Card Type Device to Support Acquirement of Card Techniques

Koji Tsukada[1], Kenki Tsuda[1], and Maho Oki[1]

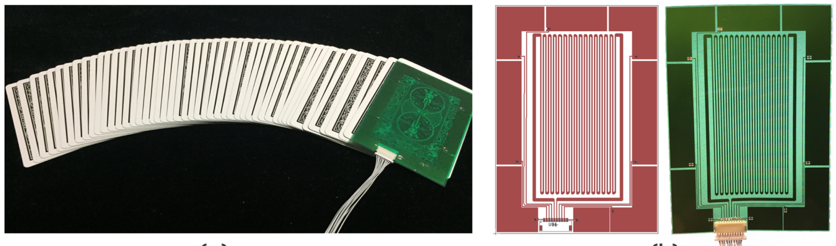
Future University Hakodate, Hokkaido, Japan {tsuka,okimaho}@acm.org

Abstract. Recently, the development of methods that use sensors and computer technology to evaluate how people learn and use skills in sports or performance art has become a subject of active research; and various tools, such as balls used in sports games, have been equipped with sensors to detect motion. However, the acquisition of card techniques, such as shuffling and cutting, has rarely been studied. Therefore, we propose a system based on a device with a form factor resembling a common playing card to support computational measurement and analysis of users' skills acquisition related to card manipulation. We designed thin sensors with patterns of conductive ink to maintain the thickness and shape of common playing cards. We also implemented the proposed system as a prototype card device to measure users' manipulations of a deck of cards. Further, we measured and compared three common card techniques using the prototype system. The results of our analysis demonstrate the possibility of using the proposed system to learn card techniques.

Keywords: Cards · Acquirement of Techniques· Conductive ink

1 Introduction

Many studies have been conducted on methods to collect data on human activities in various fields such as performance art and sports [1, 5, 8]. However, relatively few studies have considered collecting such data on card manipulation techniques (hereafter referred to as card techniques) in card games and magic, although classic movements such as shuffling or cutting a deck of playing cards are well-known in popular culture. Hence, existing methods of learning card techniques are quite traditional, and mainly include activities such as watching skilled people perform the technique and practicing repeatedly with reference to literature. In addition, because the population of skilled people who are familiar with card techniques is smaller than that of common popular sports, learning techniques directly from people who have the skill can be difficult. Considering this background, we propose an electronic device with a form factor resembling a common playing card designed to collect analyze, and quantitatively evaluate a users' application of card techniques.



(a) (b)

Fig. 1. Prototype of a card device. (a) Usage example. (b) Designed patterns (left) and implemented flexible printed circuit board (right).

2 Related work

2.1 Magic augmentation with digital technology

In this study, we focus on card techniques commonly used to perform magic with playing cards. In the field of magic, various attempts have been made to adopt computer technology to create novel tricks and performances. Many magicians, including Marco Tempest [10], used iPads, AR, and drones to create magic tricks. In addition, new magic shows that integrate mixed reality and augmented reality [2] as well as the use of humanoid robots [7, 9] have been recently proposed. Although their project is still in a technical validation stage, Koretake et al. [4] proposed a robot magician designed to perform card magic with four fingers, with an ability to manipulate cards like a human. In contrast to these approaches that incorporate digital technology into specific tricks and shows, in the present work, we developed a system designed to support the acquisition of card manipulation skills used in card games and magic.

2.2 Skill acquisition support system

Various systems have been proposed to support effective practices to help users learn to do activities, such as playing sports and musical instruments, or dancing, by detecting user actions and providing feedback [1, 5, 8]. Such systems use sensors and motion capture to collect information on movements and timings from video, sound, vibration data, numerical values, etc. The SwingTracer[6] device, which is designed to be attached to a baseball bat, and the Adidas Smart Ball [3], which incorporates a sensor in a soccer ball, have been marketed as products for sports analysis. In contrast, card techniques in magic are mostly practiced and learned using classical methods, such as watching skilled players or repeating exercises by referring to literature. Many instructional books have been published on magic techniques, and card techniques are also widely described on the web with photos, text, and videos on wiki sites and YouTube. However, in terms of actual practice, the only approach is to repeat the exercise independently, but it is challenging to recognize the reasons for good or poor performances without a teacher. In this study, we developed a card-shaped sensing device for use with playing cards and a software package for recording and viewing data from the cards to contribute to the quantification of card techniques and identification of correct actions, which has not been explored in prior works.

