A Table-top Interface for Real-time Coaching in Abacus Learning

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***Abstract*—Numerical calculations using an abacus (also known as *Soroban*) require understanding numerical representations through beads, and the manipulation of beads in multiple methods and sequences necessitates long-term repetitive learning to master. Traditional abacus instruction involves checking the correctness of answers and observing learners to identify and address mistakes or difficulties in bead manipulation. However, this depends heavily on human resources and requires considerable effort. Therefore, this study proposes a learning support system for abacus learning using a commercially available abacus and a table-top interface to provide coaching content based on real-time estimation of the abacus input values using a document camera.**

***Index Terms*—abacus, education, learning support system, interface, camera as a sensor**

I. Introduction

A numerical calculation tool, the abacus (*Soroban*), is still used today to acquire calculation skills. It can assist in various calculations, including the four arithmetic operations, by expressing numbers with the positions of five beads which can be moved vertically. The combination of the physical manipulation of beads and the visual representation of numbers on an abacus enables calculations in a different way from general calculations. Although the number of situations in which one directly uses an abacus as a calculation tool has been decreasing in recent years, the abilities and effects that can be acquired through the study of the abacus have been garnering attention [1]–[7]. However, calculation with an abacus requires understanding the numerical representation using beads and manipulating them in multiple ways and orders, necessitating long-term repetitive learning for mastery.

In general school education and abacus schools, instruction is typically provided by determining whether answers are correct/incorrect. Instructors encourage understanding by demonstrating the calculation procedure and finding and instructing on errors or inefficient bead manipulation based on their observations. However, this coaching relies heavily on the instructors' manual efforts. It can be considered there are regularities and patterns in calculation mistakes and poor bead manipulations (points where learners struggle), however, the knowledge is accumulated as tacit knowledge within the instructors, making it unavailable for reuse by others.

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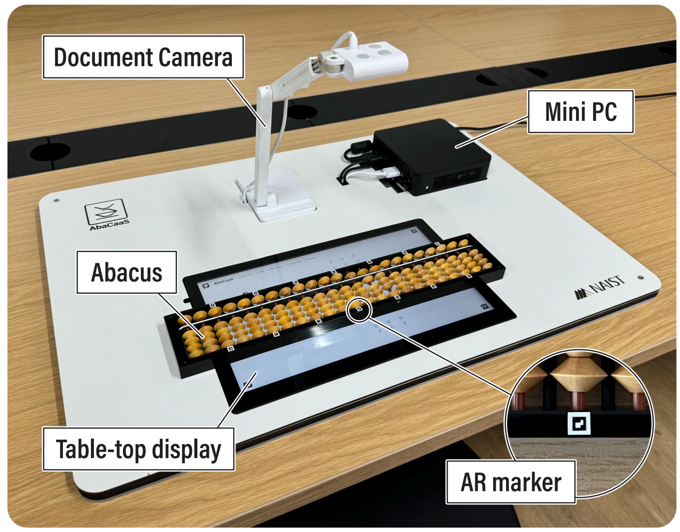


Fig. 1. Abacus learning support system using table-top display and document camera as a sensor (AbaCaaS).

Upon these backgrounds, this study aims to realize the ICT-based learning support system using a commercially available abacus. We have previously proposed an abacus input value estimation method based on image recognition captured by a document camera [8]. Based on this method, this paper proposes a learning support system for abacus learning using a table-top interface to provide instructional content based on real-time recognition of the abacus board using a document camera as shown in Fig. 1.

II. Related Work

There are several approaches to support abacus learning with commercially available abacus. Kitagawa *et al.*[1] proposed an abacus learning support system consisting of a board estimation system using a camera and a projection mapping system that overlays images on the beads to convey manipulation methods. Arakawa *et al.* [9] proposed a Learning Management System (LMS) for abacus education, managing learning software such as flash mental arithmetic, reading aloud arithmetic, and quick-view arithmetic on the LMS, and

[1]This paper is published only in Japanese: http://www.interaction-ipsj.org/proceedings/2022/data/pdf/6D04.pdf

combining it with individual grades and learning progress to enable learning anywhere with a PC equipped with the software.

There are also approaches to support abacus learning by reproducing the abacus on the screens of smartphones and tablet devices. Saito *et al.* [10] proposed an electronic abacus function as one of the plugins for a learning support system on smartphones. By reproducing the abacus on the screen, basic abacus manipulations can be performed, and the process of calculation using the electronic abacus can also be displayed as a formula. Baharudin *et al.* [11] proposed an interactive abacus learning application, which was implemented as PC software, for beginners. Digika offers a service called *SoroTouch* [12], which provides mental arithmetic learning instruction based on the abacus UI and manipulation methods. The system reproduces an abacus-like interface on tablet devices and adopts a calculation method that operates buttons corresponding to beads with both hands. Besides, Tokuda *et al.* [13] propose a method for estimating abacus learners' performance by utilizing matrix factorization on the student-generated learning data with the Sorotouch app.

