Abacus Manipulation Understanding by Behavior Sensing Utilizing Document Camera as a Sensor

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Abstract

The abacus (also known as *Soroban*) is a numerical calculation tool that is traditionally used in East Asian countries. With the advancement of information technologies, the abacus is no longer used as a standard calculation tool. However, abacus learning is garnering global attention due to the secondary skills it can foster, e.g., mental arithmetic ability. Numerical calculation using an abacus requires learning numerical expressions using the beads of the abacus and manipulating beads in multiple ways and in different orders. Due to this complexity, a long period of repeated learning is usually required to acquire the skill of using the abacus. However, the teaching method of the abacus mainly relied on lecturers' observation through finding errors and poor bead manipulations and pointing them out, and there is no other way but to rely on human labor at this moment. In this study, we aim to realize an ICT-based learning support system for arithmetic with a common abacus. This paper proposes a method of estimating input values on an abacus based on image recognition captured by a document camera. Through the evaluation experiments, we have confirmed that the proposed method showed an accuracy of 95.0% in the estimation of 7-digit number input on an abacus. Additionally, this paper will provide discussions to realize the proposed method with other cameras such as wearable camera devices, and to design the coaching system of abacus learning.

1 Introduction

A numerical calculation tool, the abacus (*Soroban*), is still used today as a method of acquiring 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

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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, 2, 7, 8, 11, 13, 14]. 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 school, instruction often be provided based on the correct/incorrect determination of answers to problems. Depending on the learner's situation, instructors encourage understanding by demonstrating the calculation procedure, and find and instruct on mistakes or poor bead manipulations based on the lecturers' observations. However, this coaching relies primarily on the manual efforts of lecturers. 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.

Based on these backgrounds, this study aims to realize the ICT-based learning support system using a common abacus. In this paper, we propose an abacus input value estimation method based on image recognition captured by a document camera to understand the learner's "abacus manipulation behavior" required for providing learning support. As a result of the evaluation experiments, we confirmed that it is possible to estimate the inputted 7-digit numbers on the abacus with an accuracy of 95.0%.

The rest of this paper is organized as follows. In Section 2, we summarize the preliminary knowledge of the abacus and describe the motivation of this study. Section 3 provides a literature review of existing work and services. Then, we will propose a system for estimating the input value of the abacus in Section 4. Finally, Section 5 provides the evaluation of the proposed method and discussion, and we conclude this paper with Section 6.

2 Preliminary

The abacus is an assistive tool for various calculations such as the four arithmetic operations by expressing numbers with the positions of five beads which can be moved vertically. In this section, we will summarize the preliminary knowledge of the abacus and describe the motivation for this study.

2.1 Numerical Representation Using Abacus

First, the components of the abacus are shown in Figure 1. A "digit" corresponds to one digit in base 10, and the placement of five beads can represent numbers from "`0`∼`9`." Each "digit" is divided into an upper and lower section by a "beam," and the single bead in the upper section (`five-bead`) represents the base-10 number "`5`," while the four beads

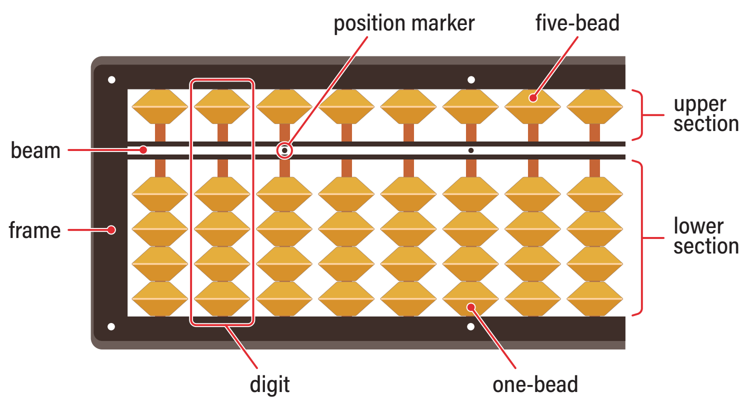


Figure 1: Components of the abacus.

