learning situation and e-learning systems. In this paper, we describe a chemical laboratory experience system using VR technology for primary school students, as a VR-learning system. In addition, we confirm the usefulness through experiments that several primary school students use this system.**

***Keywords*-Education culture; VR-learning; Chemical laboratory system; 3D tablet interface**

I. INTRODUCTION

Education is very important to build culture of human. First we would like to look back upon bygone education. When an institutional school did not exist, transmission of information, in another word; education to children depended on oral communication traditionally. However, it became to be necessary to socialize enormous numerical children systematically and uniformly in the industrial society. Therefore cultural human being made the artificial communal space such as a school, when there were some literal people who used letter and character. They introduced a private elementary school at the Edo period for example (figure 1) [1] [2] [3]. Then it had become possible to transfer a large amount of the unified information by using a textbook.

Times had changed after that, language education program was started to broadcast on radio at 1925 by Nippon Housou Kyoukai (present NHK; Japan Broadcasting Corporation) (figure 2) [4] [5] [6]. Although people had been able to see text and picture (include photo) printed on a textbook, they became to be able to listen a good example at home without a teacher (figure 3). Other education programs were started also on TV, they could see, i.e., gesture and situation as a video. In addition a music tape and video tape of them were started also to sale, students were set free from not only place but also time.

The culture of education has changed recently, students can browse electric textbook on PC, and of course watch and listen sound and video. You usually call this system as an e-learning [7] [8]. Some of these systems can mark answers for questions, also voice student vocalizes (figure 4). Students are still free from place, time and teacher who gives some advice, but we feel something is missing for education and we are not satisfied without it.

While education is made efficiently, the opportunities that children contact with real things decrease rapidly, and the experiences in real life are getting evolved into something artificial represented by TV, video and electronic device such as PC. Then the reality is going missing from children's environment. There is a surprising experiment [9]. The author gave a task to draw the picture of a chicken for 153 children at Hiroshima Takehara Municipal Yoshina junior high school in 1989, then 19 chidden drew the chickens which had four feet (figure 5). Some of them drew no-beak chicken and no-tail one. You can know that there is a problem about education since lack of real life experiences such as activities that bring them into contact with nature.

Generally speaking, experience is important for the education such as physical education, art, music, craft, cooking and also science. It is usually difficult to have a good environment for experience at a self learning situation and e-learning systems. However the development of the education gives new various knowledge to a human being, and it will lead to the development of culture.

In our laboratory, we focus on experience-type education system based on information technology, actually virtual reality technology, and develop a chemical laboratory

Figure 1. Private school; Tera-koya [2]

Figure 2. Radio text, English-conversation [4]

Figure 3. Illustration of education program on radio

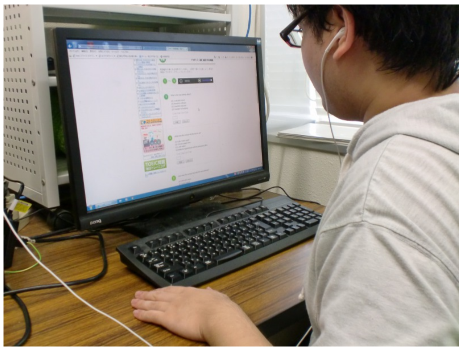

Figure 4. Self-study using e-learning system

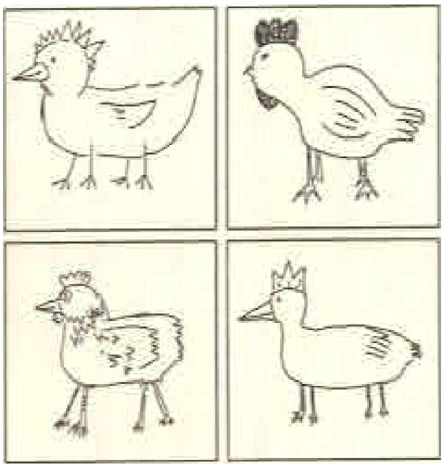

Figure 5. Chickens which have four feet [9]

experience system for primary school students [10] [11]. They can move actual beaker and flask on which position sensors are attached, and see chemical reaction on visual monitor, then confirm a procedure of experiment. We are developing also VR cooking learning system (figure 6, 7) [12] [13].

