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Experimental Use of Error-Based Simulation for Dynamics Problems in National Institutes of Technology

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Abstract: In order to solve mechanics problems, force finding in the problem is an indispensable step. Also, this step is often difficult for not only beginners and also learners who have learned. Therefore, there are several researches proposed supporting method for learners in this step. Error-Based Simulation (EBS) is one of the support methods. In this research, we have experimentally evaluated EBS for a dynamics problems.

Keywords: Error-Based Simulation, Physics, Mechanics, Force, Visualization

1. Introduction

One of the most difficult steps in solving of mechanics problem is the step of force finding in the problem. Therefore, examinations and developments of support methods for this step are important research issues (Clement, J., 1982, Clement, J., 1993, Tao, P.-K., & Gunstone, R., F., 1999). Also, this step is hard for students who have learned physics one time (Clement, J., 1982).

Error-Based Simulation (EBS) is one of the methods to support a learner at force finding (Hirashima, T., Horiguchi, T., Kashihara, A. & Toyoda, J., 1998, Horiguchi, T., Imai, I., Toumoto, T., & Hirashima, T., 2014). EBS is a motion simulation reflecting the forces that a leaner find in the problem. This means that if any incorrect force is included, EBS shows incorrect behavior reflecting it. Therefore, EBS visualizes errors as difference between wrong behavior and normal simulation. By observing the incorrect behavior, it is expected that the learner detect his/her mistake and correct it. The effectiveness of EBS has already been confirmed at statics problems. In this research, we have been experimentally evaluating the effectiveness of EBS for dynamics problems. In this time, we held the experimental use for the students in national institutes of technology who have learned physics.

2. Learning System with EBS

Evaluation of the effectiveness of EBS system is the goal of this research. Here, we will illustrate about EBS system of this research.

EBS System

In this research, we implemented EBS system for dynamics problems on Android tablet. The user interface of our system consists of problem sentence, some buttons, and drawing area (figure 1). Drawing of force, and showing of EBS are done on drawing area. On drawing of force, learners draw force they think acting on target objects by flicking as arrow. Then, motions of objects are simulated based on this drawing. It is supposed that learners detect and correct own error by observation for this simulation because correct motion is known for them.

Figure 1 shows the example problem about the forces act on the person who skating on the ice without friction with uniform motion. In this problem, many learners draw the force direction of motion. For that drawing, the parson is accelerated in EBS.

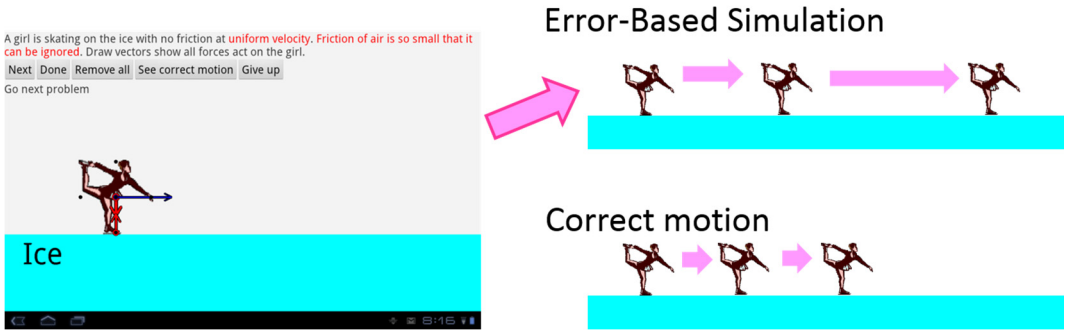

Figure 1. System Interface and Example of EBS

Problems in EBS System

In this section, problems implemented in our system are explained. In this research, learning about dynamics problems is main target. On elementary mechanics, these three kinds of motion are treated: (1) linear uniform motion without force of motion direction, (2) linear uniform motion with balanced forces of motion direction, (3) motion with acceleration.
We implemented these three problems corresponding to above three kinds: (A) a person who skating on the ice without friction, (B) a person who dropping at constant velocity by parachute, (C) a ball thrown up vertically. Also, we implemented these three applied problems corresponding to above three kinds: (D) a space ship moving linearly at constant velocity in cosmic space, (E) an object pushed at constant velocity on horizontal plane with friction, (F) a ball thrown up on the angle. From here, we call above six problems “learned problems”.

