

# Research on Recognition of Pedestrians' Abnormal Behaviors Based on Naive Bayesian Classifier

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**Abstract.** Recognition of abnormal behaviors is a prerequisite for effective stampedes prediction in crowded scenes. By tracking the trajectory of a pedestrian in the monitoring video, this paper has demonstrated that the kinetic features of pedestrians in the video dominate the judgment of abnormal behaviors. Using the Naive Bayesian Classifier(NBC), we have built a recognition model of abnormal behaviors, which precisely collected the kinetic features of pedestrians in the video and accurately made judgement of their behaviors. This model has been proved to be effective in predicting stampedes and is promising in various applications.

## Introduction

With the number of stampedes at home and abroad has been rising in recent years, the demand for recognition systems of pedestrians' abnormal behaviors based on video surveillance has become greater (Idrees H, 2014). At present, deep learning (Rasheed N, 2014), social force model (Xu D, 2016), and particle force model (Revathi A R, 2016) are all used to identify abnormal behaviors among the crowd. Neural networks (Makris D, 2005), Stacked Denoising Autoencoders (Li B X, 2016) are also applied in the analysis of the trajectory of a single individual. In this way, the abnormality of pedestrians' behaviors is judged based on the abrupt change of the moving trajectory. Histogram (Chaker R, 2016) and Support Vector Data Description (Sun Q, 2016) have also been used to identify pedestrians' abnormal behaviors in a static background, which have gained certain theoretical achievements. However, most of the above methods tend to judge whether a certain group of pedestrians' behaviors are abnormal or not. The judgment of an individual's abnormal behaviors is mainly based on the mutation of its moving trajectory, while there is less research on the judgment of pedestrians' retrograde and sudden pause and cannot meet the real-time requirements for emergent events. Using the Naive Bayesian Classifier, this paper takes pedestrians' kinematic features consisting of velocity, acceleration and direction as characteristic parameters to judge the behaviors of them. It not only can recognize more abnormal behaviors than traditional methods, but also improves the real-time performance of the judgment.

## Definition and Classification of Pedestrians' Abnormal Behaviors

Pedestrians' kinematic information under normal conditions has strong smoothness (Zhang Y, 2015), or the kinematic features of the entire group are relatively consistent. If pedestrians' kinematic characteristics abruptly change, or the kinematic features of a small group of pedestrians are so different from the else, then abnormal behaviors may follow. The significant difference of kinematic characteristics is reflected on the inconsistency in the kinematic direction or velocity of small group comparing to the else. Based on this, there are four kinds of abnormal behaviors of pedestrians: pedestrians' aggregation, pedestrians' scatter, opposite direction and unusual speed.

Pedestrians' aggregation refers to the situation where a group of people are suddenly attracted a central point in a convergent manner while pedestrians' scatter indicates that the crowd suddenly disperse from a central point in an explosive style. Both of these two situations are called radiate anomalies of pedestrians. The radiate anomaly is mainly caused by emergencies at a central point

and with great acceleration. These two types of abnormal behaviors have a relatively rapid influence and expand quickly. It can cause global panic easily, leading to serious consequences. For example, when staff in shopping malls throw prizes, the participants will be attracted to the prize and quickly gather. Most of the attention will be focused on free gifts. Then, people may forget their own personal safety and cause security accidents. Opposite direction is a situation in which an individual or a small part of people are inconsistent with the whole group in the direction of movement. Unusual speed describes the fact that the speed of a single target in a group is significantly different from the rest. These two kinds of abnormal behaviors are called single-point anomalies, which are mainly manifested in the unusuality of the kinematic direction or velocity of an individual or a small group. Single-point anomaly may be followed by pushing or collision. Besides, these two anomalies can not be quickly known by the whole group under high crowd density. If pedestrians surrounding to the anomaly cannot avoid it in time, backlog and other consequences resulting in stampedes may happen.

### Model to Recognize Abnormal Behaviors Based on Naive Bayesian Classifier

**The basic process of identifying abnormal behaviors of pedestrians.** The kinetic features of pedestrians describe their movements accurately and completely. And they can be calculated by decomposing the video data into a sequence of frames and extracting the position information of the pedestrians in each frame. The features of a large number of pedestrians can be input to train the Naive Bayesian Classifier and obtain the feature distribution results. Then the distribution results can be applied in video surveillance to find the abnormal behaviors of pedestrians.

