Crime Scene Classification

Ricardo O. Abu Hana[1] Cinthia O. A. Freitas[1] Luiz S. Oliveira[1] Flávio Bortolozzi[2]

[1]Pontifical Catholic University of Paraná (PUCPR) — Curitiba — PR — Brazil — (55-41-3271-1353)

ricardohana@ppgia.pucpr.br, cinthia@ppgia.pucpr.br, soares@ppgia.pucpr.br

[2]OPET College (OPET) — Curitiba — PR — Brazil — (55-41-3028-2800)

flavio.bortolozzi@opet.com.br

ABSTRACT

In this paper we provide a study about crime scenes and its features used in criminal investigations. We argue that the crime scene provides a large set of features that can be used to corroborate the conclusions emitted by the experts. We also propose a set of features to classify the violent crime considering two classes: attack from inside or outside of the scene. The classification stage is based on conventional MLP (Multiple-Layer Perceptron) Neural Network and SVM (Support Vector Machine). The experimental results reveal an error rate of 30.3% (MLP), 22.8% (SVM-linear), and 19.4% (SVM-polynomial) using a database composed of 400 crime scenes.

Categories and Subject Descriptors

I.5.2 [**Pattern Recognition**]: Design Methodology – *classifier design and evaluation.*

General Terms

Measurement, Documentation, Experimentation.

Keywords

Classification, Neural Networks, SVM, Features, Crime Scenes.

1. INTRODUCTION

Crime scenes are the places where a crime is detected. A crime is an act (or sometimes a failure to act) that is deemed by statute or by the common law to be a public wrong and it is therefore punishable by the state in criminal proceedings. Every crime consists of a guilty act followed by a specific guilt mind, and the prosecution must prove these elements of the crime beyond reasonable doubt.

The existence or nonexistence of some criminal act tends to be proved by the evidences in the criminal scene. It may consist of testimony, documentary evidence, real evidence, and, when admissible, hearsay evidence.

Considering that crime scenes have a lot of evidences, the first foresight is the isolation of the place. This procedure must guarantee the integrity of the evidences [8]. Any modification in the crime scene must be considered and discussed by the experts.

SAC'08, March 16-20, 2008, Fortaleza, Ceará, Brazil.

When the evidences are modified the dynamic of the facts are being modified too.

The experts use different technical procedures to provide a legal documentation about crime scenes such as annotation, drawing, measurement, photograph, and movies, as depicted in Figure 1. Every material is then analyzed by a group of experts. All these procedures are important to describe and document the crime, but the most used in the Court is 2D-drawing. In Brazil there is no standard for the crime scene 2D-drawings. The Court often needs to consult specific literature to understand what is represented in the drawings. Since the 3D models are more reliable representation, the 2D drawings can be considered as a retrocession.

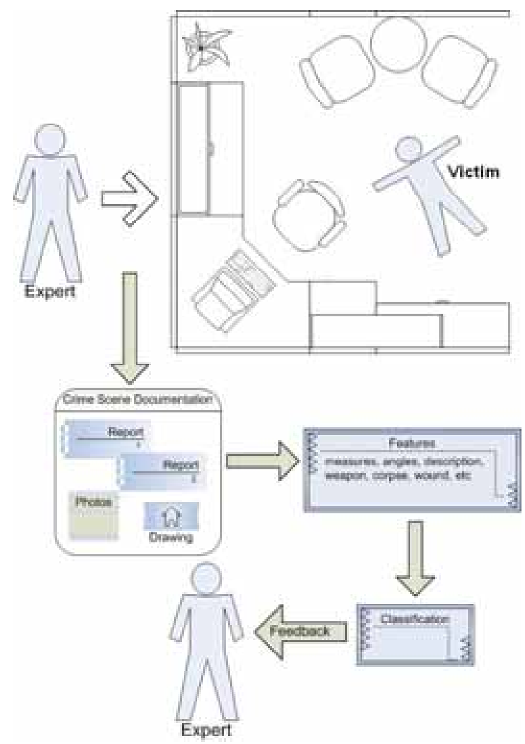

Figure 1. Crime scene documentation and classification.