It is necessary to represent liquid behavior to make VR chemical laboratory experiment system. However hydrodynamics is too complex to solve in real time. There is an SPH method which is a kind of particle method [14], and it makes possible to represent exact behavior of liquid for computer graphics and VR systems. However it still needs enormous calculation, and high performance computer. Therefore it is not suitable for our system that is designed for using in educational institutions and households. Using it at school, facilities have to prepare much number of systems. Students who have to stay at home and hospital needs low-cost and light-weight device. It means we have to develop faster calculation method to represent liquid behavior.

We have developed a particle and volume based liquid model focused on real time processing and interaction. In this model it is considers to divide liquid into two conditions; one is the stay condition in a container, and another is the free fall condition. The stay one is expressed with particles which are not consider to be interfere between each other. The fall one is managed based on the volume in the container. This model realizes that user can scoop, receive and spilling liquid with a container. Our pilot system obtains position and orientation of a container through a 3D motion sensor.

On the other hand, tablet devices become popular and are introduced to education platform as e-learning devices. Also applying our system to more low-cost and light weight device such as tablet, occasionally it is difficult to propose 3D motion sensor for VR-learning system. Then we try to develop the method to manipulate three dimensional operation of liquid container using a touch panel of tablet device. We propose new model that user can rotate an object along latitude and longitude lines like the earth after consideration of some typical methods. This model can realize to rotate an object as expected without discomfort.

As below, we describe the overview of a particle and volume based liquid model and the chemical laboratory experience system on PC in Section 2, and 3D rotation model on tablet touch panel in Section 3. Then we show experiments and conclude.

II. PARTICLE AND VOLUME BASED LIQUIDMODEL

A. Virtual liquid model

We consider that liquid is divided into two conditions in particle and volume based liquid model we have proposed.

1) Free fall condition liquid: spills from a container and a tap
2) Stay condition liquid: stays in a container such as a cup

Figure 6. VR cooking learning system (1)

Figure 7. VR cooking learning system (2)

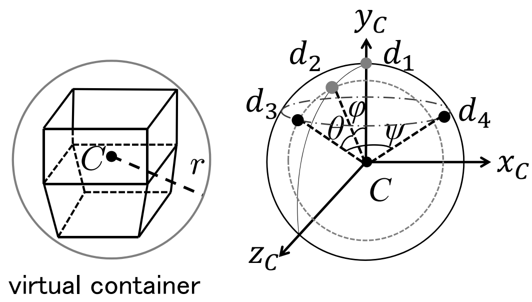

Figure 8. Representation of virtual container

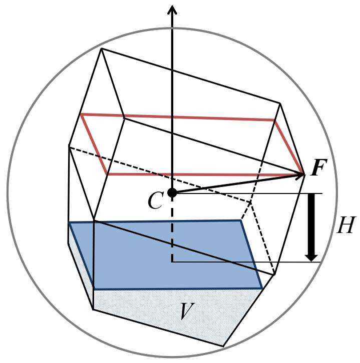

Figure 9. Liquid parameters for virtual container

The liquid of condition 1 is represented based on particles. We do not consider interferences among particles such as collisions and intermolecular forces between particles and the size of them. Each particle moves according to only inertia and gravity. The particle coordinate $\mathbf{P}_i(t)$ at time t is calculated by the following equation (equation 1).

$$\mathbf{P}_i(t) = 2\mathbf{P}_i(t-\Delta t) - \mathbf{P}_i(t-2\Delta t) + \mathbf{g}\Delta t^2 \tag{1}$$

Where $\mathbf{g}$ is gravitational acceleration vector, and Δt is the rendering update interval.

The liquid of condition 2 is managed by the volume. The volume of liquid in a container at time t is defined as V_t. It means, we can decide the height of liquid surface where we know the volume and the attitude of the container, of course without any wave and convection. When one condition liquid transits each other, it is changed to another condition with exchange rate N[number of particles / volume].