**Extracting and Smoothing Moving Features.** In the pedestrian's movement, the trajectory is usually seen as a set of time series (Dehghan A, 2014). Taking a pedestrian's horizontal velocity( $v_x$ ), vertical velocity( $v_y$ ), horizontal acceleration( $a_x$ ), vertical acceleration( $a_y$ ) and kinematic direction ( $d$ ) at a certain moment as the kinematic features of her or him at this moment, represented by the vector  $R=(v_x, v_y, a_x, a_y, d)$ , and  $t$  denotes a specific moment.

Fig. 1 describes the position information of a pedestrian in video frames. The rules for calculating the values of every kinematic features in a short period of time is shown in Eq.1.

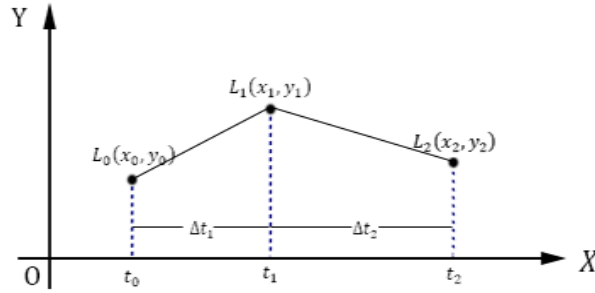


Figure 1. Finite Position Information of a Pedestrian in Video Frame

$$\left\{ \begin{array}{l} v_{x1} = \frac{x_1 - x_0}{\Delta t_1} \\ v_{y1} = \frac{y_1 - y_0}{\Delta t_1} \\ a_{x1} = \frac{v_{x1} - v_{x0}}{\Delta t_1} \\ a_{y1} = \frac{v_{y1} - v_{y0}}{\Delta t_1} \\ d_1 = \arctan \frac{y_1 - y_0}{x_1 - x_0} \end{array} \right. \quad (1)$$

In order to eliminate the fluctuation of the data caused by the pedestrian's jittering motion, five groups of kinematic eigenvalues obtained from the six adjacent frames of the video (see Fig. 2) are averaged to smooth the data. The averaged values will be seen as the kinematic features of a moving pedestrian at a certain moment  $t$ , the average process of these variables is shown in Eq. 2.

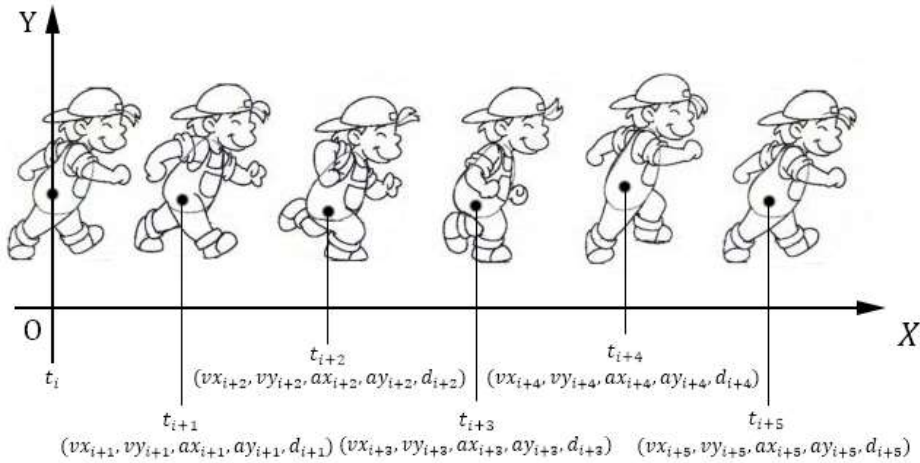


Figure 2. Finite Kinematic Features of a Pedestrian in 6 Adjacent Serial Frames

$$\begin{cases} vxi = \frac{\sum_{j=1}^5 vx_{i+j}}{5} \\ vyi = \frac{\sum_{j=1}^5 vy_{i+j}}{5} \\ axi = \frac{\sum_{j=1}^5 ax_{i+j}}{5} \\ ayi = \frac{\sum_{j=1}^5 ay_{i+j}}{5} \\ di = \frac{\sum_{j=1}^5 d_{i+j}}{5} \end{cases} \quad (2)$$

**Model Construction Based on Naive Bayesian Classifier.** The Naive Bayesian Classifier consists of individual attributes, classification results and converting probabilities. In the NBC-based model that identifies pedestrians' abnormal behaviors, each individual in the samples that needs to be classified is described by his or her five attribute features, represented by the attribute set  $A = \{vx, vy, ax, ay, d\}$ . Besides, every attribute in this attribute set is corresponding to a kinematic featured which has been defined before and independent on the else. In addition, each individual sample belongs to a category. There are two categories for all the samples, represented by the classification set  $C = \{c1, c2\}$ , while  $c1$  means normal and  $c2$  means abnormal. The NBC-based model to recognize pedestrians' abnormal behaviors is shown in Fig. 3. According to the trained NBC model, after the attribute set of a sample which is also called  $A$  has been input, the judgment of a pedestrian's behavior can be calculated.