3 Design of card device

In this study, we proposed a device with a form factor resembling a playing card to support the acquisition of card techniques. The device is designed to collect data on a user's performance of card techniques using integrated sensors to enable a quantitative analysis and comparison. In the design of the sensor in the proposed device, we aimed to measure physical changes related to the execution of card techniques while retaining the shape of a standard playing card as much as possible.

Regarding the former, one of the authors is an experienced magician with some proficiency with card techniques, and we determined the properties to be measured by the system based on that experience. As a result, we designed the device to measure where the user's fingers are touching and the extent to which the card is bent while in use, which are important for basic card techniques, such as shuffling and cutting a deck. Regarding the latter, we designed capacitive touch and bending sensors using a thin flexible substrate with a special pattern. The device is designed to be placed at the top or bottom of a deck of cards. We also attached the device to a real playing card, which was thinned down with sandpaper to retain the approximate shape and thickness of a standard playing card.

4 Implementation

In this section, we describe the implementation of the prototype device and the feedback application.

4.1 Card device

Fig. 1 shows the prototype device. The card part was implemented as a P-Flex-brand flexible circuit board for conductive ink[1] to closely resemble the shape and feel of a standard playing card. The card was 73 µm thick, and its face was the same size as that of a common playing card (63 x 89 mm).

The capacitive touch and bending sensors were designed using the pattern printed on the flexible circuit board (Fig. 1-b). The eight polygon areas arranged along the edge of the card comprised capacitive touch sensors, and a single line pattern across the center comprised a bend sensor. Each pattern was connected to the control circuit and a microcontroller (an Arduino Pro Mini) via a cable. For the design of the bend sensor, we referred to Vadgama's method [11].

[1] https://info.elephantech.co.jp/en/p-flex-fpc

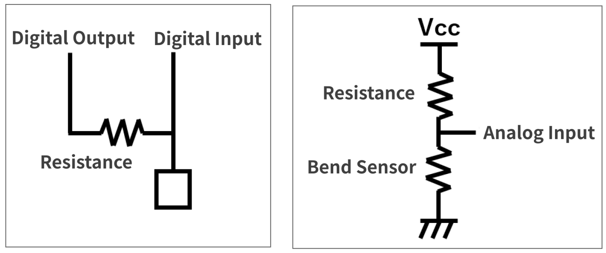


Fig. 2. Control circuit for touch sensor (left) and bending sensor(right).

The capacitance touch sensor was implemented using the CapacitiveSensor library[2], and the delay time between the digital input and output was measured as shown in Fig. 2. When the user touches the capacitive touch sensor with their finger, the delay time increases, and the length of the delay time is used to determine whether a finger is touching. When the microcontroller detects a change in the sensor values, it normalizes the data and sends it to the computer via serial communication.

4.2 Feedback application

The feedback application records sensor data along with a video from a camera connected to a computer. After recording the execution of a technique, the user can view their video and a graph of the sensor data. Fig. 3 shows the overall system configuration and a screen of the feedback application displaying sensor data.

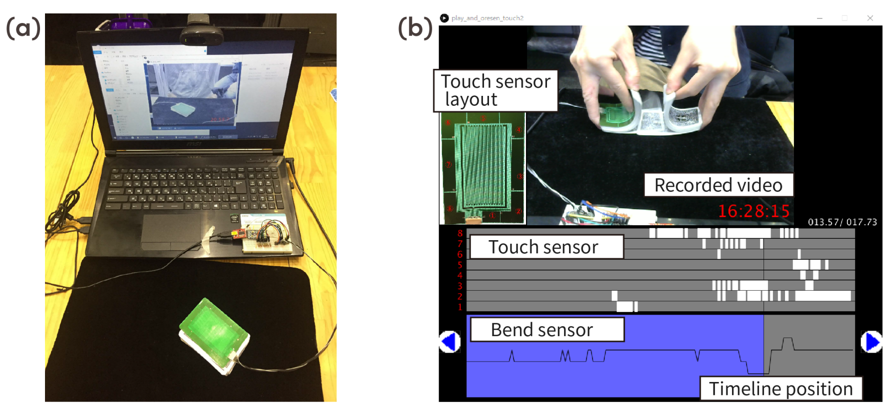


Fig. 3. (a) System configuration used to record data when users perform card techniques. (b) Screenshot of the feedback application.