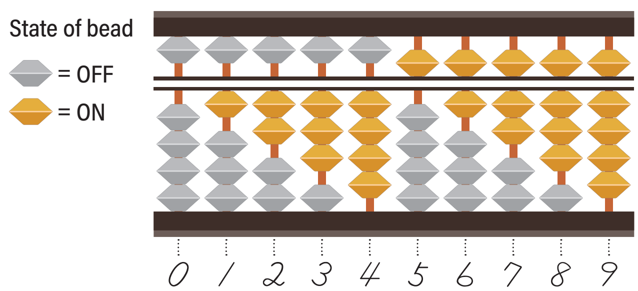


Figure 2: Numerical representation on the abacus.

in the lower section (`one-beads`) represent base-10 numbers "`1`" each. A specific example of numerical representation is shown in Figure 2. There is a space half the height of the beads in both the upper and lower sections, and the state of each bead is represented by moving the beads up and down. In the upper section, the bead in the raised position represents OFF (`0`), while the lowered position represents ON (`5`); conversely, in the lower section, the raised position represents ON (`1`), and the lowered position represents OFF (`0`). The sum of the beads in the same digit (the total of the numerical values represented by the beads in the ON state) represents the value of that digit. The "position marker" in Figure 1 is indicated on the beam every three digits and is used as a marker to determine the ones place. The digits to the right of the determined position marker are used to represent decimals.

2.2 Calculation Methods with the Abacus

Calculations using the abacus are characterized by the extensive use of complementary combinations of 5 and 10. Specifically, there are three types of manipulations. In the following, we explain the procedure for each manipulation with addition as an example, but subtraction can also be represented in a similar manner by performing the inverse manipulation of it.

1. **Calculations involving either one-beads or five-bead**
   This is the simplest manipulation, which can be completed by moving either `one-beads` or `five-bead`. The following are examples of addition. First, for the calculation of `1 + 2`, starting from the state with only one `one-bead` raised (`1`), a manipulation to raise two more `one-beads` (`+2`) can be performed, resulting in the state representing `3`. For the calculation of `3 + 5`, with three `one-beads` raised (`3`), the manipulation of lowering the `five-bead` (`+5`) can be performed, resulting in the state representing `8`.

2. **Calculations involving one-beads and five-bead**
   This manipulation requires simultaneous movement of `one-beads` and `five-bead`. Specifically, it corresponds to the manipulation where the state changes from `0`∼`4` to `5`∼`9` (or the reverse). The following are examples of addition. The calculation of `1 + 6` can be obtained by combining manipulation (1), adding `6` (i.e., `5` and `1`) to the state with one bead raised (`1`), resulting in the calculated result of `7`. On the other hand, the calculation of `2 + 4` requires adding `4` to the state with two beads raised (`2`), but since there are only four `one-beads` per digit, this calculation cannot be represented by the combination of only `one-beads`. Therefore, the concept of the complement of 5 is introduced. Since `4` can be expressed as `5 - 1`, performing the manipulations of "subtracting `1` (lowering one `one-bead`)" and "adding `5` (lowering the `five-bead`)" simultaneously from the current input value of `2` results in the calculated result of `2 + 4`, which is `6`.

3. **Calculations involving two digits (carrying and borrowing)**
   This manipulation requires the movement of beads over two digits. Specifically, it corresponds to the manipulation where the state changes from `0`∼`9`, which can be represented in one digit, to a number of `10` or greater (or the reverse), i.e., carrying or borrowing. The following are examples of addition. In the calculation of `3 + 8`, `8` will be added to the state with three beads raised (`3`), however since it cannot be represented within a single digit, the concept of the complement of 10 is introduced. Since `8` can be expressed as `10 - 2`, performing the manipulations of "subtracting `2`" and "adding `10`" simultaneously from the current input value of `3` results in the calculated result of `3 + 8`, which is `11`. In addition, there are cases where the complement of 5 must also be considered. For example, in the calculation of `6 + 8`, although `8` requires considering the complement of 10 as mentioned above, and subtracting `2` from the one's place, subtracting `2` from `6` requires considering the complement of 5 (`5 - 3`). Thus, to obtain the calculated result of `6 + 8`, which is `14`, it is necessary to perform the three manipulations of "adding `3`", "subtracting `5`", and "adding `10`" simultaneously.

2.3 Challenges to Realize Abacus Learning Support System

Calculations using an abacus, as mentioned earlier, require constant consideration of the complements of 5 and 10 while performing manipulations, which is significantly different from general calculations on paper. It supposes that in order for beginners to acquire abacus calculation skills, repetitive and continuous abacus learning is necessary. However, the common approach of abacus coaching relies on the observation of learners, especially discovering and teaching mistakes and poor bead manipulations, which consume much effort from lecturers. Therefore, providing effective learning and coaching support based on the sensing of learners' abacus manipulation behaviors is considered necessary to solve this problem.

