

## Research Article

# Wallet Operation Inspection System Using Deep Learning for Image Processing

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## ABSTRACT

As the average age of Japan's population increases, it is becoming increasingly important to identify persons suffering from mild cognitive impairment (MCI), which is one of the pre-stages of dementia, to ensure they have proper care while working to suppress the progression of the disease. As a method for investigating MCI, wallet operation evaluations have been receiving considerable attention recently. Herein, we propose a system for inspecting wallet operation based on deep learning for image processing. In our system, the bills and coins extracted from a wallet are automatically scanned and recognized, which makes it possible to evaluate a person's ability to correctly select and extract the correct bills and coins from the wallet within a reasonable period.

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## 1. Introduction

The average age of Japan's population is increasing, and this trend is expected to continue. As a result, the number of elderly persons suffering from dementia is growing rapidly, and it has become necessary to find ways to identify persons suffering from mild cognitive impairment (MCI) [1] in order to ensure they have proper care while suppressing the progression of the disease.

As a method for investigating MCI, which is one of the pre-stages of dementia, wallet operation evaluations have been receiving considerable attention recently [2]. However, in the normal course of such testing, the test subject must be observed by an examiner who provides instructions on how the inspection is conducted, observes the testing, and records the results [2].

In contrast, this paper reports on an automatic inspection system in which deep learning is used to conduct wallet operation evaluations automatically. We recommend readers to see [2] in more details on the relationship between a method for the MCI investigation and wallet operation inspection.

## 2. Wallet Operation Inspection

During a conventional wallet operation inspection [2], a subject is tested by an examiner who instructs him or her on how to proceed, observes the process, and then records the results. This process can be broken down into the following six operational units performed in order:

- (1) The examiner hands the test subject a wallet containing five (¥1, ¥5, ¥10, ¥50, ¥100 and ¥500) Japanese coins each, five ¥1,000 Japanese bills, and one (¥2,000, ¥5,000, and ¥10,000) Japanese bills each, as partially shown in Fig. 1. (In the wallet, the total number of coins is 30, while that of bills is eight.)
- (2) Next, the test subject is shown a sheet of paper describing two trials for 10 seconds. In the first trial, he or she is instructed to extract ¥1,165 from the wallet and place the money on the desk. The second trial is the same but the amount is ¥123.
- (3) The test subject is instructed to begin the trials described in (2) when the examiner presses the button on his or her stopwatch.

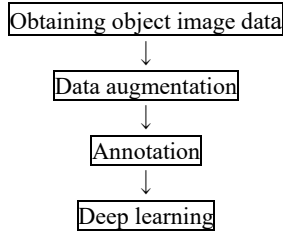


Fig. 2. Processing flow of data preparation and deep learning.

- (4) The test subject performs the two tests and reports his/her completion as instructed by the examiner.
- (5) After visually confirming that both operations have been completed and receiving the test subject's report, the examiner presses the stopwatch button and informs the test subject that the evaluation is over.
- (6) The time required by the test subject to complete both the first operation and second operation is then recorded by the examiner.



Fig. 1. Some of objects used in wallet operation inspection.

### 3. Proposed System and Method

For developing a system for inspecting wallet operation, precise recognition of coins and/or bills is indispensable. For example, the coins and/or bills put on a table might be overlapped each other, and they might have rotations and/or reflections of lighting. Moreover, an image input into a computer might have variations of object-size depending on the distance between the camera and the object. Under these circumstances, deep learning is one of the most promising methods for better accuracy of recognition. We assume that our proposed system is used under the normal lighting condition using some fluorescent lights.

Our proposed system consists of two parts: (1) data preparation and deep learning and (2) the wallet operation evaluation module. Fig. 2 shows the processing flow of the first part of this system, which consists of four processing units:

- (1) Obtaining object image data
- (2) Data augmentation
- (3) Annotation

#### (4) Deep learning

As objects to be recognized, we use ¥1, ¥5, ¥10, ¥50, ¥100, and ¥500 Japanese coins and ¥1,000, ¥2,000, ¥5,000, and ¥10,000 Japanese bills. For dataset assembly and recording the bills and/or coins during actual testing, we use a web camera set 40 cm above a desk plate to obtain object images, as shown in Fig. 3.



