A technique of deviant behaviour detection in video surveillance systems based on complex behaviour analysis

A B Klimenko, I S Korovin

Scientific research institute of multiprocessor computer systems of Southern Federal University, 2, Chekhov Street, 347922, Taganrog, Russian Federation

E-mail: anna_klimenko@mail.ru

Abstract. This paper deals with deviant behavior detection using video surveillance systems. Deviant behaviour detection is a complex problem and includes not only the recognition of the abnormal patterns of individual’s behaviour, but also the problem of general methodology development, which consists of deviant behaviour markers and techniques to identify them. A new complex approach to the object behaviour analysis is presented in this paper as well as the integrated distributed classifier generic architecture is described. The novelty of this research is the consequent subject analysis based on a complex of potentially deviant and socially dangerous behaviour attributes.

1. Introduction

A problem of deviant behavior detection and prevention is quite important and topical in the field of intelligent surveillance systems. The general reasons for this are population growth, multiple public events, crowded indoor and outdoor places and, at the same time, the existence of numerous extremist and religious organizations and communities, crime, stress situations, aggression, individuals with drug-uncompensated mental disorders. Besides, the problem of personnel fatigue is acute, so it is not possible to watch the observed object with the appropriate level of attention.

The socially dangerous behavior can be provoked not only by some aggressive ideology, but also can be a consequence of a certain psychological state of the individual or a manifestation of some mental disease. Such origins of deviant behavior make it difficult to be detected in time, because the deviant can have the same movement trajectory, the same speed of movement as others. So, we deal with a kind of deviant behavior or with a potentially deviant one, which is hazardous, but can hardly be detected by automatic facilities.

Most surveillance systems are fully connected with the operator’s competence, his knowledge of the context of the place to be observed and his ability to watch the subject for hours. However, it is almost impossible to keep one’s attention for a long period of time, so, the attempts to do without the operator and to make the surveillance systems to be proactive and intelligent take place.

In this paper we consider the following deviant behavior definition: deviant behavior is the one, which can be socially dangerous in the given context. This definition differs from the one, presented in [1], but it includes a wider range of behavioral types: not only those types which are not similar to the behavior, considered as normal in the given situation (e.g., loitering, aggressive behavior, fight), but those which can be caused by the individual’s psychological state, and, at first glance, the same as the “normal” behavior.
A good example of such deviant behavior is as follows: a man with a backpack goes through the underground checkpoint. One can see that the posture, the hand position, the speed of movement are the same as those of other passengers, so the attempt to spotlight his behavior as socially dangerous fails. If his shoulders are raised, lips are compressed and the pupils are widened, it is a good reason to pay attention to this person.

The main contribution of this paper is as follows: a complex approach to the subject’s behavior analysis and the integrated classifier generic architecture are considered.

2. Related works
As is known, there are the following general approaches to the video surveillance systems design:
- attempts to detect the abnormal/suspicious behavior by comparing subject’s behavior with the “normal/abnormal” samples;
- comparison of the individual’s face with the faces of socially dangerous persons, which are stored in a particular database.

One can see that the latter approach is hardly suitable for the intelligent proactive deviant behavior detection: if there is no object in the database, no recognition is possible. Some systems of this kind were implemented and have been functioning successfully (e.g., Facefirst, Eagle Eye, Deep Face). The paramount idea of this approach is that the face image is preprocessed according to the particular algorithms and then is compared with the faces, collected in the database. These systems provide face recognition and are useless in case of sample absence in the database. The examples of methods and algorithms, which are used in such systems, are described in [2, 3].

The attention of the scientific community is also focused on the first approach, though there are some significant issues and challenges, e.g., the forming of “normal” behaviour samples database, labeling, the threshold values for the rule-based systems, and others.

The common structure of the intelligent system for the deviant behavior detection is presented and described in [4]. The system includes two main levels: the first one of a “low semantic level” allows for the formal description of the subject, which can be used as input data for the “high-level” classifier. In the current paper we focus on the classifier design, considering that the previous abstraction level provides the classifier with the formal subject descriptions.

According to [4], classification methods are divided into:
- supervised;
- semi-supervised;
- unsupervised.

Supervised methods use the labeled data with the samples of “normal” and “abnormal” behaviour. The good examples of the systems used the supervised classification in abnormal behavior detection [5-7].

Semi-supervised methods need only normal samples for training and can be divided into rule-based methods and model-based ones. The first category is aimed at developing a rule using normal patterns. Then, any sample that does not fit this rule is considered as foreign (anomaly).

The model-based method builds a model representing normal behavior, so, any new sample which does not correspond to the model is considered to be abnormal [8-10].

And, finally, unsupervised method conducts learning based on statistical properties extracted from unlabeled data. The examples of this method implementation are given in [11, 12].

It is expedient to mention that the methods listed above have their advantages and limitations. For example, rule-based semi-supervised methods are easy to perform and close to human reasoning, but have relatively high resource requirements. The supervised methods detect specific behavior, but strongly depend on the labeled data.