3 Related Work

Kitagawa *et al.*[2] 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. To estimate the board, they used a method that captures the abacus with an RGB camera from the backside of a transparent table and detects objects using the brightness difference caused by the shape of the abacus beads. To emphasize the brightness difference, an LED light needs to be installed on the underside of the table, similar to the camera. This method relies on vision-based object detection, all beads of one digit should be detected precisely to perform the estimation of the input number on the abacus.

Arakawa *et al.* [3] 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 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.* [4] proposed an interactive abacus learning application, which was implemented as PC software, for beginners. Digika offers a service called *SoroTouch* [5], 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. Beside, Tokuda *et al.* [12] propose a method for estimating abacus learners' performance by utilizing matrix factorization on the student-generated learning data with the Sorotouch app.

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

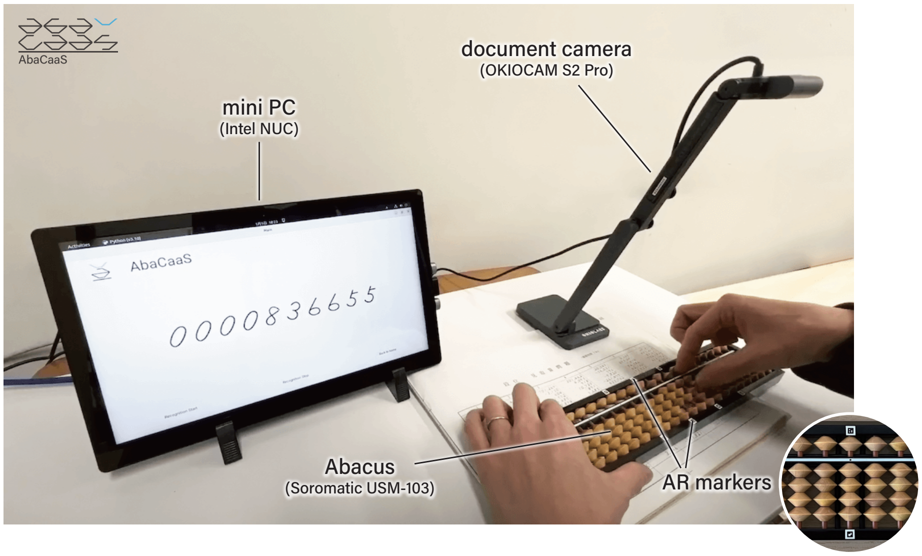


Figure 3: System configuration of AbaCaaS.

4 Proposed System - AbaCaaS

We propose a novel system, named *AbaCaaS* (Abacus Manipulation Sensing Using Camera as a Sensor), that realizes abacus manipulation behavior sensing using a document camera, targeting general abacus learning using a commercially available abacus. In this paper, we focus on the particularly important aspect of abacus manipulation behavior sensing, "what numbers are being input on the abacus board?," and propose an abacus input value estimation method using the AbaCaaS system.

4.1 System Configuration

The system configuration is shown in Figure 3. The AbaCaaS system consists of a commercially available abacus with pasted AR markers[3], a document camera that captures an overhead view of the abacus board, and a mini PC that performs image processing and abacus input value estimation. The document camera is assumed to be placed at an angle parallel to the desk to capture the image directly below, however, the position of the abacus can be freely set as long as it fits within the camera's field of view (no need to fix the abacus position).

In this paper, we employed the following devices — the document camera: Okio Labs OKIOCAM S2 Pro (resolution: 1920×1080 px)[4]; the abacus: Unshudo SORO-MATIC USM-103 (23-rod, boxwood beads)[5]; and the mini PC: Intel NUC8i5BEH (CPU: Intel Core i5-8259U, RAM:

[3] Placements of AR markers on the abacus will be explained in Section 4.2.1 and Figure 5.
[4] `https://www.okiolabs.com/product/okiocam-s2-pro/`
[5] `https://www.unshudo.co.jp/global/product/124/`