[2] https://www.arduino.cc/reference/en/libraries/capacitivesensor/

5 Target card techniques

The types of card techniques that can be measured with this device are limited owing to the need for a connector and cable and the fact that not all cards in a deck can be replaced with the device. However, some card techniques can be measured using the proposed approach. Among these, we selected the most commonly used basic techniques, including a riffle shuffle, a spring technique, and a Charlier cut, and measured users attempting to perform these techniques. The procedure for each technique is shown in Fig. 4 and described in detail below.

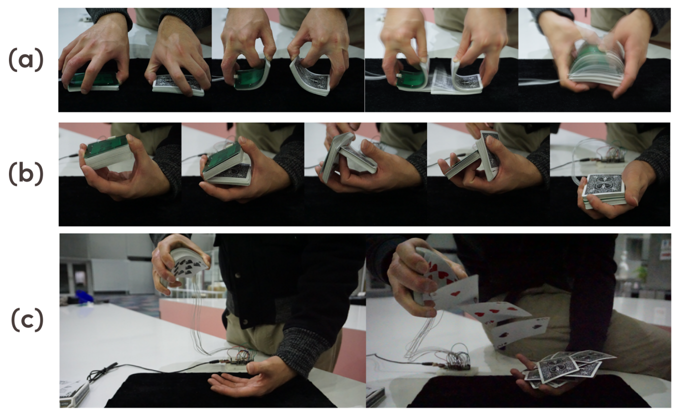


Fig. 4. (a) Riffle shuffle, (b) Charlier cut, and (c) card spring.

5.1 Riffle shuffle

The riffle shuffle is a shuffling technique in which a deck of cards is first divided into two piles. Both stacks of cards are then popped together with both hands, and the two piles are combined back into a single stack with a quick sliding motion that rearranges the order of the cards. A player always touches the top and bottom cards until all movements are completed. The degree of bending when flipping the cards is also considered an important factor in successful shuffling.

5.2 Charlier cut

The Charlier cut is a cut technique in which the top and bottom halves of the deck are swapped using a single hand. First, the player holds the deck of the card with the fingertips of one hand and drops the lower half of the card on their palm. Subsequently, the dropped lower half of the deck is pressed with the index finger, the upper half is replaced, and the card is merged into a single stack. In this technique, the fingers always touch the top and bottom cards of the deck, and it is important to know where to place ones' fingers to support the cards when replacing them.

5.3 Spring

The spring is a technique in which the player holds a deck of cards in one hand and bends the cards so that they fly one by one into the other hand. The bending of the cards is considered critical for the success of this technique.

6 Evaluation

We performed two evaluations, first considering the basic performance of the system and then the measurement of card techniques performed by users.

6.1 Evaluation of basic performance

The detection accuracy of each sensor was evaluated using the card device.

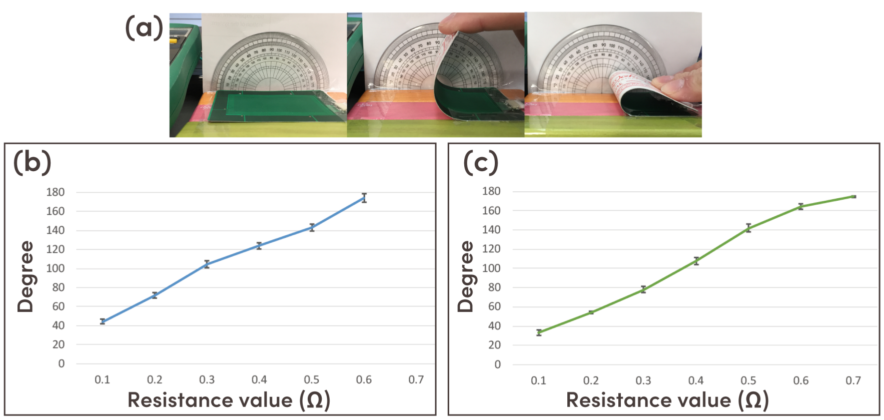


Fig. 5. (a) Experimental method for evaluating bending sensors (from left to right: 0°, 104°, 176 °). (b) Results of bending the sensor in the front direction. (c) Results of bending the sensor in the back direction.

