Abnormal Behavior Detection using Image Sensing

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OKI's aim is to establish a technical base that will support a more secure and convenient social infrastructure, and one of the technologies that make up the technical base is the abnormal behavior detection using image sensing. Generally, abnormal behavior detection is a technology in which a model is created using normal behavior data and any behavior deviating from the model is deemed abnormal. In many cases, it is difficult to comprehensively collect abnormal behavior data in advance, thus being able to detect abnormalities with a model created using only normal behavior data is extremely useful for actual implementation.

This article first shows application examples of abnormal behavior detection using image sensing, which is followed by typical examples of abnormal behavior detection through motion image processing. Additionally, an OKI product that applies abnormal behavior detection to ATMs is described.

Applications of Abnormal Behavior Detection

Figure 1 shows possible applications of abnormal behavior detection using image sensing. An example in the financial and retail field is ATM abnormal behavior detection. In this example, a camera captures the motions of the hands operating the ATM, and determination is automatically made as to whether it is a normal transactional motion or an abnormal motion for a criminal purpose. If it is determined that there is abnormality, alarm is triggered, security is notified, and/or warning is displayed on the terminal screen. In the transportation field, traffic conditions are monitored with a camera. Such conditions as reverse driving, weaving through traffic and stopped vehicle are automatically detected and reported as abnormal ensuring safe/secure driving. The traffic monitoring center only needs to make a visual confirmation of the notified abnormal image to decide if highway patrol should be dispatched. In the manufacturing field, it is possible to automatically detect defective products and analyze the cause of the defect to improve productivity or the manufacturing process.

In addition to image sensing technology, OKI is working on abnormal behavior detection using logs and vibration data. An example is the failure prediction of plant facilities and equipment at manufacturing sites[1), 2)].

As described above, various applications of abnormal behavior detection are possible, and development is proceeding for their realization.

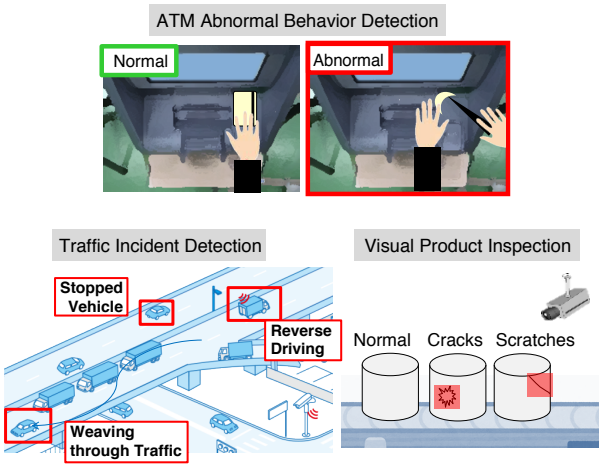

Figure 1. Applications of Abnormal Behavior Detection

Abnormal Behavior Detection using Motion Image Processing

Among image sensing, this section introduces typical examples of abnormal behavior detection targeted at motion images.

Abnormal behavior detection based on motion images is generally composed of motion image feature extraction and recognition processes. Specific examples of these processes are presented below.

In an example of detecting a person's falling motion in the presence of a group of pedestrians as abnormal[3)], Cubic Higher-order Local Auto-Correlation (CHLAC) is used for motion image feature, and subspace method is

used for recognition. CHLAC is a method of binarizing an image then comparing the local regions between three consecutive frames with the 251 CHLAC patterns and feature extracting the number of times the patterns appear. There is an advantage in that abnormal behavior can be detected even when mixed in with normal behavior, and detection performance does not depend on the position within the image. In the subspace method, a subspace of normal behavior is configured over the feature space, and the distance between the feature value obtained from the input frame and that subspace is treated as the degree of abnormality.

For detecting a person falling on an escalator[4], Space-Time Patch (ST-Patch) and Continuous Rank-Increase Measure (CRIM) are used for motion image feature and recognition, respectively. The ST-Patch is obtained from statistics of concentration gradient values in a small area of the moving image. Since the gradient value is obtained from between continuous frames in addition to the upper, lower, left, and right pixels, the feature value contains both a "view" and "motion" information. CRIM is the degree of abnormality that can be calculated from ST-Patch, and a condition is regarded as abnormal when this value exceeds a threshold value. An area of humans is detected by a machine learning method called Real AdaBoost using ST-Patch as a feature value. Abnormality is detected by CRIM in which people within the human area is weighted using the reliability of Real AdaBoost.