B. Virtual container model

In this model, we consider the sphere which contain a container for simple interference detection. The center of the sphere is C and its radius is r. In addition, we define the container coordinate system (x_c, y_c, z_c) with the origin C, and represent the attitude of the container with the intersection point between the sphere and the axis y_c (d_1 in figure 8). First the container is rotated by ϕ with the axis x_c and point d_1 moves to d_2. Then it is rotated by θ with also the axis z_c and point d_2 moves to d_3. Its attitude is represented as the parameters (ϕ, θ). In addition its orientation is the rotation ψ with axis y_c where point d_3 moves d_4. In a first pilot VR system, these parameters are obtained using 3D position sensor. Introducing tablet device to VR-learning system, we consider to get these rotations through a touch panel interface in the next section.

C. Liquid manipulation model with container

The liquid condition in a container changes from 2 to 1 when the container is tilted and liquid spills. First we assume a convex container and some parameters are defined as shown in figure 9. Where we assume the maximum volume of liquid which can exist in the container as maximum capacity V_m. When the liquid volume V in it exceeds V_m, liquid flows out at point $\mathbf{F}$ with exchange rate N. The flow point $\mathbf{F}$ is defined as a relative vector based on point C (equation 2). The liquid surface level H is also defined as a relative hight based on point C (quation 3). And the equation 4 of the liquid volume V is obtained from equation 3. Starting up a system, it makes a lookup table for these equations.

$$\mathbf{F} = f(\theta, \phi, \psi) \tag{2}$$

$$H = h(\theta, \phi, V) \tag{3}$$

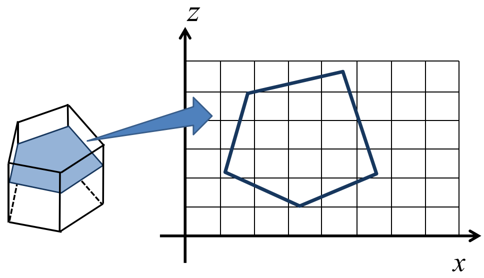

Figure 10. Grid for liquid surface

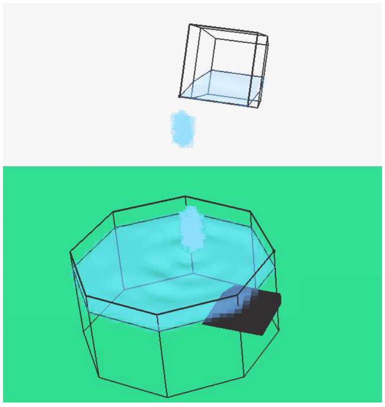

Figure 11. Falling liquid into another container and wave

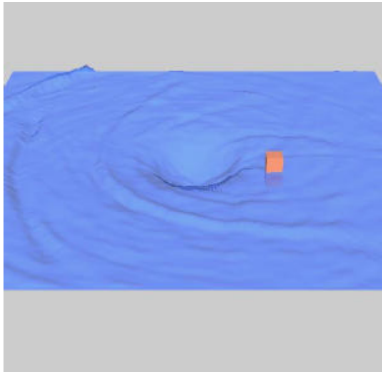

Figure 12. Stirring liquid with red cube and vortex

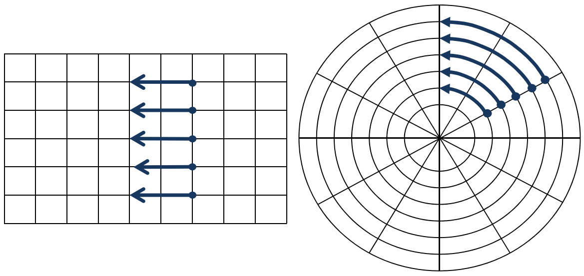

Figure 13. Orthogonal grid and concentric grid

$$V = v(\theta, \phi, H) \tag{4}$$

The liquid condition which falls changes from 1 to 2 when a container catches liquid. The particles which are caught into it is added to the volume V of the container according to exchange rate N. When a container skims liquid from another container, appropriate volume is transferred still as condition 2. In addition a concave container like flask is represented as some convex ones.