Bending sensor. We verified how many steps could be measured and the amount of change in the angle per step. The experiment was conducted as follows. The card-type device was gradually bent in front of a protractor (Fig. 5(a)) and the angles at which the resistance measured by the tester changed by 0.1Ω was recorded. This was performed five times each for the front (side with the connector) and back. Fig. 5(b) shows the measured values when the device was bent in the front direction and Fig. 5(c) shows the measured values when it was bent in the back direction. These are the average values of the angles for a 0.1Ω change. Bending angles of approximately 44–174° in six steps on the front side and approximately 33—175° in seven steps on the back side could be measured. This difference in the number of steps was presumably caused by the fact that the back of the device was covered with a thinly shaved playing card. Thus, the device was able to measure bending in six to seven steps.

Touch sensor. The accuracy of the touch detection was verified for each of the eight touch sensors. In the experiment, we graphed the data obtained by touching each touch sensor with an index finger for approximately 5 s using the feedback application. The results are shown in Fig. 6. All of the touch sensors were able to detect the input. There were two to five discontinuous areas where the touch was not detected; however, we believe that these brief detection failures could be eliminated with a smoothing filter.

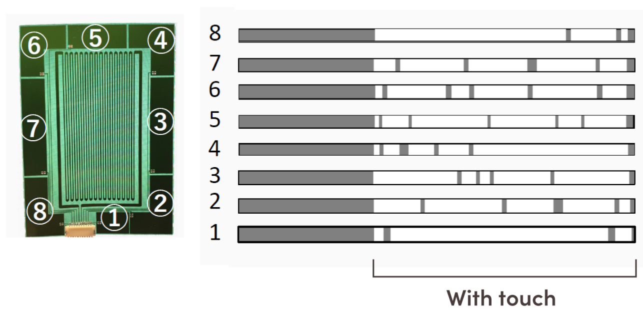


Fig. 6. Touch detection results visualized in the feedback application. The white area indicates the touch detection status.

6.2 Measurement of card techniques

We verified whether the prototype device could successfully acquire sensor data using the card technique. In addition, data from skilled and novice players were collected, analyzed, and compared to determine the essential characteristics of successful execution of each card technique.

Method. The initial state of this experiment is shown in Fig. 3(a), with a deck of playing cards on a magic mat and the card device on top of the deck. The card device was connected to a laptop computer running the feedback application, and sensor data and video were recorded when the subjects performed the card techniques. At the beginning of the experiment, an experimenter (who was skilled in card techniques) explained and demonstrated the basic procedure of each technique. The subject was asked to practice several times to confirm that they understood the procedure, and then the main experiment was conducted. The tasks examined in the experiment involved the riffle shuffle, spring, and Charlier cut, in that order. Three subjects were skilled (with four to eight years of experience with magic using playing cards) and six were novices.

The data obtained from the experiments were visualized using the feedback application to compare skilled users with successful novices and successful with unsuccessful subjects.

Result for the riffle shuffle. All the skilled subjects succeeded in performing the riffle shuffle technique, and one of the six novices succeeded. When two separate piles of cards were completely combined into a single pile, the shuffle was judged to be successful. In the successful case shown in Fig. 7, the deck of cards was combined into one stack; however, in the failure case, the cards are disorganized.

There was no noticeable difference between the skilled and successful novice participants other than the time they took to complete the shuffle. The difference in time was owing to the difference in familiarity with shuffling. The finding that no other differences were observed is attributed to the fact that the riffle shuffle is a relatively easy technique; and as long as the correct method is used, shuffling can be performed successfully.