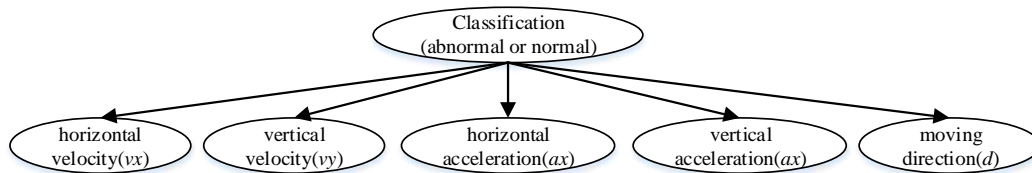


Figure 3. Finite The NBC-based Model to Recognize Pedestrians' Abnormal Behaviors

Independence between attributes, Bayesian rule and maximum posterior probability are the bases for NBC to solve the classification problems. For an unknown individual, we need to obtain the characteristic attribute set which means  $A$  of the individual and its posterior probability  $p(c/A)$  under each category. The posterior probability  $p(c/A)$  means the probability that the individual belongs to every category. The classification which owns the maximum posterior probability is the result. The Bayesian rule can be used to calculate the posterior probability by probability  $p(A/c)$ ,  $p(c)$  and  $p(A)$ . Probability  $p(A/c)$  represents the priori probability calculated from all the samples which are classified as abnormal or normal. Probability  $p(c)$  means the percentage of every classification in all the samples. And the attributes' probabilities  $p(A)$  is the likelihood that every attribute resulting in

every classification. Since  $p(A)$  is a variable that independent on the classification result, the final judgment is only related to the product of  $p(A/c)$  and  $p(c)$ . According to the independence between attribute features,  $p(A/c)$  can be represented by the product of the probability of each attribute resulting in each classification. The value of  $p(c)$  is usually relatively stable in a particular situation. The calculation formula for  $p(c/A)$  is shown in Eq. 3, while  $c^*$  means the classification result of the sample.

$$\begin{cases} p(c|A) = \frac{p(A|c) * p(c)}{p(A)} \\ p(A|c) = p(vx|c) * p(vy|c) * p(ax|c) * p(ay|c) * p(d|c) \\ c^* = \operatorname{argmax}_{c \in C} (p(c) * p(A|c)) \end{cases} \quad (3)$$

### Training and Testing the NBC-based Model

From the videos we have collected under various scenarios, 24 videos have been selected which contains abnormal behaviors such as pedestrians' aggregation, pedestrians' scatter, opposite direction or unusual speed. After pretreatment and manual classification of these videos, 1548 groups of pedestrians' kinematic features and their corresponding categories have been obtained.

All the pedestrians' kinematic information have been divided into two parts, one is for training and the other one is for testing. The percentage of normal behavior and abnormal behavior in these two parts is assured to be equal, so the probability  $p(c)$  of abnormal behavior and normal behavior in the samples have been get. According to one part of the samples and the definition of attributes' set A and classification set C, the Bayesian probability relationship  $p(vx/C)$ ,  $p(vy/C)$ ,  $p(ax/C)$ ,  $p(ay/C)$  and  $p(d/C)$  can be calculated. The probability distribution of the pedestrians' kinematic features can be calculated after the model has been trained. For the five kinematic features, their probability distributions of different classification corresponding to different values are shown in Fig. 4.

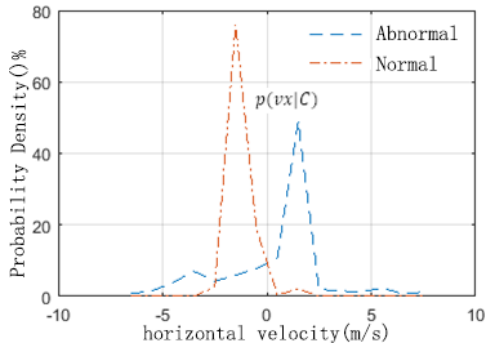


Figure 4(a). Finite Probability Distribution Chart on Different Horizontal Velocity