D. Representation of wave

The liquid condition 2 is stay condition as mentioned above. However liquid is usually waving when a container is moved and swung. Our idea was that we considered steady state and that liquid surface as a basic surface first. Then some effects are mapped on the basic surface. In order to represent wave, liquid surface is devised into a orthogonal grid (figure 10), and wave is propagated by two-dimensional wave equation as followed (figure 11).

$$\frac{\partial^2 z}{\partial t^2} = v^2 \left(\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2}\right) \tag{5}$$

Where v is the speed of wave propagation, and z is the hight of each grid point.

Furthermore, we considered vortex when liquid is stirred, i.e. by stick, and propose a concentric grid. We also introduced the equation to represent an outline of vortex (figure 12) [10]. The outline is set at the basic surface level, then concentric wave is mapped there to represent vortex (figure 13).

E. Representation of diffusion of color

We also considered about a diffusion of liquid color using a grid (figure 14). Representing liquid surface more realistic, the grid is configured with a few layers (figure 15). The diffusion happens according to the equation below:

$$\frac{\partial P(x,y,z,t)}{\partial t} = D\left(\frac{\partial^2 P(x,y,z,t)}{\partial x^2} + \frac{\partial^2 P(x,y,z,t)}{\partial y^2} + \frac{\partial^2 P(x,y,z,t)}{\partial z^2}\right) \tag{6}$$

P denotes the concentration of the liquid at a certain point, and D is the diffusion coefficient.

A similar method is used for the side surfaces. A slice from the middle of the container facing the viewer but parallel to the y axis is used for diffusion of color as shown in figure 16. The side projection is put onto the surfaces that are visible from the viewpoint and that are facing forward. The diffusion is then represented by applying a texture on each polygon of the side surface (figure 17).

III. 3D ROTATIONS WITH TOUCH PANEL INTERFACE

A. Conversion from projected 2D circle to 3D spherical coordinate

Rotating an object in 3D space through 2D plane, we first explain about the method to converse the 2D coordinate on a plane to 3D coordinate on a sphere. We consider that the sphere which contains a container in 3D space is projected as a circle on a 2D screen which is a touch panel (figure 18). The locus touched with fingertip

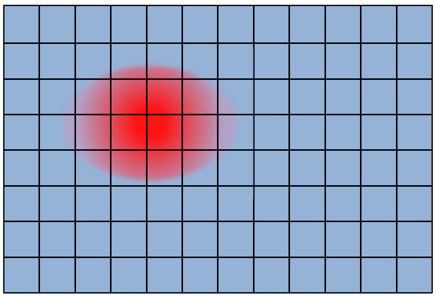

Figure 14. Diffusion of color in liquid surface

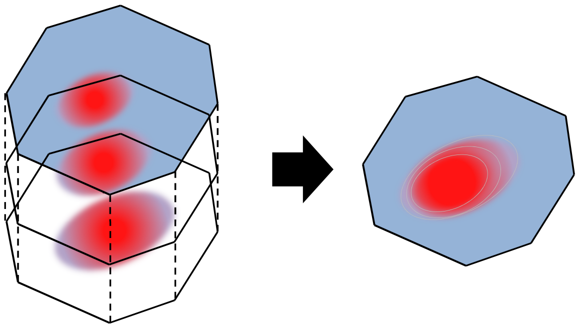

Figure 15. Multiple layers of grid to represent coloring

from A to B is mapped to the locus from a to b on a 3D sphere (figure 19). Then we assume that there is a hemisphere on the screen, and its section matches to the circle for easy understanding. The position touched on the touch panel with fingertip is designated as the coordinate (X, Y), and the radius of the circle is designated as R. Then the height Z on a virtual hemisphere is calculated by equation 7.

$$Z = \sqrt{R^2 - X^2 - Y^2} \tag{7}$$

In other words, we obtain the 3D point (x, y, z) on the sphere which radius is r in 3D space from equation 8.

$$\frac{r}{R} = \frac{x}{X} = \frac{z}{Z} = \frac{y}{Y} \tag{8}$$

From this equation, we can get the three-dimensional coordinate corresponding to the touch position.