3. Experimental Use

In this research, EBS system explained above was used experimentally to evaluate its effect. In this section, this use is explained.

Plan for Experimental Use

In this research, experimental use of EBS system with 19 subjects of fourth years at national institutes of technology was conducted to evaluate its effect. On this use, we conducted pre-test just before, system use, post-test just after, and delayed-test after a month. While this use, subjects dealt with above six learned problems. Also, some questionnaire survey were conducted with each test.

Evaluation Test

In this use, we conducted written test as evaluation. Each test was drawing of forces same as practice.
In pre-test, we used learned problems (problem (A) to (F)), and test was done for 10 minutes. In post-test, we used six problems on pre-test, and additional four problems which not used at system. So, total ten problems were used at post-test for 15 minutes. Added four problems: (G) a truck moving on slope and horizontal plane without friction, (H) a sled which being pushed and accelerating on ice without friction, (I) a box decelerating on horizontal plane with friction, (J) an elevator which being lifted up at a constant speed. From here, we call above four additional problems “transfer problems”.
Delayed-test was conducted after a month of use, also used problems and time are same as post-test.

Results of Evaluation Test

In this section, the result of three tests above are explained. In this research, we used the number of correct answer (we call this number "point" from here).
In learned problems, the point rose significantly between pre-test and post-test ($p = 0.0000021$). Also, although the point decreased at delayed-test, but the point of delayed-test was higher than pre-test significantly ($p = 0.00627$) (Figure 2).
In transfer problems, the point was not so high. Also, there were no significant declination between post-test and delayed-test (Figure 2).

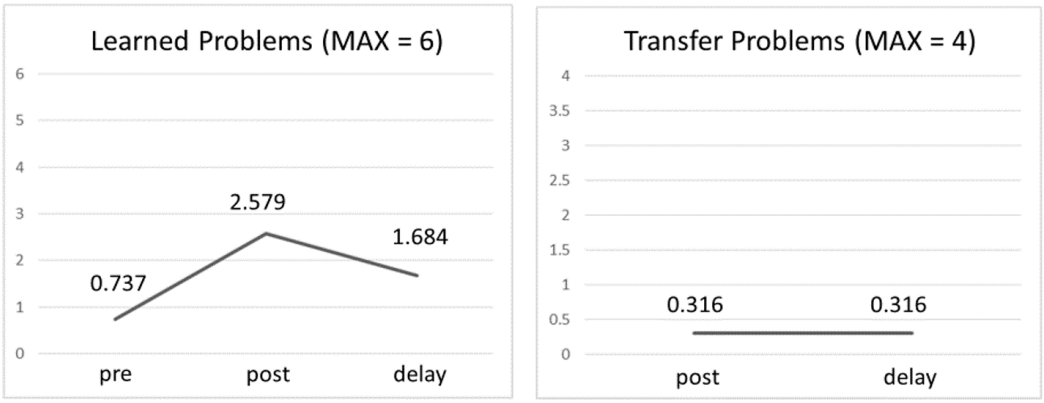

Figure 2. Results of Evaluation Test

4. Conclusions

In this research, we are trying to evaluate the effectiveness of Error-Based Simulation in dynamics problems. In this paper, we reported about the design of EBS system and its experimental use.
In this experimental use, there was some effectiveness for learned problems. From this, it is confirmed that EBS was acceptable at dynamics problems. However, the knowledge was not so applicable.
As future work, we will analyze the results of questionnaire with results of evaluation test in detail. Also, as the means to encourage more deep understanding, the using of additional feedback with EBS can be needed. Also, learning support that focuses on Motion Implies Force (MIF) misconception (Clement (1982)) on dynamics problem is important.

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