Fig. 3. Example of object image.

In this study, we use a region-based convolutional neural network (R-CNN) known as Faster R-CNN [3] for deep learning and object recognition.

At the beginning of the evaluation, the same wallet containing the same coins and bills described in Section 2 is set in front of the test subject. The processing flow of the second part of the proposed system consists of the following 10 processing units performed in order:

- (1) Japanese explanations of the evaluation process (three pages) are displayed sequentially on a personal computer (PC) screen, as shown in Fig. 4. The test subject indicates when he/she has finished reading each page by pressing the button connected to the PC.
- (2) The PC then displays a 10-second message showing the two monetary amounts (first: ¥1,165, second: ¥123) the test subject will be requested to extract from the wallet.
- (3) The evaluation begins when the test subject presses the button. At that point, the web camera and the system begin recording the elapsed time.
- (4) The test subject extracts the appropriate bills and coins from the wallet and then presses the button again when he/she desires to report that an amount of money equal to ¥1,165 has been placed on the desk plate as instructed.
- (5) An image showing the present state of the desk plate is then uploaded into the system.
- (6) Next, the test subject proceeds to extract ¥123 from the wallet and place it on the desk plate. Note that a condition of this test portion is that the test subject is instructed not to use the coins extracted for the ¥1,165 test portion.
- (7) The test subject then signifies the completion of that portion of the text by pressing the button again.
- (8) An image showing the present state of the desk plate is uploaded into the system.
- (9) (a) the total amount of money extracted from the wallet by the test subject for the first test segment, (b) that for the second one, and (c) the time required for both test segments are calculated by the proposed system.

(10) Finally, the time test and object recognition results are displayed on the PC screen, as shown in Fig. 5.

The Japanese description of upper left of Fig. 4 mentions as follows:

The wallet operation inspection starts from now on. The two monetary amounts will be shown as test subjects. Please extract the appropriate bills and/or coins from the wallet for the first test subject, following by placing them on the desk plate and then presses the button. Please press the button for forwarding the explanation page.

The Japanese description of upper right of Fig. 4 mentions as follows:

After pressing the button for expressing the finishing of the first trial, please extract the appropriate bills and/or coins from the wallet for the second test subject, following by placing them on the desk plate and then presses the button again. You can see the ending page describing the time test and object recognition results on the PC screen. Note that in the second trial, use neither the coins nor bills extracted for the first test portion.

The Japanese description of lower left of Fig. 4 mentions as follows:

Note that after inputting the image, which consists of bills and/or coins extracted from the wallet for the first trial, into this system, the bills and/or coins must be out of the region where objects are captured by the camera used in this system.

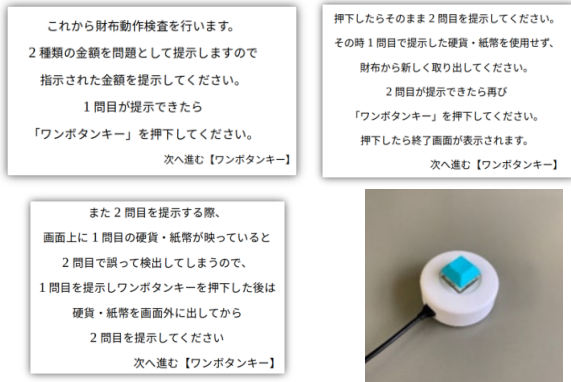


Fig. 4. Japanese language explanations of the inspection process as displayed on the PC screen in order of upper left, upper right, and lower left. The bottom right photos show the button used for changing the display and recording elapsed time.