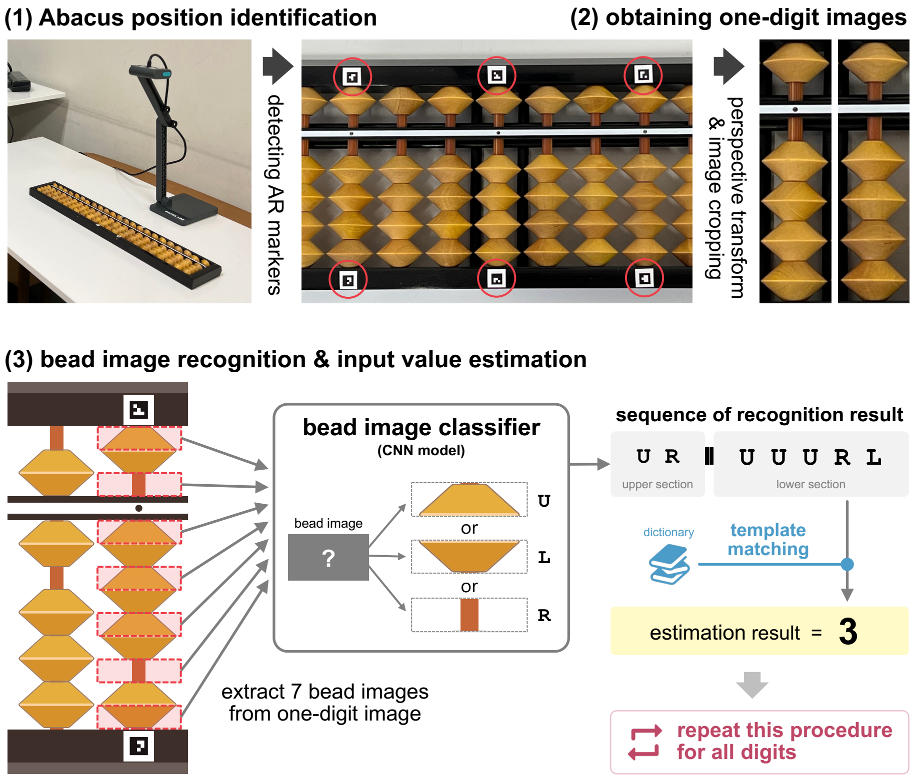


Figure 4: Workflow for estimating input values on the abacus.

16 GB, GPU: Intel Iris Plus Graphics 655, OS: Ubuntu 22.04.1 LTS)[6]. The system is developed using Python (version 3.10.6), and TensorFlow[7] is used for building and executing the recognition model[8].

4.2 Abacus Manipulation Behavior Sensing Method

Here, we describe a method for detecting the abacus area and estimating the input values on the abacus board using video data obtained by the document camera. The sensing procedure is shown in Figure 4 and below.

(1) Abacus position identification using a document camera and AR markers

[6] `https://www.intel.co.jp/content/www/jp/ja/products/sku/126148/intel-nuc-kit-nuc8i5beh/specifications.html`

[7] `https://www.tensorflow.org/`

[8] The major libraries and these versions for developing the proposed system are following: `numpy==1.23.5,opencv-python=4.6.0.66,opencv-contrib-python=4.6.0.66,Pillow==9.3.0,keras==2.11.0,tensorboard==2.11.0,tensorboard-data-server==0.6.1,tensorboard-plugin-wit==1.8.1,tensorflow==2.11.0,tensorflow-estimator==2.11.0,tensorflow-io-gcs-filesystem==0.29.0`.

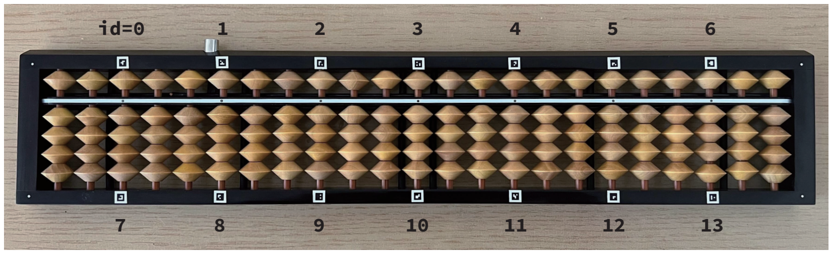


Figure 5: AR markers and corresponding IDs to be pasted on the abacus.

(2) Obtaining 1-digit images by perspective transformation and image cropping

(3) Bead image identification and input value estimation using template matching

In the following, we describe each step in detail.

4.2.1 Abacus Position Identification using a Document Camera and AR Markers

Normally, the abacus position is moved on the table during calculation, hence the abacus area must be detected from the video frames obtained by the document camera. However, to avoid interference with abacus manipulation, modifications/customization to the abacus must be minimized. Also, taking actual learning situations into consideration, it is not desirable to require the use of desks with special shapes or materials. Therefore, we adopt a method of identifying the position by detecting AR markers [6] pasted to the abacus frame from the video frames.

The appearance of the abacus with pasted AR markers is shown in Figure 5. We generated 14 distinct AR markers (dictionary size: 3×3, print size: 5×5 mm) using the ArUco [9] AR marker generation and detection module in OpenCV. These markers were then pasted to the abacus frame, above and below the digits with position markers. Note that since the size and shape of the beads in commercially available standard abacuses are generally the same, the proposed method can be applied to other abacuses too. Since abacus users mainly move the beads of the abacus, AR markers pasted on the frame will not negatively affect natural abacus manipulations.