The 2D-drawings play an important role when the goal is to represent the local in terms of scale, proportions, and dimensions. On the other hand, the 3D models can provide a better representation of the evidences, understanding the crime scene as a dynamic action. Moreover, it can provide features based on 2D and 3D measures.

The goal of this paper is to contribute to the expert's training based on the crime scene documentation as shown in Figure 1.

Our proposal is to use a classification system based on features extracted from the crime scene documentation and to assist the investigation about crime. We are interested in crime called unlawful homicide, which is the act of killing a human being and constitute the crime of murder, manslaughter, or infanticide.

The classification is related to violent crimes taking into account two classes: attack from inside the scene and attack from outside of the scene, as depicted in Figure 2. The feature set is extracted from 3D-models and is based on distances, angles, and other information; forming a feature vector. Experimental results show that this methodology can be considered as a tool to build more reliable crime scenes representation and to support the conclusions emitted by the experts.

(a)

(b)

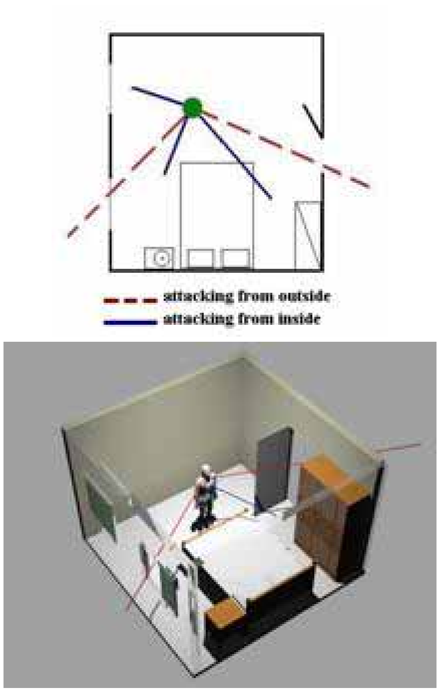

Figure 2. Crime scene classification: a) 2D-drawing; b) 3D-model.

The paper is divided into six sections. Section 2 summarizes the crimes scenes presenting the problem and the procedures used by the experts to analyze and prepare a criminal and legal documentation. Section 3 explains the feature set based on crime scene representation. Section 4 presents the database, the classifiers (MLP-NN and SVM), and the experimental results. In Section 5, our conclusion and a plan for future works are presented.

2. CRIME SCENE REPRESENTATION

There are different ways to register a crime scene such as description, written notes, printed forms, 2D-drawing or scheme (Figure 2a), 3D-model (Figure 2b), photography, and audio/videotapes [8]. The documentation is important to create a detailed record of the scene, evidence recovered, and actions taken during the search of the crime scene. Our interest in this paper is to focus on the feature set that can be extracted from a scene. Therefore, the documentation of the crime scene is the key to the description of the dynamic acts occurred in the scene. The documents need to be clear, contains the evidences, and provide the information about what happens in that scene.

As the name indicates, description is about a document written of everything what the expert, policeman or coroner, could observe in the scene. To the first sight it could seem that this document is very subjective, but in the fact it does not occur. Two reasons for non subjective reports are training and technique. The influence of the training in the perception capacity is evident; therefore the perception improves based on the experience. The technique is very important as well as the drawings used as visual information about the scene are depicted in the documentation made by the experts.

The use of the movies in the study of the local of the crime is used by the experts, especially for reconstitution. However this methodology is not applicable in an action at law. It must be remembered, that as method of documentation, its use is only eventual. Some roads in Brazil are equipped with cameras and can, eventually, register a crime have caused an accident. Other countries, where the traffic is controlled by television circuit, facts of police or judiciary interest can be registered (accident, running over, movement suspicion).