The results of the comparison of the data of the successful and failed subjects are described. The data for the successful subjects all showed two bending steps from the previous state during shuffling. However, all failed subjects bent the cards in only one step. Fig. 8 shows examples of the data from the bending sensor obtained from a successful subject and a failed subject. The interval under "shuffling" in the figure was later added in red to the graph visualized in the feedback application. The results of this experiment for the task shown in Fig. 5, suggest that bending the card more than 70° is key to successfully performing a riffle shuffle.

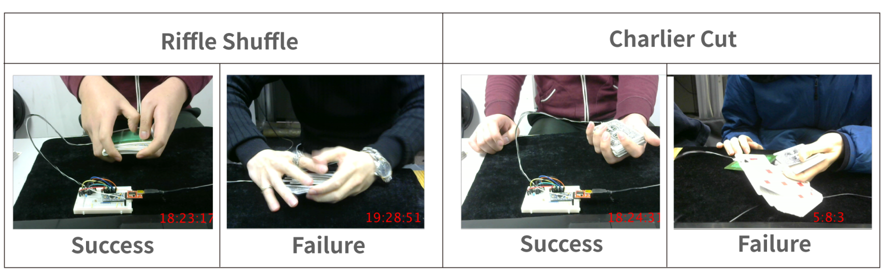


Fig. 7. Examples of successful and failed executions of the riffle shuffle and Charlier cut techniques.

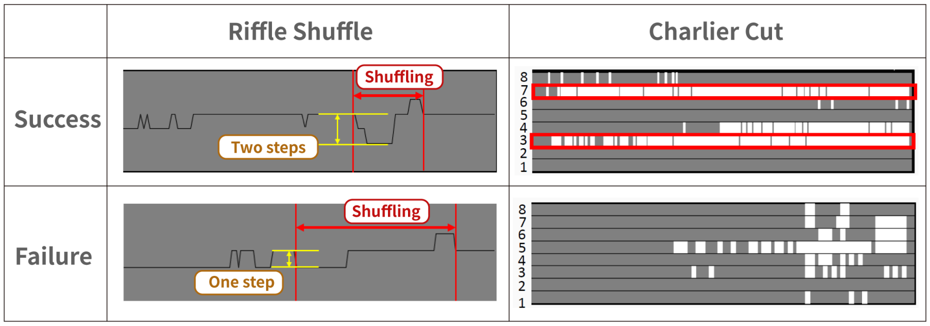


Fig. 8. Comparison of bending sensor data from successful and failed attempts to perform a riffle shuffle and touch sensor data from successful and failed attempts to perform a Charlier cut.

Result of Charlier cut. All of the skilled subjects succeeded, and three of the six novices succeeded. The technique was considered successful if the top and bottom halves of a stack of cards could be swapped without significantly disrupting the deck.

Fig. 7 shows examples of successes and failures. As in the riffle shuffle, there was no noticeable difference between the skilled subjects and successful novice subjects.

A comparison of the touch sensor data of successful and unsuccessful subjects is shown in Fig. 8, showing that successful subjects commonly touched their fingers at locations 3 and 7 in Fig. 8 when performing the Charlier cut, and they held and supported this area firmly to prevent the upper half of the card from falling out of their hands. In contrast, subjects who failed to perform the technique did not touch these locations but only held the card together. This result suggests supporting the deck of cards while maintaining contact with the topmost card is important to perform this technique.

Result of spring. All skilled subjects succeeded, and one of the six novice subjects succeeded. Success was defined as catching all cards flung by one hand with the other hand.

Fig. 9 shows a comparison of the results of skilled users with those of successful novice participants, and Fig. 10 shows a comparison of the successful novice participant with and those who failed to perform the technique. Unlike the other techniques, differences were observed between the two groups.

Regarding the comparison between skilled and successful novice subjects, the data from the bending sensor showed that both increased their bending in the second half of the spring motion. The change in the touch sensor differed between skilled and novice subjects. Skilled subjects touched only the areas corresponding to touch sensors 4 and 8 with their fingertips and hardly touched other areas, whereas most novice subjects touched many parts of the touch sensor and held the card deck in their hands as if they were grasping it, including the novice subject who performed the technique successfully.