Other methods for abnormal behavior detection include Optical Flow[5], STACOG[6] and MHI[7] for extracting moving image features, and Linear Discriminant Analysis (LDA), Support Vector Machine (SVM) and Gaussian Mixture Models (GMM) for recognition.

ATM Application of Abnormal Behavior Detection

OKI has developed and tested an ATM abnormal behavior detection using image sensing.

Crimes such as skimming that steals card information and PINs from ATM users have become serious problems. Detecting such crimes as they happen is important in that it leads to crime deterrence through on-site alarms and warnings, and reduces the burden on the surveillance staff. However, advancement in the miniaturization of criminal devices in recent years has made it difficult to recognize those devices from the ATM's external appearance. Therefore, it has become necessary to develop technology that detects not only the crime devices, but also the act of attaching such devices. Since crime behaviors are diverse, and it is difficult to predict every possible behavior in advance, an abnormal behavior detection that can create models only from normal behavior data is used. A surveillance camera is installed at the top of the ATM and shots are taken of the operation panel ensuring the detailed motions of the hands are visible (**Figure 2**), so that the attachment of a criminal device can be detected.

Regular operation of an ATM such as "withdrawing" and "depositing" are regarded as normal behaviors. The motion speed of a normal behavior will vary by individual and other motions such as "placing hands on the terminal" or "holding a bag" may be present. On the other hand, abnormal behavior may mimic normal behavior such as pretending to insert an ATM card into a slot while installing a criminal device. As described above, sufficient recognition accuracy cannot be expected using moving image processing alone due to the diversity in normal and abnormal behaviors. Therefore, OKI has developed an ATM abnormal behavior detection that combines moving image processing with ATM state awareness.

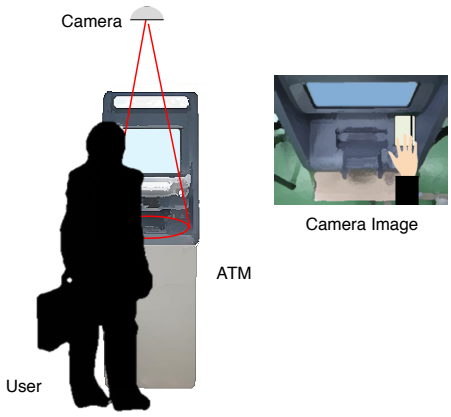

Figure 2. Camera Image

Abnormal Behavior Detection Integrated with ATM State Awareness

Abnormal behavior detection using moving image feature extraction, ATM state awareness and recognition processing is described below.

ATM state awareness is being aware of the ATM's transaction state (hereinafter, ATM state) such as "unmanned state" and "PIN input state." The ATM state is made aware using the internal state information notified from the ATM itself. By being aware of the ATM state, the normal behaviors that are likely to occur can be limited, thus improving the recognition performance of abnormal behavior detection.

For example, as shown in **Figure 3**, the ATM state goes through various changes from the unmanned state to the time the user completes the transaction and leaves. In the "PIN input state," motion takes place on the numeric keypad, but it is rare for motion to occur around the keypad during other ATM states, and in such a case, behavior can be detected as abnormal. Also, "proximity state" is before the start or after the end of a transaction. Therefore, complex motions such as ATM operation should not occur, but if there is complex motion, it can be detected as abnormal.

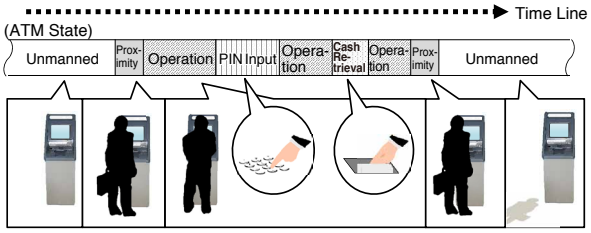

Figure 3. Example of ATM States

Figure 4 shows the flow of ATM abnormal behavior detection. Similar to the recognition process of typical abnormal behavior detection, the development is divided into the training phase for creating an abnormality detection dictionary and the detection phase for detecting abnormal behavior using the abnormality detection dictionary. The flows of the training and detection phases are shown below.