In our previous study, we proposed a method for estimating the input value of a commercially available abacus based on image recognition captured by a document camera [8]. Based on this method, this paper proposes a novel abacus learning support system using a table-top display.

III. Table-top Interface for Realtime Coaching

We use a table-top display shown in Fig. 1 to dynamically present calculation problems and coaching information. The specific procedures are shown below and in Fig. 2 and Fig. 3 (a).

1) Detect the AR marker displayed on the table-top display using a document camera, and calibrate the positional relationship between the display and the document camera.
2) Continuously detect the AR markers attached to the abacus with the document camera, identifying the position of the abacus.
3) Display the first problem above the outer frame of the abacus.
4) Based on the estimated input values, monitor the progress of the calculations and update the displayed calculation problem accordingly.

With the above procedures, the position of the abacus captured by the document camera can be used to constantly display the row the learner is attempting to input (addition/subtraction) or the problem is calculated (multiplication/division) above the outer frame of the abacus. The alignment usually done by moving the abacus manually when using a textbook can be digitally replicated, minimizing the movement of the abacus. This feature also allows the system to prevent the abacus from going outside of the camera angle, i.e., in situations of input value estimation doesn't work.

The system can sequentially collect data on "the calculation problems to be solved" and "the input values on the abacus." By comparing them, it becomes possible to detect events

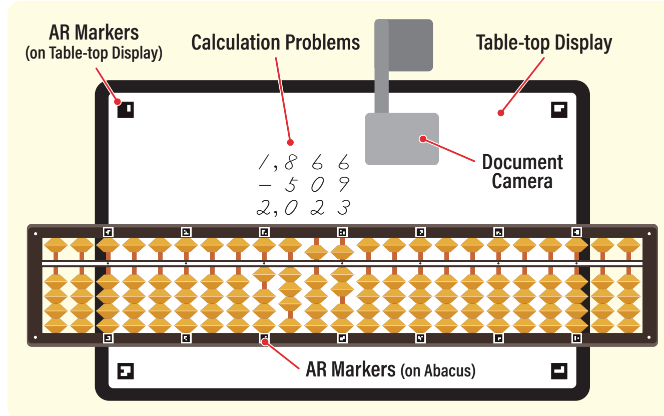
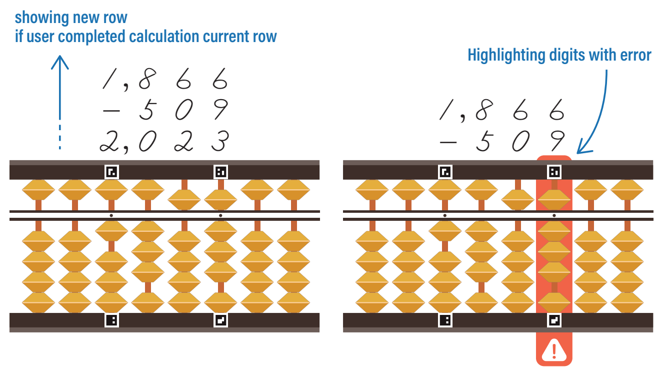


Fig. 2. Design of a table-top interface.



(a) Showing calculation problem on table-top display dynamically depending on calculation progress

(b) Pointing errors out on table-top display real-time if user inputs wrong calculation result on abacus

Fig. 3. Example of coaching information shown on table-top display.

where the learner has made calculation errors or misinputs. Based on the detected results, some coaching information can be displayed on the table-top display, e.g., highlighting abacus digits where the error occurred, enabling real-time and intuitive pointing out of calculation mistakes and misinputs, as shown in Fig. 3 (b).

After using this system certain period, the time-series event data on calculation errors and misinputs will be accumulated. Aggregating this data allows for an analysis of which calculation procedures learners have not understood or mastered, and which bead manipulations they feel difficulty. Based on this analysis, calculation problems can be generated automatically to focus on training in manipulations that are challenging to learners. Additionally, since the problem-solving process is somewhat applicable to other learners, sharing information such as logs of calculation errors and misinputs, the generated problems, and the learning progress made using them through online platforms can be useful for generating problems for other learners. By organizing the accumulated data, the formalization of knowledge regarding abacus learning coaching can be realized.

IV. Conclusion

Generally, acquiring abacus skills requires long-term repetitive learning. Therefore, this study aims to enhance learning efficiency through an abacus learning support system utilizing ICT. In this paper, we proposed a learning support system that presents coaching content in real-time on a table-top display, based on abacus input value estimation using a document camera as a sensor. In future work, we will proceed with the specific implementation of the coaching content via the table-top display and conduct short-term and medium-to-long-term experiments with actual learners to evaluate whether this system contributes to abacus learning.

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