Liquid Tangible User Interface: Using Liquid in TUI

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Abstract. In recent years, tangible user interface (TUI) has been paid attention on as a next generation user interface. In most TUI researches, solid body is mainly used as manipulators to assist interaction and they do not focus on "liquid". So, I focused on liquid as real world object, and I proposed the interaction using liquid in TUI and confirmed advantages of the interaction. As the result, there are some advantages in the adjustment of a sensuous amount comparing solid TUI.

Keywords: Tangible User Interface, Liquid, Education.

1 Introduction

Tangible user interface (TUI) is one of the active research fields in Human-Computer Interaction. In TUI, physical affordance of real world objects is utilized to assist the interaction. In most of TUI researches, solid bodies, such as blocks and panels, are used, as real world object to assist interaction [3, 4, 5, 6, 7] and only few researches have not paid attention to "liquid" which is one of real world object as the physical objects though there must be some specific advantages to using liquid in TUI as real object.

One of studies about using liquid in TUI is Mann's study[1]. In this study, water is used instead of piano keys and the users can listen to a song as if they play the piano when they press down their fingers into the continuous water flow. However, they just replace the piano key to the water and don't utilize the features of liquid.

In this paper, therefore, we propose an interaction used liquid in TUI, named Liquid Tangible, and discover the advantages in Liquid Tangible.

While solid is a discrete substance, liquid is a continuous substance. So, using liquid as a manipulator in TUI must have two merits. First, we can use much information by using liquid. Liquid can represent decimal point number, while it is hard to represent it by solid. For example, if we want use blocks to represent decimal numbers, we need many types of block (for example, brocks for the one's place, the ten's place, the tenth's place and etc of block) and many blocks. Second, we can more easily adjust

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volume continuously with liquid than with solid, because liquid is a continuous substance.

To utilize these advantages, we focused on the virtual "chemistry experiment" because they require the subtle adjustment of chemical reagents. By adopting the Liquid Tangible to the chemical experiments, the system allows users to observe various stage of chemical reaction by the difference in the amount of multiple chemical reagents according to the users' sensible adjustments of their amounts.

Song[2] was developed a virtual chemical experiment system using used empty beakers and table-top interface . However, in this system, there is no movement of the actual content, because of using empty beaker. Consequently, they don't discuss advantages of using liquid in this study.

2 Liquid Tangible System

In this study, I focused on neutralization experiments and salt crystallization experiments as chemical experiments. In this system, we use water instead of chemical reagents.

We also designed some actions for the Liquid Tangible chemical experiments by mimicking the actions which are used in actual chemical experiments. There are three types of actions. First action is the one to mix multiple types of liquid. To mix multiple types of chemical reagents, user can actually pours each liquid into a beaker. By this action, the system visualizes the process of chemical reaction according to the poured amount (Fig.1). The process of changing the molecular structure is displayed just beside the beaker and the colors of liquid also change according to the pH value as same as in using bromothymol blue.

The second action is stirring liquid by a stick. This action is used to mix the liquid well. By this action, the chemical reaction proceeds more when the molecules are separated from each other (Fig.2).

The final action is adding hot water. This action represents boiling liquid (Fig.3). The temperature of the poured hot water means the heating power. Only this action is different from the actual operation. I prepare this action because I confirm whether the actions different from actual actions are accepted by users.

In this way, Liquid Tangible can easily represent more information than using solid. The table 1 shows the information that is considered to be represented.

Table 1. The information that is considered to be represented

	using solid	Liquid Tangible
type of color	yellow,green,blue	from yellow to blue
pictures of numerator structure	2 type	9 types