Favela Naval (City: Diadema, State: São Paulo, Country: Brazil) is the only situation where the 3D-model was applied to present in Court a crime scene based on a amateur filming [1]. Based on the movie, a 3D-model was created. In this in case, the use of the computer added to information of the IML (Instituto Médico Legal – Medical Legal Institute), clarifying that, on contrary of what was affirmed (that the victim would be shot to the back of), the victim was looking back and he did not take the shot on the back, but on the left side of the chest [1]. Differently from this case, our approach is based on a feature set extracted from a 3D-model and it is composed of distances, angles, and other information such as type of the weapon, evidence that the projectile hit an obstacle.

In Brazil two different documents produced by the Criminal Institute (Instituto de Criminalística) and IML (Instituto Médico Legal – Medical Legal Institute) are the goal in the investigation procedure. The first is the expert report which is about the local where the crime took place. The second is the autopsy report which is about the victim or corpse.

Thus, the expert report is an instrument of great importance to be used in judicial situations, and that, for being based on technique and scientific knowledge they have a great acceptance in the Court.

Another possibility is to create the scene based on photorealistic 3D-models that can be viewed from multiple angles. The first method investigated was created by Howard and Murta in collaboration with the Greater Manchester Police, UK [4]. Data was collected via a set of forensic photographs. These were taken from four corners of a room to give as much coverage of the scene as possible. Photographs were also taken of individual objects with police rulers placed next to them to give an indication of their scale. An initial 2D-drawing was produced from measurements taken at the scene and entered into scene builder software in the form of line segments. These were then extruded to produce the 3D-model. In this case, the experts need to know the relative position of the camera in the scene.

Gibson & Howard [3] present a reconstruction system through photographs and consider that is can be used in the documentation of crime. Wang and Oliveiras [11] describe a similar system that tries to solve the problem of occlusion, found very often in approaches based on 3D-modeling. The occlusion problem occurs when the photograph presents an object in front of another one. In these cases the set of photos does not supply the visualization of this occluded part; the same one will be occluded in the 3D-model as well.

Different programs can be used by the experts for representation of crime scenes. These programs are called Computer Aided Design - CAD, such as AutoCAD, QCAD, Maya 3D, 3D Studio Max, Rhinoceros (see Figure 3), Flamingo and Eyeswitness.

Differently from CAD software, the 3D computational visualization involves the use of tools and techniques for the representation of the same ones. The main tools of support to this activity can be cited such as, OpenGL, Ogre3D, DirectX and API Java3D. These graphical libraries offer a set of routines, supported for programming languages such as C, C++, and Java, used for the 3D object visualization. Besides they include advanced resources of animation, image pre-processing, and textures, thus allowing the virtual environment construction.

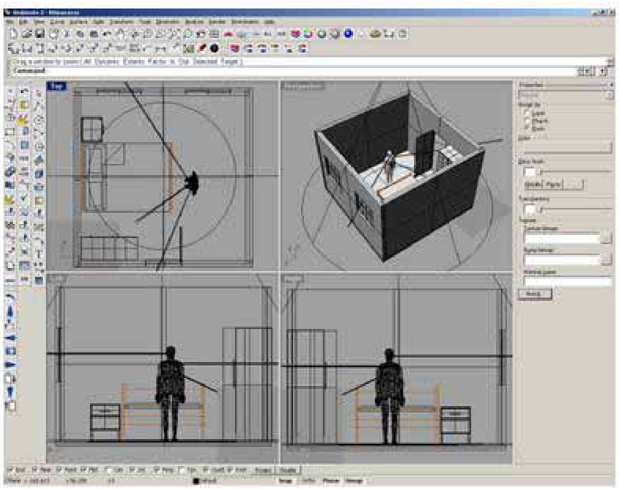

Figure 3. Working space in the Rhinoceros.

3. FEATURE SET

After the crime scene documentation have been introduced, let us concentrate on how we can extract features from the scene to classify whether the attack comes from inside or outside.

When the expert prepares the report about the crime scene, a large set of features can be cited such as, broken furniture or object disarrangement; direction and distance from the victim to doors and windows; presence of blood spots and other liquids; occurrence of fingerprints visible or latent); firearms/weapons or other instruments (knife, scissor); signals of violence in the victim; injuries of defense, distance to adjacent buildings or other landmarks [1].