4.2.2 Obtaining 1-digit Images through Perspective Transformation and Image Cropping

Next, we extract the abacus region from the detected AR markers. Due to occlusion caused by the hand using the abacus and the influence of light reflection, not all AR markers may be detected. Therefore, we first complete the missing AR marker positions based on the detected AR marker's positional relationship. The area enclosed by these AR markers is determined as the abacus region. Since the angle and position within

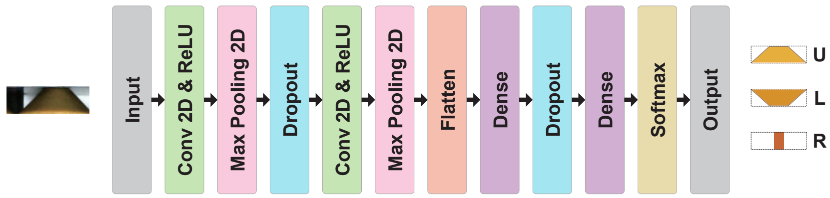


Figure 6: Building blocks of bead image recognition model.

the image differ, we apply a perspective transformation[9] to convert the image to one taken from a normal position. By dividing and cropping the resulting image, we obtain the 1-digit images.

4.2.3 Bead Image Recognition and Input Value Estimation by Template Matching

Finally, by recognizing the obtained 1-digit images, we estimate the input values for each digit. We focus on the characteristics of the abacus structure and simplify the problem to achieve high-performance input value estimation.

As mentioned earlier, an abacus represents numbers by moving five beads (four `one-beads` and one `five-bead`) up and down for each digit, with the space for moving beads being approximately half the height of a bead. This means that, as shown in the bottom left of Figure 4, seven bead images can be obtained from a 1-digit image. Each bead image corresponds to either the "upper half of the bead," "lower half of the bead," or "digit rod," and the sequence of the seven bead images is unique for each input value.

Therefore, we construct an image recognition model that classifies each of the seven bead images into the three classes mentioned above, and apply template matching between the sequence of the recognition results and a dictionary of bead image sequences for each numeric value (`0`∼`9`), resulting the estimated input value for the target digit. We estimate the input value on the abacus by repeating this procedure for all digits. In this paper, the image recognition model is a five-layer CNN model, as shown in Figure 6, trained only with a custom dataset of 4,845 samples (upper half: 1,925 samples, lower half: 1,540 samples, digit rod: 1,386 samples). For training, we used TensorFlow and the Keras library[10], and constructed model is quantized to int-8 and converted to TensorFlow Lite format using TensorFlow Lite Converter for lightweighting.

5 Evaluation

We conducted the experiment to evaluate the performance of the proposed method of abacus input value estimation.

[9]A function `cv2.warpPerspective()` in OpenCV is used.
[10]`https://keras.io/`

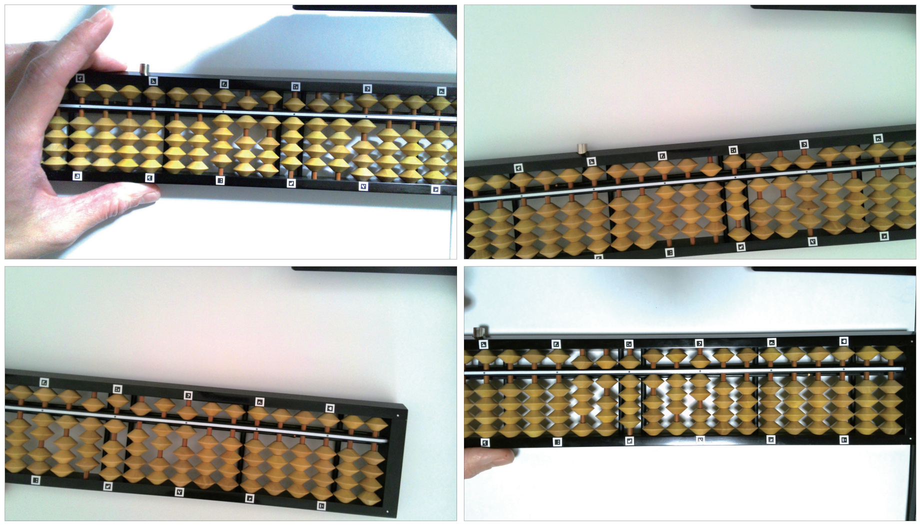


Figure 7: Example images in our dataset for evaluation.