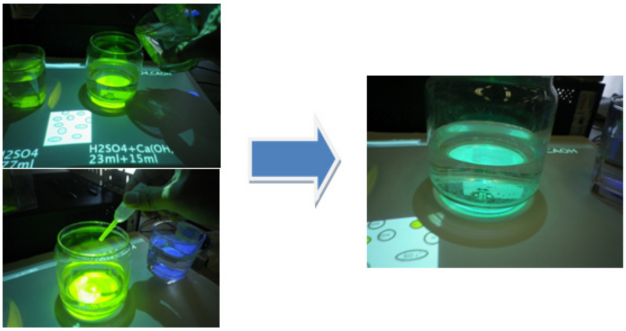

Fig. 1. The reaction by mixing multiple types of chemical

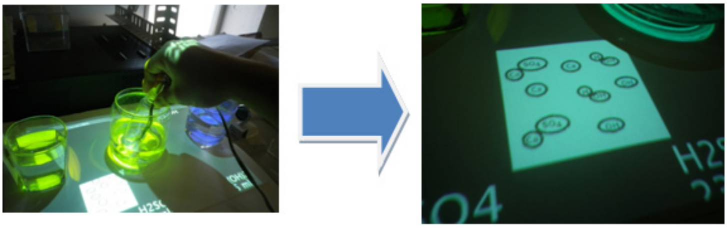

Fig. 2. The reaction by stirring by stick

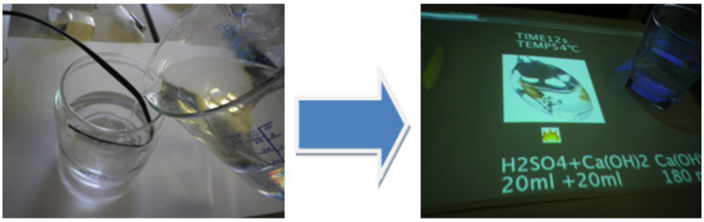

Fig. 3. The reaction by adding hot water

3 System Architecture and Implementation

This system consists of electronic weight scales, stirring sticks, thermometers, projector, WEB camera and PC. The electronic weight scales, the stirring stick and the thermometer are connected with the microcomputer board and WEB camera and microcomputer board are connected with PC by USB cables (Fig.4)

The electronic scales are used to measure how much liquid are poured into the beaker (Fig. 5). This device is made by disassembling a commercial electronic scale, and sends the weight to the PC via a microcomputer board. We implemented two of this device in order to measure the two types of chemical reagents. Accordingly, it is possible to mix two types of chemical reagents in this prototype.

We also implemented the electronic stirring stick (Fig.6). The stirring stick recognizes a stirring motion by triaxial acceleration sensor. The thermometer was used thermal sensor to measure temperature (Fig.7). The thermal sensor can measure from 0℃ to 100℃.

To recognize what kinds of chemical reagents, WEB camera and QR code attached on each beaker are utilized (Fig.8).

In this study, hydrochloric acid, sulfuric acid, nitric acid as the acidic chemical reagents and sodium hydroxide, calcium hydroxide, potassium hydroxide, barium hydroxide as the alkaline chemical reagents are prepared as virtual chemical reagents. The color of chemical reagents and the CG of molecular structure to show the information about the chemistry reaction are projected from the projector (Fig.9). The information is changed in real time. They are projected as so to overlap on the beakers (Fig.10).

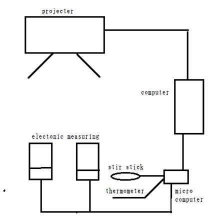

Fig. 4. Overall system architecture

Fig. 5. electronic scales

Fig. 6. stir stick

Fig. 7. Thermometer

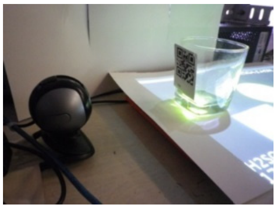

Fig. 8. Recognition of chemical

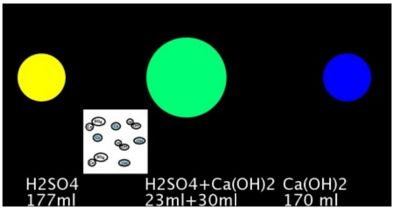

Fig. 9. The screen

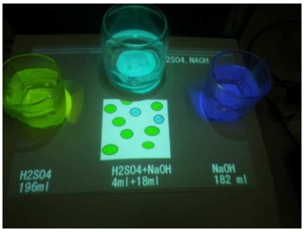

Fig. 10. Overlapped on the beakers

4 How to Use Liquid Tangible

In this section, we explain how to use the system in neutralization and salt crystallization experiment.

4.1 Neutralization Experiment

Here, we will show one usage of this system for the neutralization experiment. In preparation, user chooses the beaker of one acidic chemical reagent and one of alkaline one attached the QR code which has information of each chemical on the electronic scales.

First, user adds the acidic reagent to beaker on the center. At this time, only the molecular structures of the acidic reagents are displayed. The color of the beaker is, of course, yellow.

Then, user pours the alkaline reagent to beaker on the center. If the user stops adding when the quantity of acidity is more than alkalinity, many figures of molecular structures of acidic reagent and a little of molecular structure of alkaline agent molecular structure are displayed. The color of the liquid is yellow-green. The state of the molecular structure changes to the salt when user stirs the liquid by the stirring sticks.

When the user adds alkaline reagent until the same amount of acidic reagent into the beaker on the center, only the figure of the salt comes out. The color becomes green.

If the user continues to add alkaline reagent, the figures of the salt and the alkaline molecular structures are displayed.