B. Rotation through 2D interface

1) Rotation sphere which is fixed only center: There are some methods to rotate an object in 3D space through 2D interface, but each method has advantages and disadvantages. First we describe the rotation method where the object center is fixed. As shown in figure 20(a), the 3D points a and b is obtained from the 2D points A and B on the touch panel. The rotation axis $\mathbf{Q}$ is defined as a normal line of the plane which contains the point a, b and C. Then the object is rotated by λ on the axis $\mathbf{Q}$. However you feel uncomfortable when you move your fingertip horizontally, because you usually image rotation of the earth and the top/bottom-touch rotation is different from center one (figure 21).

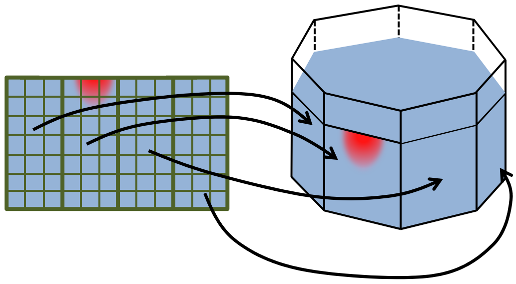

Figure 16. Mapping to the side surface

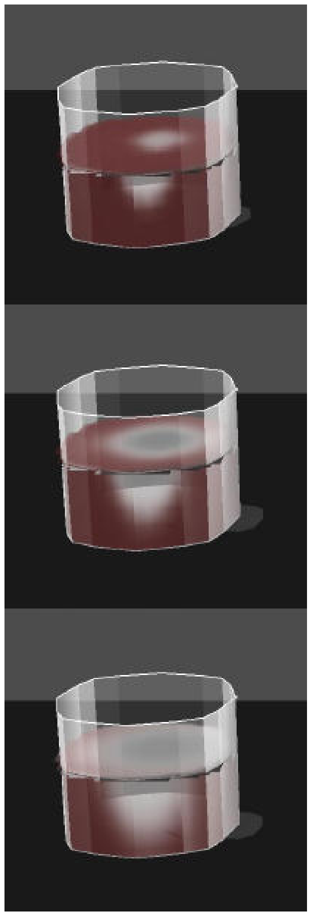

Figure 17. Color diffusion on side surface

2) Rotation sphere with axis parallel to screen: Next we describe the rotation method where the rotation axis is limited parallel to screen. As shown in figure 20(b), the 3D points a and b is also obtained mentioned above. The rotation axis $\mathbf{Q}$ is defined as the line passing through the sphere center, and the projected line $\mathbf{Q}$ onto 2D screen is perpendicular to the movement of finger from A to B. Then the object is rotated by λ' on the axis $\mathbf{Q}$. Thus we can solve the uncomfortable feeling of preceding model. However the rotation on the vertical axis to the screen is impossible in this model (figure 22), although preceding one can realize it by drawing a path on a circumference.