In the training phase, an abnormality detection dictionary for each ATM state is generated through machine learning using only normal behaviors. First, an image is acquired from the camera. Then a normalized image is generated for each frame and feature value is extracted. In ATM state awareness, the ATM state corresponding to the input frame is acquired. Thereafter, an abnormality detection dictionary is generated for each ATM state with respect to the accumulated feature values.

In the detection phase, normality/abnormality determination is made for each frame. The process from image acquisition to ATM state awareness is common with the training phase. An abnormality detection dictionary generated from the feature value of the same ATM state as the input frame is selected and recognition process is performed to determine normality/abnormality.

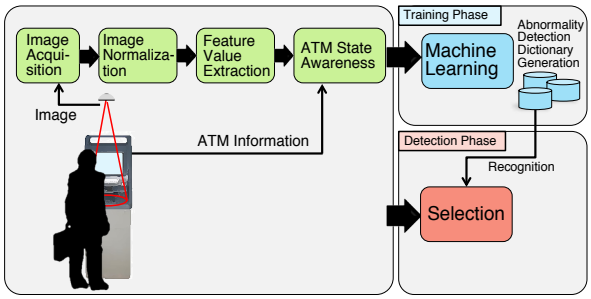

Figure 4. Flow of Abnormal Behavior Detection

Testing of ATM Abnormal Behavior Detection

Tests were conducted to confirm the effectiveness of the developed technology.

A simulated in-house environment was built to acquire images of actual motions during ATM transactions. As test subjects, the motions of 149 employees were shot, and both normal and abnormal behavior data were obtained. Normal behavior data were images of regular ATM transactions. Regular transactions include distinctive motions such as operation with the left hand, putting down the hands and counting bills. As a result, it is possible to evaluate a variety of normal behaviors. For the abnormal behavior data, scenarios were created based on commonly known criminal cases to capture behaviors that mimicked criminal behavior. In the tests, the motion of attaching a device imitating a crime device to the card insertion slot was chosen as the detection target of an abnormal behavior. The breakdown of the training and detection data is shown below.

- **Training data**

  Normal behaviors: About 800 motions (About 600,000 frames)
- **Detection data**

  Untrained normal behaviors: About 240 motions

  Abnormal motions: 32 motions

Images were acquired at a frame rate of 10fps and resized to 640×480 pixels during image normalization. Here, ST-Patch and subspace method were used for moving image features and recognition processing, respectively. The ST-Patch was selected since the feature value can handle fine motions. The subspace method was selected as it is a commonly used method. The distance between the feature value of the input frame and the subspace of the normal motion was calculated as the degree of abnormality, and when the degree of abnormality

exceeded the threshold value, it was determined as "abnormal."

In order to show the effectiveness of ATM status awareness, the detection accuracy was compared with and without status awareness. The evaluation was performed on a per motion basis, and if there was a frame determined to be abnormal even once during a motion, that motion was considered as "abnormal," otherwise the motion was considered as "normal." Equal Error Rate (EER) was used as the evaluation index. EER is the error rate at which the false detection rate of normal behavior and the undetected rate of abnormal behavior become equal.

As shown in **Table 1**, EER was 8.3% without ATM status awareness. The motion to reload the ATM card, which is part of a normal behavior, receiving a high abnormal value was believed to be the cause. On the other hand, when ATM status awareness was introduced into the developed technology, EER was 0%, and all normal and abnormal behaviors were correctly recognized. As oppose to the situation without ATM state awareness, in which various normal motions are expressed as one subspace, the developed technology learns normal motions that may occur for each ATM state and expresses them as respective subspaces. This is believed to be the reason for the false detection/non-detection improvement.

Table 1. Test Results

	Without ATM Status Awareness	With ATM Status Awareness
EER	8.3%	0%

Conclusion

OKI's development of ATM abnormal behavior detection was introduced as an example of abnormality detection using image sensing. The technology combines ATM state awareness with moving image feature extraction and recognition processing, which are typically used in abnormality detection using moving images. Testing of the technology confirms that the results are improved in distinguishing between abnormal behavior and normal behaviors, such as card reinsertion that could not be correctly identified using moving image processing alone. In this article, ST-Patch was used for moving image feature extraction and subspace method for recognition processing. However, methods used for ATM abnormal behavior detection are not limited to these, and alternative methods may be selected depending on environmental conditions and other factors.

Currently, research and development is being continued to apply abnormality detection using image sensing to business fields other than ATMs. In the future, OKI will promote initiatives for commercialization through demonstration experiments. ◆◆

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