5.1 Dataset

First, we constructed the evaluation dataset, assuming an actual usecase. The author inputted the 7-digit numbers which are randomly generated between `0000000`∼`9999999` on the abacus, and captured images using a document camera. Example images in the evaluation dataset are shown in Figure 7. As the requirements of images for the dataset, we set the following three conditions: 1) at least two AR markers are included in both the upper and lower sections, 2) the entire input part of the abacus is included in the image, and 3) there is no occlusion by hand. Insofar as filling these conditions, the angle and position of the abacus were arbitrary. In this dataset, a position marker between `id = 4, 11` shown in Figure 5 is always set as the ones place. Note that the images in this dataset are not included in the training dataset.

5.2 Evaluation Result

The evaluation results are shown in Table 1. Out of the 300 total samples in the evaluation dataset, the proposed method correctly estimated the input values for 285 samples, confirming that our method can achieve highly accurate estimation (Accuracy: 95.0%). Among the 15 samples that failed, 11 samples were due to the misidentification of AR markers, which causes failure in the perspective transformation of step (2). In the current method, we apply a completion process only for undetected AR markers assuming all detected markers are correctly identified. We are sure that adding a filtering process for AR marker misidentification will address this issue. If the samples with failed perspective transformation are excluded, the accuracy improves to 98.6%. The remaining 4 samples had failed

Table 1: Evaluation results of 7-digit input value estimation.

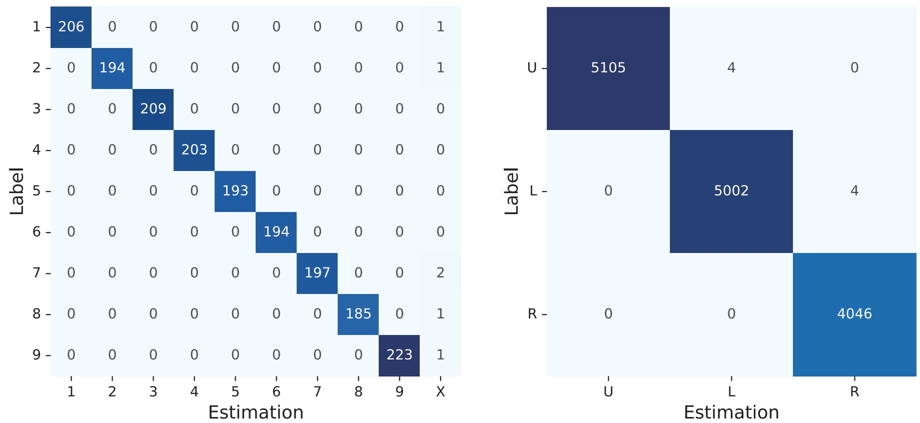
Item	**Value**
Number of evaluation dataset samples	300
Number of samples estimated correctly	285
Number of samples including digit(s) estimated as "X"[a]	15
– Due to failed projection transformation	11
– Due to failed bead image recognition	4
Number of samples misestimated as different input numbers	0
Accuracy (correct answer rate) across all samples[b]	**95.0 %**
Accuracy (correct answer rate) when excluding[b] failed projection transformation samples	**98.6 %**
Average of inference time	0.176 sec
Standard deviation of inference time	0.013 sec

[a] A digit that is not matched to any numbers in a dictionary of bead image sequences.
[b] Precision, Recall, and F-measure are the same as their Accuracy due to no confusion with different input numbers.

Table 2: Samples with failed bead image recognition. The letters "U," "L," "R," and "‖" represent the upper half of the bead, the lower half of the bead, the digit rod, and the beam, respectively.

Input value		**Estimated value**	
0504152	1 ⇒ U R ‖ U R L L L 2 ⇒ U R ‖ U U R L L	U R ‖ U R L R L ⇒ X U R ‖ U U R R L ⇒ X	0504X5X
0159781	9 ⇒ L R ‖ U U U U R 7 ⇒ L R ‖ U U R L L 8 ⇒ L R ‖ U U U R L	L R ‖ U U L L R ⇒ X L R ‖ U L R L L ⇒ X L R ‖ U L U R L ⇒ X	015XXX1
0156797	7 ⇒ L R ‖ U U R L L	L R ‖ U U R R L ⇒ X	015679X
0937390	0 ⇒ U R ‖ R L L L L	U R ‖ R L L R L ⇒ X	093739X

with bead image classification, however, the estimation results were "no matching value (X)" through the template matching process as shown in Table 2. For more detailed analysis, we derived the confusion matrices, as shown in Figure 8, of 1-digit input number estimation and single bead image recognition with the evaluation dataset excluding failed projection transformation samples (= 289 samples). Figure 8 (a) shows that all mis-