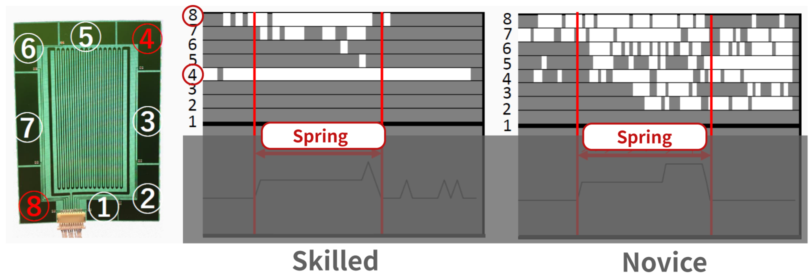


Fig. 9. Comparison of skilled/novice data on the spring.

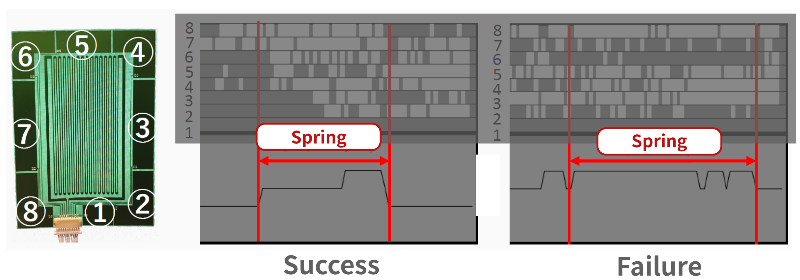


Fig. 10. Comparison of successful/failure data on the spring.

Next, we compared the successful and unsuccessful novice users. The successful novice subject increased the degree of bending in the second half of the spring, whereas the data from unsuccessful subjects included parts where bending was weakened. Regardless of the success or failure of the touch sensor, the novice participants touched many parts of the card. These results suggest that to perform the spring technique successfully, strengthening the bending of the cards while executing the movement is important, and the skilled users held only the positions marked as four and eight.

7 Discussion

In this section, we discuss the availability of the system and some issues noted by users.

7.1 Availability

Through performance evaluation experiments on the prototype system, we confirmed that touching and bending could be detected with a certain level of accuracy. Furthermore, by collecting and analyzing the card technique data of skilled and novice players, we found that the differences between skilled and novice users and between successful and unsuccessful users allowed us to estimate the specific motions or "tricks" associated with successfully executing the card techniques like a skilled card manipulator. This suggests that the system can be used to collect and analyze data on card techniques. The availability of the system could be increased by verifying the effectiveness of the tricks identified in this study in acquiring the technique and by examining the range of other card techniques that can be recorded and analyzed by the system.

7.2 Issues

Card device. In the experiment, some participants commented that the thickness and hardness of the device was not a problem, but the cable was in the way, and that the cable was hard and the card sometimes moved unintentionally. To solve these problems, we considered integrating the card and microcontroller parts.

The current card device also has a problem with the strength of the card itself. After several measurements in the experiment, we found that the electrical connection was faulty. Some other problems also occurred with the prototype device, and each time the card device was replaced with a new unit. We attribute this outcome to the fact that the board and connector of the card section were bonded only by solder. This electrical connection should be reinforced to improve the connection method or the strength of the connector.

Feedback application. In this study, one of the author with skill in card techniques compared the graphed data and organized the features, differences, and commonalities of the data. The tricks required to perform the techniques were also examined. However, novice users may not be able to discover the features of such data on their own. Therefore, a more user-friendly feedback method that enables novice users to understand the features of the recorded data should be developed and implemented.

8 Conclusion

In this study, we have proposed a card device to support users in learning to perform card techniques. A prototype of the card device equipped with bending and touch sensors was developed with shape and stiffness almost identical to that of a standard playing card. We also developed a feedback application to record and analyze the sensor data and video of the user performing the card techniques. By measuring, comparing, and analyzing three different card techniques, we found notable differences and similarities between successful and failed attempts and between users with and without skill in performing the techniques. The results demonstrate the possibility of gaining knowledge that could help a user to learn to perform card techniques. Therefore, the usefulness and reliability of this device should be increased by verifying the effectiveness of this knowledge in acquiring skills, investigating the range of applicable card techniques, and improving the feedback application.

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