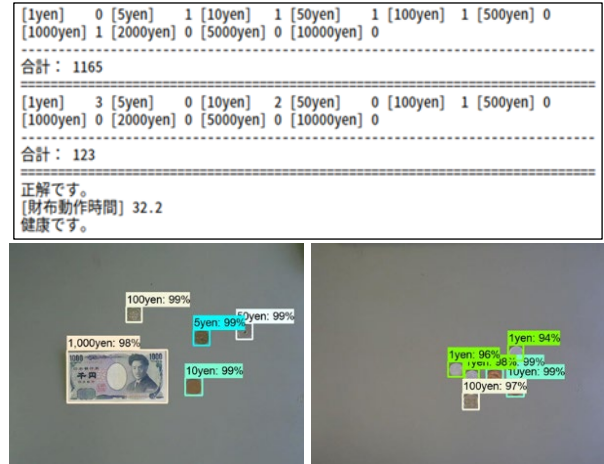


Fig. 5. Calculated inspection results (upper) and object recognition results (lower left: ¥1,165, lower right ¥123).

## 4. Experiment

### 4.1. Conditions

The experiment was performed on a PC equipped with an Intel Core i7-6700K central processing unit (CPU), a GeForce GTX 1080 graphics processing unit (GPU), and 32.3 GB of random access memory (RAM). The Ubuntu LTS18.04 64-bit operating system (OS) was installed on the PC and Python 3.7.3 was used as the development language. Jupyter Notebook [4], TensorFrow [5], ImageDataGenerator [6] labellmg [7], CUDA10.0 [8], cuDNN [9], and OpenCV1 [10] were used as toolkits and libraries.

For moving image input, a stream web camera was used. ImageDataGenerator was used for data augmentation, while rotation, vertical shift, horizontal shift, expansion, shrink, and channel shift were used as processing. Next, labellmg was used for annotations.

For deep learning, the TFRcode [11] for the faster\_rcnn\_resnet\_101\_coco model in TensorFlow [11] was generated using a program obtained from [12]. The mean average precision (MAP) obtained by the learning model used in the present study was 0.755.

The resulting dataset contained 1,200 images showing the wallet and/or the Japanese bills and coins used in our experiment. Using ImageDataGenerator for data augmentation, 12,000 images were generated from the above 1,200 images. 10,000 of those images were used as learning data and the remaining 2,000 images were used for the evaluations. Fig. 6 shows an example of data generated by augmentation.

To evaluate our proposed system, nine males (Subjects A to I) and one female (Subject J), all of whom are in their 20s, participated in our experiments.

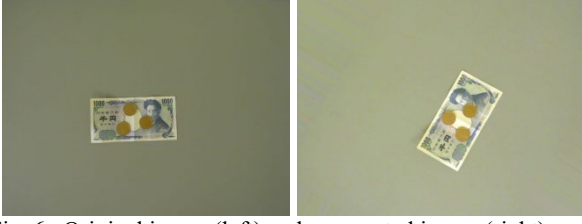


Fig. 6. Original image (left) and augmented image (right).

Under the common lighting condition using fluorescent lights, the experiments were performed under two conditions listed below:

- Condition 1: with the conventional method<sup>2</sup> described in Section 2.  
Condition 2: with the proposed system described in Section 3.

After the experiments, all of the test subjects were requested to select one of five answer-choices ([5] definitely yes, [4] yes, [3] no difference, [2] no, [1] definitely no) for each question in Table 1 in order to evaluate the proposed system.

Table 1. Questionnaire to evaluate the proposed system.

No.	Question
1	Was the wallet operation test on condition 2 easier than that on condition 1?
2	Did you feel less stress during the wallet operation test on condition 2 than on condition 1?

#### 4.2. Results and discussions

Table 2 shows the average time measured for the 10 subjects during these experiments. Here, it can be seen that the time required for the wallet operation inspection using our proposed system was slightly longer than that of the conventional method. This might be caused by the additional button-pushing operations required during the process of our proposed method.