4.2 Salt Crystallization Experiment

Here, we will explain one example of the salt crystallization experiment. To extract the crystallized salt, generally, the neutralized reagent is boiled until the water is disappeared. In this system, this process is done by adding hot water into the neutralized reagent. The reason we adopted a different operation from the actual one is to investigate whether user accept the virtual behavior for a computational function.

In this system, after the neutralization experiment, boiling the reagent begins when the user pours hot water into it. The speed of the reaction changes by the temperature of hot water.

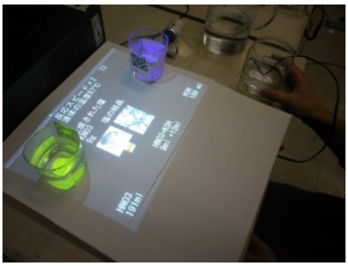

Fig. 11. Information in salt formation experiment

Here, the user can observe the process of forming the solid salt from first step to the end. The chemical formula of a salt, the quantity of salt crystal and the picture of the salt crystal was displayed (Fig11).

5 Acceptance Evaluation

5.1 Experiment Procedure

We conducted an experiment to investigate the users' acceptance for the Liquid Tangible. In this experiment, 4 participants, who are undergraduate students from 21 to 23 years old were participated.

The experiment are consists of four steps as follows: 1) Explain how to use the system, 2) Use the solid tangible object in the neutralization experiment (Fig.12), 3) Use Liquid Tangible in the neutralization experiment 4) Use Liquid Tangible in salt crystallization experiment. After the experiment, we conducted the interview about the Liquid Tangible's usability and advantage.

In neutralization experiment with the solid tangible objects, user uses the blocks instead of beakers filled with water. In this experiment, user can't adjust amount by using solid. Instead of stirring the liquid by the stirring stick in the Liquid Tangible, the participants asked to hit the block to each other to mix the reagent.

5.2 Result and Consideration

The participants' responses for Liquid Tangible were very positive. All participants mentioned that Liquid Tangible allows us to be more understandable about the chemical reaction than using solid objects. Such opinions means the mutual relation between adjusting the mount of the liquid and observing the change of the status according to the operation can enhance the understanding of the chemical reactions.

Furthermore, all participants claimed that our interaction is intuitive because it is close to actual chemical experiment. Many participants also claimed that the interaction can use for the education in the elementary school. One participant mentioned about the reason as follows: "This interaction is very fun because I felt to do a real chemical experiment. So, I think curious children must enjoy leaning more secure than an actual experiment". As the results, it can be said that Liquid Tangible was accepted by participants because they mentioned the very positive feedback.

On the other hands, there were some negative opinions to be improved. Some participants claimed that it was little bit hard to understand the molecular structures because their figures were too small. So, we improved the size of the displayed figures. Some participants also claimed that it is hard to understand the process of chemical reaction because the CG animation changes too fast. So, we also improve the speed of the CG animations. The improved system was used in the next experiment (Fig. 13)

6 Comparison with Solid TUI

We have been described adjusting amount by using solid is difficult because solid is discrete substances so far. However, there are some ways to adjust amount with solid

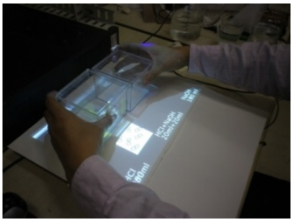

Fig. 12. Use solid in neutralization experiment

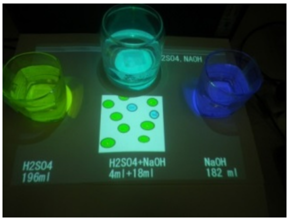

Fig. 13. after Improvement of a system

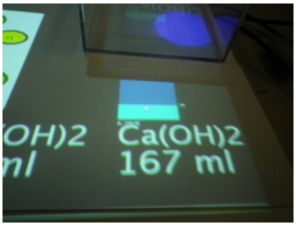

Fig. 14. using solid with the slide bar

TUI, for example, using dials or sliders, combining the TUI and GUI, and so on. To comparing the Liquid Tangible and traditional solid TUI, adjustment of the amount must be able to be controlled in both conditions. In this experiment, we adopted the way of combining the TUI and GUI to adjust the amount in solid TUI (Fig. 14). In this way, though the users can acquire the same information, only the operations of adjusting amount and the speed of molecular bond are different in both conditions.

6.1 Experiment Procedure

10 participants who are undergraduate students ages ranging from 21 to 23 years old involved in this experiment. This experiment consists of following four steps: 1) Explain how to use the system 2) Try Solid Tangible in neutralization experiment (Fig.15) 3) Try Liquid Tangible in neutralization experiment (Fig.16) 3) Try Liquid Tangible in salt crystallization experiment (Fig.17). 4) Answer the questionnaire.