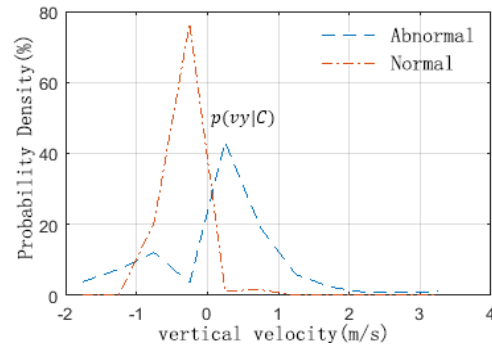


Figure 4(b). Finite Probability Distribution Chart of on Different Vertical Velocity

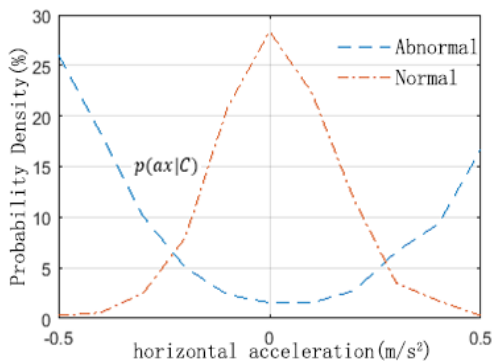


Figure 4(3). Finite Probability Distribution Chart on Different Horizontal Acceleration

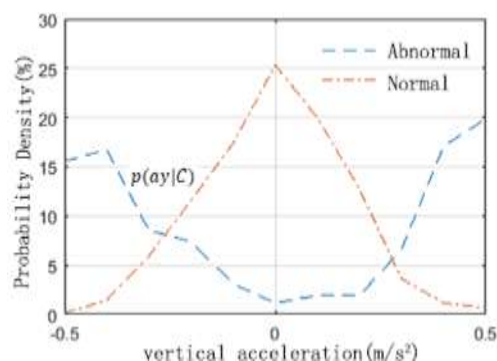


Figure 4(d). Finite Probability Distribution Chart on Different Vertical Acceleration

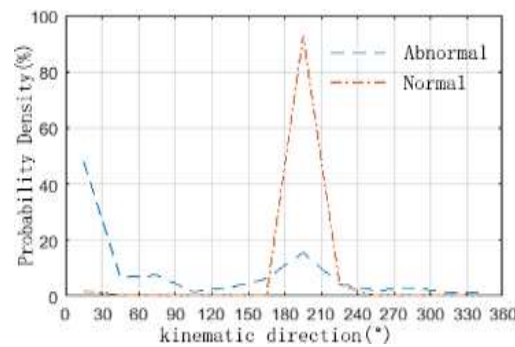


Figure 4(e). Finite Probability Distribution Chart on Different Kinematic Direction

Figure 4. Finite Probability Distribution Chart of Different Classification Corresponding to Different feature values

As shown in Fig. 5, abnormal behaviors' probability distribution on every kinematic feature is much different from normal behaviors'. Compared to abnormal behaviors, the speed and direction of normal behaviors are more evenly distributed, and the acceleration distribution is close to zero. It can be seen that the selected set of kinematic features can accurately distinguish these two kinds of behaviors and is suitable for the training of NBC model.

Test results of the rest part of the samples using the trained NBC model shows that the model is valid. For example, for a pedestrian in the video, its kinematic feature set  $A = \{1.29, 0.43, 0.4, 0, 14\}$ . It can be known from formula 3 that the probability of abnormal behavior also called  $p(C/A)$  is 96.4%, which is much more than the probability of normal behavior. It is consistent with the movement of the pedestrian in the video. Test results of the prediction using the NBC model is shown in Table 1.

Table 1 Testing Results Using the NBC Model

	abnormal behaviors' kinematic features set (288 samples)	normal behaviors' kinematic features set (486 samples)
right predictions	259	420
wrong predictions	29	66
accurate rate	89.9%	86.4%

The accurate rate of the trained NBC model in the samples exceeds 85%, and the correct rate of the abnormal behaviors is close to 90%. It can be considered that the model is effective in identifying the abnormal behaviors of pedestrians.

## Conclusion

In response to frequent stampedes at home and abroad, the kinematic features of pedestrians are collected to recognize and classify their behaviors using Naive Bayesian Classifier. Test results of the samples show that the establishment of this model is reasonable and effective. In the follow-up study, it is planned to take advantage of some excellent domestic and foreign videos such as the PETS database and the abnormal behaviors' video library of the University of California, San Diego for further training and optimization of the model so as to improve the accuracy and efficiency of it.

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