3. A complex approach to the object behaviour analysis
A complex approach to the object behavior analysis to detect any socially dangerous deviant behavior
is based on attributes, which are defined in works related to the “body language” [13-16].

The main attributes to be analyzed are:
- facial expressions;
- the state of eyes and pupils;
- the mouth;
- gestures;
- the arms and legs positions;
- postures;
- personal space.

Each of these attributes can be analyzed by a particular method, paying attention to the specific state of the attribute. For example, open posture involves keeping the trunk of the body open and exposed. This type of posture indicates friendliness, openness, and willingness, [17], while the closed posture involves hiding the trunk of the body often by hunching forward and keeping the arms and legs crossed. This type of posture can be an indicator of hostility, unfriendliness, and anxiety [17].

Such an approach allows one to analyze the individual’s state in aspects of the non-verbal communication with the usage of the appropriate classifiers. Yet, in most cases there is no possibility to analyze the complex of attributes, so, the following principle is proposed in this paper: first detected – first analyzed. It means that there must be a kind of data preprocessing to determine which parts of the body are visible at the moment. So, the visible part of the object is analyzed first.

The common scheme of the approach proposed is presented below (figure1).

![Diagram](image)

**Figure 1.** A complex approach to the object behaviour analysis.

The key difference of such approach is that, firstly, the deviant behavior detection process is a
complex one, and a set of particular methods are involved. Secondly, the order of these methods application is determined by a principle mentioned above “first detected – first analyzed”. The element, which is responsible for this procedure, is mentioned as “The identifying features choice”. It is a simple classifier, which allows to determine, which feature is to be processed and analyzed first. Then, the appropriate processing methods are performed. For example, if the body can be seen only, the methods of skeletoning and the related analysis are called. Such complex and consequent approach based on visibility allows:

- implementing the classifier in a distributed manner with concurrent performance;
- involving the fog- and edge-computing as far as the classification and data processing can be resource-consuming (semi-supervised rule-based method).

4. Generic architecture of the integrated distributed classifier
One can see that in figure 1 the classifier has a modular structure and consists of different classifiers, which are related to the particular method of analysis, e.g., eye state analysis, posture analysis and so on. Such combination of independent classifiers allows one to locate them through the system network, to implement workload mechanisms and to optimize the network traffic. Besides, the classification can be performed in a concurrent manner, when the first classifier, which detects an abnormal sample, completes the detection procedure. The classifiers are used to classify a particular detected attribute, as well as more than one classifier, located on different nodes, can be involved into the classification process. It is an important feature for the heterogeneous environments: in this case the classifier located on the node characterized by the highest performance completes the classification procedure earlier than the others do and, therefore, reduces the time of classification.

So, two features of the concurrent classification are proposed:
- more than one classifier performs the task in conditions of the heterogeneous computational environment;
- the classification procedure is called according to the attributes of the subject detected. In other words, the order of the complex classification is defined by those subject attributes, which are visible.

Taking into account the description of the distributed combined classifier, the following scheme has been developed (figure 2).

![Diagram](image.png)

**Figure 2.** The combined distributed classifier architecture

Formal data presentation

- Classifier 1
- Classifier 2
- Classifier 3
- Classifier 4
- Classifier 5
- Classifier 6

node1 node2 node3 node4

High node performance

Cumulative result

- First detected attribute, e.g., hands
- Second detected attribute, e.g., face
As is shown in figure 2, the classification procedure becomes a kind of competition between classifiers distributed through the system network. If attribute 1, which is processed by classifier 1, is sufficient to recognize the behavior as deviant, the result will be obtained after classifier 1 completion on node 3. Yet, if attribute 1 is not sufficient, and attribute 3 is available in incoming data, classifier 3 performs its job, and, again, the fastest classifier wins the competition.

The concurrent classifiers functioning also can be considered in relevance to reliability of the results. Here the rules of majority can be implemented to avoid the multiple false-positive results.

Such distributed implementation of the combined classifier makes it possible to optimize the resource utilization by the usage of those classifiers, which are located close to the data sources. It relates to the edge and fog computing [18-20] and reduces such critical system attributes as:
- network load;
- system response time.

System response time also can be reduced by the concurrent usage of classifiers and the ordered classification procedures as it is described above.

5. Conclusion

In this paper a complex approach to the subject behavior analysis and integrated classifier generic architecture are proposed. The aim of the research is to detect potentially dangerous social behavior, which is deviant, but it is hardly detected by the particular disunited methods. Therefore, it is expedient to use these methods in a combined manner, which allows detecting the attributes of non-verbal language. As such integrated classification is hardly reachable simultaneously, we propose the ordering of the classifications according to the object attributes visibility. As the particular classifiers function consequentially, there is a possibility to implement them in a distributed manner and to perform a classification concurrently. This allows one to reduce the system response time in case of heterogeneous system network environment as well as to locate the classifiers on the particular nodes to optimize the system and infrastructure load.

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