We asked the participants to answer five questions in the questionnaires: (i) Do you feel the chemical reaction is more understandable with Liquid Tangible than solid TUI? (ii) Do you feel adjusting amount is easier with Liquid Tangible than solid TUI? (iii) How do you feel using hot water to start boiling? and (iv) Do you feel using liquid in the system make sense? The question (i) and (ii) are the ones to investigate the advantages of Liquid Tangible against solid TUI, the question (iii) and (iv) are the one to investigate the effectiveness of the Liquid Tangible

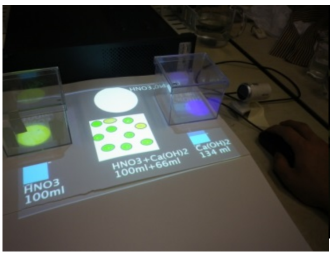

Fig. 15. use Solid Tangible in neutralization experiment

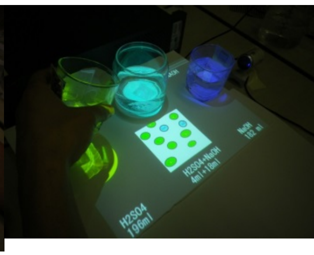

Fig. 16. Use Liquid Tangible in neutralization experiment

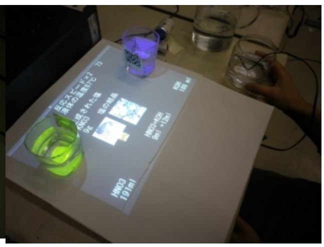

Fig. 17. Use Liquid Tangible in salt formation experiment

7 Results and Considerations

The table 2 shows the result and its reason of questions. For the question (i), 8 participants answered positively and they claimed "it is easy to understand the chemical reaction because the system is close to the real environment and allows us to control the amount with my feelings". For the question (ii), on the other hands, only the half of the participants answered positively. They claimed that "I can adjust the amount

Table 2. The feedbacks of questionnaire

questions	positeve	negative
(i)	8 participants	2 participants
	it is easy to understand in order to perate it by my hands.	it cares about adjustment of amount.
	the system is close to the real environment and allows us to control the amount with my feelings	
	it is easy to imagine a direction with a liquid.	
(ii)	5 participants	5 participants
	I can adjust the amount easily because the state of decreasing water works as the target of controlling amounts	I can't adjust the amount because there was a time lag.
(ii)	6 pariticipants	4 pariticipants
	because I imagined sensusouly.	I tought that how to go up temperaturer was insufrficient with hot water.
	it was easy to imagine boiling by adding hot water.	I think that doing hot water and using fire have a difference.
	I was actually abele to feel heat.	
(iv)	9 pariticipants	1 pariticipant
	it is easy to understand by actually working.	it seldom seemed to be about a meaning
	because the image in which it is experiment in solid from is not made.	
	I think that change may be seen when adjusting amount.	

easily because the state of decreasing water works as the target of controlling amounts." Though, on the other hands, five participants responded the negative answer, two of them claimed that the time delay between pouring water and changing displayed information make the adjustments difficult. Their comments means the difficulty does not due to the nature of Liquid Tangible but the implemented way of the system. From the results of question (i) and (ii), therefore, it can be said that Liquid Tangible is useful for the tasks which require controlling the amount.

Looking at the results of the question (iii), some people can come the boiling the reagent to mind by the pouring hot water and some cannot. This means if the behavior which is different from the real operation is assigned to a computer function carefully, it could work well.

Finally, to the question (iv), most of participants answered positively. The results indicate that Liquid Tangible is acceptable to the user and is useful in for the task of amount control and the education.

8 Conclusion

In this paper, we propose Liquid Tangible and implemented the prototype system in virtual chemical experiment. As a result from acceptance evaluation, users accept Liquid Tangible and it provide fun to the users. And, in the tasks which require adjusting amount, Liquid Tangible allows the users to control amount instinctively and is, therefore, effective in comparison with the solid TUI.

9 This Study Is an Initial Effort toward the Developing Interactions Using Liquid

In the future, I confirm that using liquid is used in other environments based on environments that can be taken advantage of Liquid Tangible in this study. Use by paint software can be considered as the environment. First, paint software has much information, including a color etc. Second, it is necessity to adjust instinctively amount when making color. Third, users imagine paints by using a viscous liquid. I think that it is necessity to make it adapted for various environments including paint software because it isn't the field fully studied

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