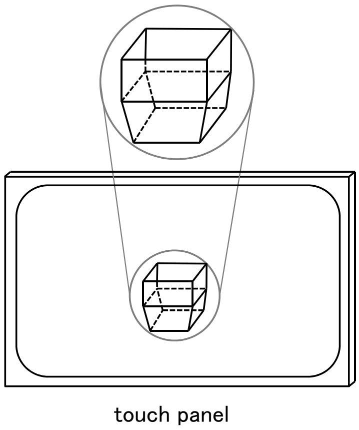

Figure 18. Projection to a touch panel

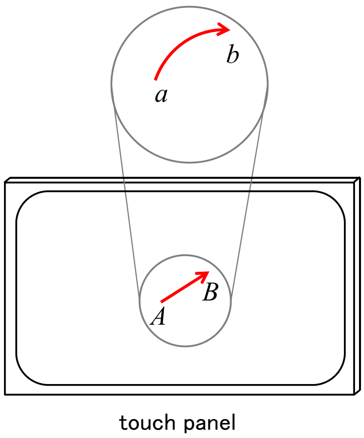

Figure 19. Loci of circle and sphere

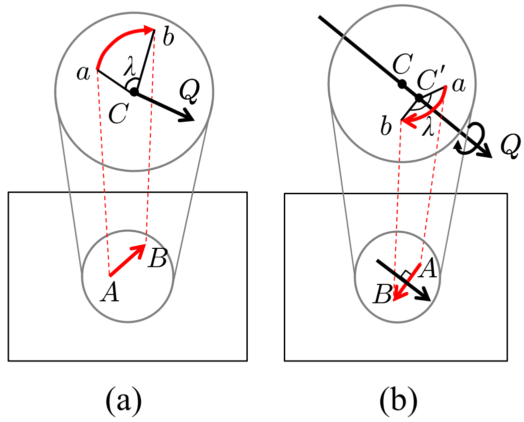

Figure 20. Typical methods to rotate through 2D screen

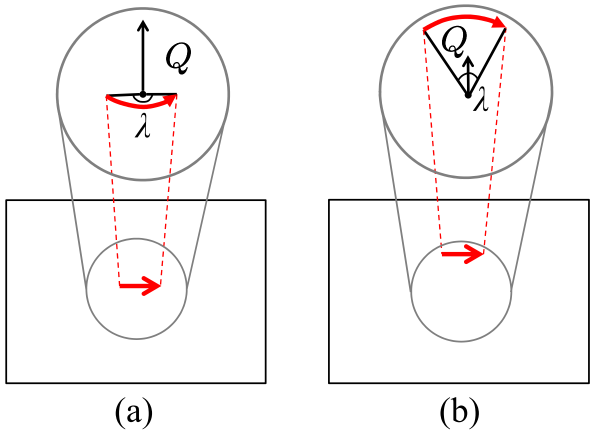

Figure 21. Different rotations between two parallel fingertip motions

C. Rotation sphere using geographic coordinate system

Therefore we introduce a geographic (latitude and longitude) coordinate system, and propose a new interface model. In this model the movement of the fingertip on a screen is decomposed into the latitude and longitude components, and an object is rotated like a terrestrial globe is rotated along longitude and latitude lines. A point on the sphere is capable of multiple representations as orthogonal coordinate system $(x,\ y,\ z)$, a polar coordinate system $(\theta,\ \phi)$ and geographic coordinate system (α(latitude), β(longitude)). First the 3D points a and b is also obtained (figure 23), and the locus from a to b is decomposed using point w. Where we define geographical coordinate of point a as (α_a, β_a) and b as (α_b, β_b), point w is represented as (α_b, β_a). Next the sphere is rotated on the earth's axis by latitude component, in other word, the amount of change in latitude parameter $(\beta_b - \beta_a)$. Finally we consider the rotation such as the touched longitude line will not move on appearance. The sphere is rotated by $(\alpha_b - \alpha_a)$ on the axis $\mathbf{Q}$ which is the normal line of the plane contains the point a, w, C, in other word, contains the longitude line β_a (figure 24). Combining these rotation, we determine the tile and the orientation (θ, ϕ, ψ) of a container after rotation based on the locus of the fingertip on a touch panel.

D. Judgment on neighborhood of circumference

In our new model, you can rotate an object on the perpendicular axis to a screen when you trace over the circumference. However it is difficult to trace it accurately due to the conditions such as the sensitivity of a touch panel and the thickness of a fingertip. We would like to introduce the auxiliary circle that radius is larger than the circle projected on the screen (figure 25(a)). When you touch the area between the circle and the auxiliary one, the operating point is assume as the intersection point between the circle and the line from touched point to the circle center (figure 25(b)). The rotation on the perpendicular axis become easier.