However, in both the conventional and proposed methods, none of the test subjects exceeded the limit time (120 s) that was assigned for the wallet operation inspection in this experiment. This was thought to be because all subjects were in their 20s and in good mental and physical condition.

Table 2. Comparison of the average time of wallet operation inspection between the conventional and proposed methods.

	Average time (s)
Conventional method	32.2
Proposed method	34.8

Table 3 shows the average questionnaire score for the 10 subjects. Here, it can be seen that the proposed method was better than the conventional method from the viewpoints of ease of use and stress reduction.

Table 3. Average questionnaire scores for 10 subjects.

Question No.	Average score
1	4.2
2	4.1

For all of the objects on the desk plate, the average correct recognition rate by the proposed system was 80% for ¥1,165 and 90% for ¥123, under the condition that the inspection was treated to be unsuccessful when at least one of the coins or bills was misrecognized. On the other hand, the accuracy rate of object recognition was 96.0% for ¥1,165 and 98.3% for ¥123.

More precisely, in case of 80% for ¥1,165, where the number of objects to be recognized for all subjects was 50, a ¥100 coin was misrecognized as a ¥500 coin, as shown in Fig. 7 as an example in two misrecognitions happened. Moreover, in case of 90% for ¥123, where the number of objects to be recognized for all subjects was 60, a ¥1 coin was misrecognized as a ¥100 coin. These three misrecognitions were possibly due to light reflection.

The test contents of proposed system are the same as those of conventional wallet operation inspection. Therefore, from the viewpoints of MCI investigation, we can recognize no difference between the conventional and proposed methods. The relationship between a method for the MCI investigation and conventional wallet operation inspection has been described in [2].

As our future targets for improving our proposed system, we intend to perform the wallet operation inspection with the participation of elderly persons who may have MCI or other forms of dementia. Moreover, we will reduce potential misrecognitions of the ¥1, ¥100, and ¥500 coins, primarily by making improvements to the lighting conditions and/or the learning dataset.

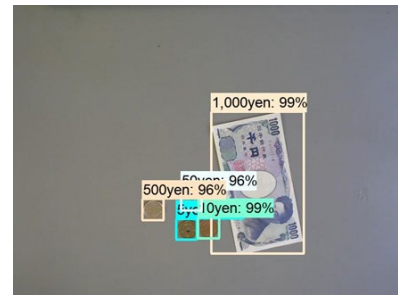


Fig. 7. Misrecognition of a ¥100 coin that was identified as a ¥500 coin.



## 5. Conclusion

As the number of elderly persons in Japan's super-aging society continues to increase, it is becoming increasingly important to find ways to identify persons suffering from MCI, which is one of the pre-stages of dementia, in order to ensure they receive proper care and make efforts to suppress the progress of the disease. As a method for investigating MCI, wallet operation inspection has been receiving considerable attention recently.

Herein, we proposed a wallet operation inspection system based on deep learning for image obtained under the normal lighting condition using some fluorescent lights. In our system, a wallet containing bills and coins is supplied to the test subject, and his or her ability to extract bills and coins in the correct amounts is automatically recognized. The proposed system also determines whether the extractions from the wallet are made within a reasonable period.

The test subject of wallet operation inspection is guided by the proposed system using a personal computer screen and a button, and the total amount money put by him/her on a table is measured automatically by the proposed system using deep learning for image showing the wallet and/or the Japanese bills and/or coins. From the viewpoints of ease of use and stress reduction, the proposed method was also better than the conventional method, where the test subject must be observed by an examiner who provides instructions on how the inspection is conducted, observes the testing, and records the results.

In future research, we will conduct experiments that focus on the elderly and/or people with MCI or dementia after the permission of the Ethnic Committee of University. It is not clear that the elderly and/or people with MCI or dementia easily read the text on the display. Some of them might feel any difficulties in reading the text on the display, which could show the symptoms of MCI or dementia.

The inspection using the proposed system is recommended to be conducted under the normal lighting condition using some fluorescent lights.

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