(a) one-digit input value estimation

(b) single bead image recognition

Figure 8: Confusion matrices of 1-digit input number estimation and single bead image recognition.

estimated digits were output as `X`, with no confusion occurring between the numbers `0` to `9`. Consequently, we obtained Precision, Recall, and F-measure values of 100%, 99.7%, and 99.8% respectively. Figure 8 (b) shows the recognition performance of bead images is highly accurate, with 14,692 out of 14,161 bead images (= 289 samples × 7 digits × 7 bead images) correctly recognized. Consequently, Precision, Recall, and F-measure values all achieved 99.9%. It suggests it is possible to eliminate misestimated input values (outputs with no matching values, `X`) by integrating the results of recognition for temporally adjacent frames. However, we could not find specific patterns or conditions in this experiment, regarding the cause of the failed bead image recognition for 8 samples.

5.3 Discussion and Limitations

In the following sections, we will engage in a comprehensive discussion and identify the limitations of this study by considering the above results from multifaceted perspectives.

5.3.1 Factors adversely affecting estimation performance

To strengthen the estimation method, e.g., improving robustness, we should identify the factors adversely affecting estimation performance.

Firstly, lighting conditions might affect adversely because our proposed method relied on an image-based approach. In the aforementioned experiments, we evaluated the system using the dataset from a typical learning environment with a ceiling light on. In addition to this, we considered a more challenging environment of a dark room with only a desk light. We built a dataset of 200 images under the environment shown in Figure 9, following the same procedure. We evaluated the proposed method using this dataset and confirmed that 145 out of 200 samples were estimated

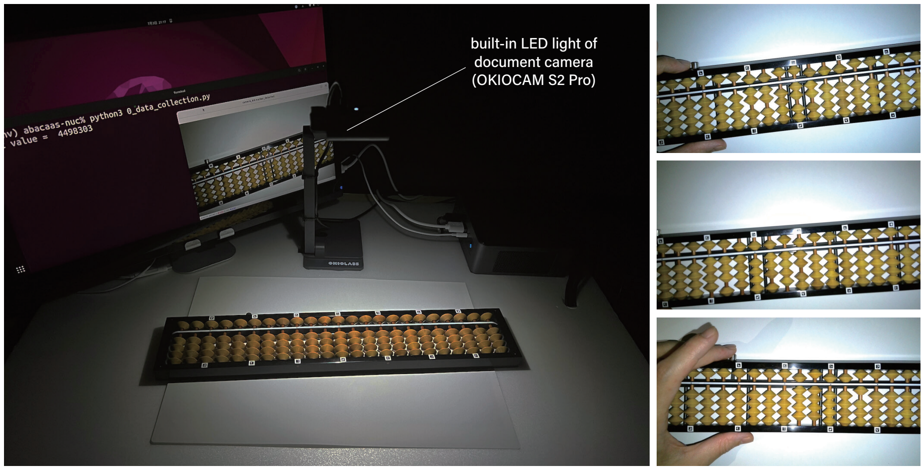


Figure 9: Experimental setup with the dark environment (with the condition that only built-in LED light of document camera is turned on, and any other light sources are turned off), and example images in the dataset.

correctly (Accuracy = 72.5%). As this environment was not included in the training dataset, the estimation performance became lower than the assumed environment. However, no confusion occurred with other input values (i.e., the Precision of 1-digit input values estimation was 100%), suggesting that our method might be applicable in darker conditions. Regarding AR marker detection, we find the lighting condition does not affect adversely performance (6 out of 200 samples are misidentified, however, there was no big difference from the case with the assumed environment).

Secondly, the position and angle of the abacus in the captured image might affect adversely because our proposed method allows users to change them. Regarding the position of the abacus, Figure 10 (a) shows the center position (midpoint between AR markers with `id = 3, 10`) of the abacus in the image and its estimation results with evaluation dataset of Section 5.1. As the abacus deviates from the center of the captured image, the small bead images differ from those captured from a frontal view, suggesting a higher likelihood of misestimation. Regarding the angle of the abacus, Figure 10 (b) shows a histogram of the abacus's angle and its estimation results with the evaluation dataset. While estimation fails in cases where the abacus is extremely tilted ($> 20\,\mathrm{deg}$), there are also several samples of failure even when the angle is small ($< 10\,\mathrm{deg}$). This suggests that factors other than angle may give significant effects. As the limitation of our proposed method, it can not estimate when the abacus is outside of the area to be captured by a document camera. To address this problem, we need to design a new interface to avoid drastic abacus movement, e.g., dynamically changing the position to display calculation problems.