IV. Experimental Result

We have already developed the first pilot system of chemical laboratory experiment using the model mentioned above on desktop PC (figure 26). The main target is primary school students. This system can help to understand chemical reaction and experiment procedure through

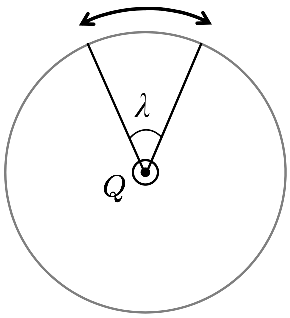

Figure 22. Rotation on vertical axis to screen

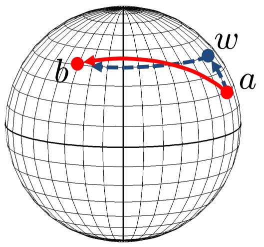

Figure 23. Decomposition of movement of fingertip

virtual experience. But we assume that the reaction and the procedure are well known, and unknown experiments are not considered. In this study, the virtual chemical laboratory system using the interface mentioned above was implemented on tablet device (figure 27). The specification of tablet is the following;

- Device: acer ICONIA TAB A500-10S16
- CPU: Tegra2, 1GHz
- OS: Android Honeycomb 3.1

In this experimental system, the operation of the mobile container that an operator can move is realized as the following.

- The translation of 2DOF by normal drag operation
- The translation which is perpendicular to the screen by the drag operations with two fingers
- The rotation of the proposed model after toggled to rotation model by tapping the container

However we implement only some functions on tablet because of the machine performance, i.e. except vortex and side surface drawing.

Figure 28 and 29 show the appearances that primary school students operate chemical laboratory experience system on tablet. The subjects are 9-year-old girl and 6-year-old boy. They could move and rotate a container through the touch panel as they expected only with simple explanation. We got the following impressions about this system.

- This was interesting, they had fun.
- They felt that they really operated and mixed water.
- The girl understood the change well when mixing two colors.

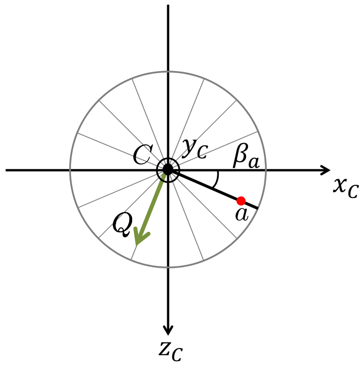

Figure 24. Axis for latitude component movement

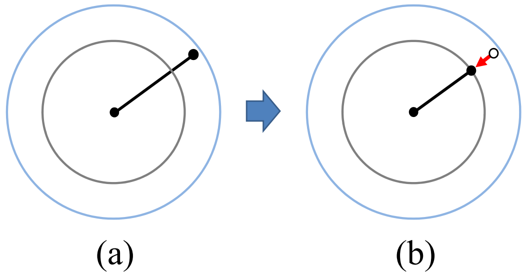

Figure 25. Auxiliary circle for perpendicular axis rotation

In addition, after our experiment they continued to use our system for more than an hour.

As a result, we found that our chemical laboratory experience system on tablet is still useful to learn chemical reactions, and our new interface to rotate an object in 3D space through 2D screen is effective.

V. Conclusion

In this paper we focused on education, and described our VR-learning system; virtual chemical laboratory experience system. In order to make it become popular, we developed our system on a tablet device that has become popular and is introduced to education platform as an e-learning device. And we proposed the 3D operation interface through 2D screen. Also it is confirmed that a few primary school children could have a good experience using the tablet VR system. This system is useful to obtain experiences that is getting decrease when education is developing. The following is considered as future works.

- Larger scale evaluation experiment in real field of education
- Develop a multi-touch 3D operation ingerface

We also would like to make VR-learning system popular to the education field, not only chemical laboratory experience system, but also other VR contents such as VR cooking learning system that is developed in our laboratory.

Acknowledgment

We thank our colleagues in our laboratory for useful discussions. This work was supported in part by JSPS

Figure 26. Chemical laboratory experience system on PC

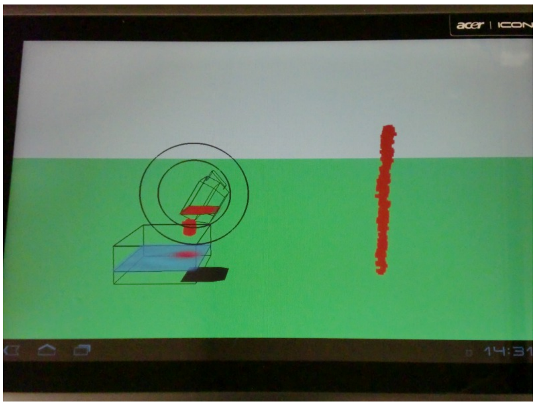

Figure 27. Chemical laboratory experience system on tablet

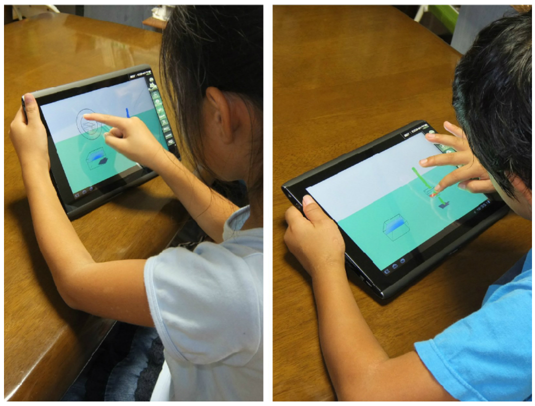

Figure 28. Appearances of experiment (1)

Figure 29. Appearances of experiment (2)

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REFERENCES

[1] Haruo Shirane, Tomi Suzuki, “Inventing the Classics: Modernity, National Identity, and Japanese Literature”, Stanford University Press, 2002.

[2] Margaret Mehl, “Private Academies of Chinese Learning in Meiji Japan: The Decline and Transformation of the Kanguku Juku”, Nordic Institute of Asian Studies, 2003.

[3] Benjamin Duke, “The History of Modern Japanese Education: Constructing the National School System, 1872-1890”, Rutgers University Press, 2009.

[4] Nippon Housou Kyoukai, https://www.nhk-book.co.jp/recommend/80-02anni/gogaku/, (in Japanese)

[5] Robert L Hilliard, Michael C Keith, “The Broadcast Century and Beyond: A Biography of American Broadcasting (5th edition)”, Focal Press, 2010.

[6] Karen Swan, Carla Meskill, Steven Demaio, “Social Learning from Broadcast Television (Media Education Culture Technology)”, Hampton Pr. , 1998.

[7] D. Randy Garrison, “E-Learning in the 21st Century: A Framework for Research and Practice”, Routledge, 2011.

[8] Rita De Cassia Veiga Marriott, Patricia Lupion Torres, “Handbook of Research on E-Learning Methodologies for Language Acquisition“, Information Science Reference, 2008.

[9] Jun Kato, “Multimedia and Education”, Tamagawa University Press, 1990. (in Japanese)

[10] Y. Natsume, A. Lindroos, H. Itoh and K. Funahashi, “The Virtual Chemical Laboratory Using Particle and Volume Based Liquid Model”, Proc. SCIS & ISIS 2010, pp.1354-1359, 2010.

[11] T. Tanabashi, H. Itoh, K. Funahashi, “Representation of Wave Surface on Virtual Water Manipulation” Proc. SCIS & ISIS 2008, pp.1460-1465, 2008.

[12] Y. Kurimoto, K. Funahashi, “The Collapse of Group of Individual Bodies Using Transformation Surface for Virtual Cooking System”, Proc. IWAIT 2013, pp.118-123, 2013.

[13] T. Ishihara, K. Funahashi, “Partial Sphere Container as Chinese Pan with Convex Bottom for Virtual Cooking System”, Proc. IWAIT 2013, pp.957-962, 2013.

[14] Jun Chen, Kejian Yang, Yuan Yuan, “SPH-based visual simulation of fluid” ,Proc. ICCSE, pp.690-693, 2009.

[15] S. Hasegawa, O. Sahara, A. Hasegawa, T. Tagawa, S. Ozaki, “Use of Tablet Terminals in Education : Introduction of iPad to Nagoya Bunri University”, Journal of Human Interface Society, Vol.12, No.4, pp.245-252, 2010.