Finally, the occlusion caused by the hand manipulating the beads, which was not dealt with in this paper, should be considered. In our proposed method, it's unable to recognize the bead image where hand

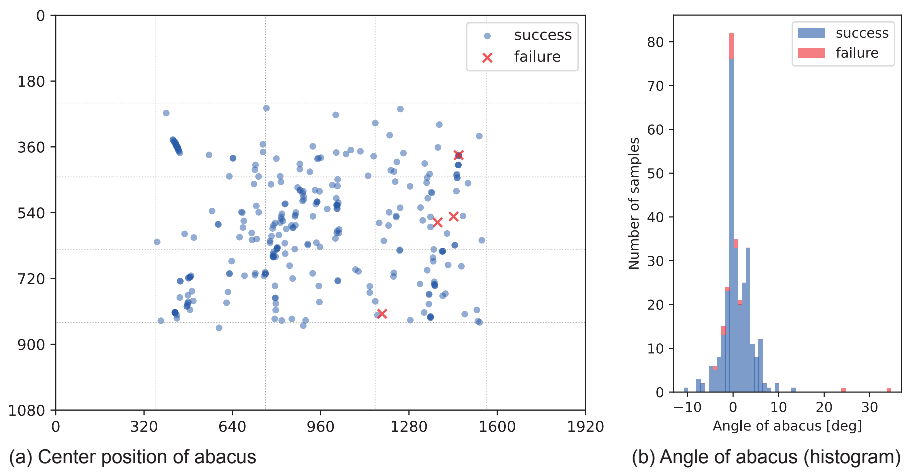


Figure 10: Analysis results of effects in position and angle of the abacus.

occlusion occurs, making it hard to extract a bead image sequence that matches the dictionary, i.e., the estimation result will be `X`, in most cases. Besides, the document camera is assumed to be positioned in front of the abacus user, capturing images close to the user's sights. As the hand moves gradually from left to right during bead manipulation, we believe that information for all digits can be obtained after inputting the rightmost digit. As a future task, we plan to construct a dataset in the wild settings, i.e., a time-sequentially continuous dataset, and we will evaluate the performance of our proposed method.

5.3.2 Computation performance, and device alternatives

As the result of evaluation in this paper, the average computational time for estimating input values of 19 digits (including the 7 digits of the evaluation target) is 0.176 seconds, as shown in Table 1. This indicates that continuous estimation is possible at about 5–6 fps with the performance of the machine used as mentioned in Section 4.1. Also, the computational complexity of the system reaches almost maximum with 19 digits, because the maximum digits number of a common abacus is 23, and several digits in the leftmost are always covered with a hand for holding an abacus. If we consider the input speed of a beginner using an abacus, it might be possible to be used even lower-performance and more affordable devices (e.g., Raspberry Pi[11]) by reducing estimation frequency. As future work, we will evaluate the user experience and effectiveness of the abacus learning support system which combines our proposed method in this paper and feedback functions.

In this paper, we use a document camera to capture images of the abacus board, but we are also considering replacing it with a different camera device. For example, by using smart glasses, represented by Google

[11] `https://www.raspberrypi.org/`

Glass[12] and XREAL light[13], which are equipped with a camera that captures the user's sights, there is a possibility that image capturing and applying our input estimation method can be performed only in wearable devices. Furthermore, since many smart glasses are also equipped with information provisioning functions, we believe they can be used as one of the abacus learning support approaches, such as overlaying images using Augmented Reality (AR) or providing guidance through audio.

6 Conclusion

Abacus learning requires understanding the numerical representation using the beads of the abacus and mastering the manipulation techniques, necessitating long-term, repetitive learning. In this study, we aim to realize ICT-based learning support for abacus learning using a conventional abacus. In this paper, we proposed an input value estimation method for an abacus based on image recognition obtained by a document camera to grasp the learner's "abacus manipulation behavior" required for providing learning support. By detecting the abacus with AR markers attached from the image and recognizing the bead images that make up the digits, we confirmed that it is possible to estimate the 7-digit numbers input on the abacus with an accuracy rate of 95.0% through template matching. In the future, we will extend our approach to continuous recognition under situations where occlusion occurs due to the manipulating hand and develop an information presentation system that provides appropriate guidance tailored to abacus behavior.

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