The expert who is preparing the report about the crime needs to point out characteristics of the scene and takes decision about if it is a suicide or a murder, and also, if the attack occurred from inside or outside of scene. As argued so far, these decisions are supported by skill, technique, and training. The goal of this paper is to contribute to the expert's training, giving to the expert a feedback based on a classification result. Our proposal is to use a classification system based on features extracted from the crime scene and assist the expert to assist in the investigation of the crime. We are interested in crime called unlawful homicide, which is the act of killing a human being and constitute the crime of murder, manslaughter or infanticide. This crime causes the death. During the expert's report preparation it is important to establish if the shooting or attack comes from inside or outside of the place where the victim was found. This kind of classification is related to crime types such as murder, manslaughter or infanticide. This classification is also important to indicate the suspected person or reduce a list of suspects. Based on these considerations, the proposed feature set is composed of the following 10 features using the 3D-models of the crime scenes, which were created in Rhinoceros:

- x_1 = type of used weapon: cutting weapon or firearm (dig, pistol, others);
- x_2 = distance of the weapon in relation to the victim: the distance can be considered four levels such as, less than 1 meter, 1 and 3 meters, up to 3 meters and greater than 6 meters (or weapon is not located) (Figure 4a);
- x_3 and x_4 = angles of the wound: in relation to the horizontal and the vertical axis (Figure 4e-f). These angles are provided by the autopsy report. Commonly the autopsy report uses the human body representation to locate the wounds in the victim;
- $x_{5,\ldots,8}$ = angles between the person and the extremities (inferior, superior, left and right) of the window or door (Figure 4b-c);
- x_9 = distance between victim and window or door (Figure 4d);
- x_{10} = evidence that the projectile hit an obstacle before hitting the victim.

4. CLASSIFICATION

The classification stage is based on conventional MLP (Multi-Layer Perceptron) Neural Network and SVM (Support Vector Machine). The MLP has been used extensively in implementing the *K*-classification module for different recognition problems [5]. One of distinct properties of the conventional MLP architecture is that all the *K*-classes share one large network [5,7,12]. Based on this and other works we have done [2,6] we have chosen this architecture for our experiments. Moreover, experimental results were obtained applying SVM [9].

The MLP was implemented via the Java-SNNS simulator program. It is composed of 10 neurons in the input layer, one hidden layer with 5 neurons and 2 neurons in the output layer. Input data is shuffled before presentation and the back-propagation algorithm plus one update function for optimizing the adaptation weights were used for training process. A validation process was employed in order to avoid over-fitting. The error obtained in the validation set for each training epoch was used as the stop criterion. The algorithm which submitted the lowest MSE (medium Square Error) with stability in the validation rate was Back Propagation, fully connected, with n = 0.01, dmax = 0.05, random weights, and about of 18000 cycles.

Support Vector Machine (SVM) is a supervised learning method used for classification and regression proposed by Vapnik [9] and it belongs to the family of generalized linear classifiers. A special property of SVM is that they simultaneously minimize the empirical classification error and maximize the geometric margin; hence they are also known as maximum margin classifiers.

The idea of using an SVM was due to the nature of the problem as there are only two classes of cuts, attack from inside and outside. Moreover, SVMs are tolerant to outliers and perform well in high dimensional data.

Let us suppose we have a given set of samples distributed in a given set of l samples distributed in a $\Re$n space, where n is the dimensionality of the sample space, and for each xi sample there is an associated label yi $\in$ {-1,+1}. According to Vapnik, this sample space can be described by an hyperplane separating the samples according to their label ({-1,+1}). This hyperplane can be modeled using only a few samples from the sample space, namely the support vectors. So training an SVM is simplified to identifying the support vectors within the training samples. After that, a decision function (Equation 1) can be used to predict the label for a given unlabeled sample [10]:

$$f(x) = \sum_i \alpha_i y_i K(x, x_i) + b \qquad (1)$$

The function parameters α_i and b are found by quadratic programming, x is the unlabeled sample and x_i is a support vector. The function $K(x, x_i)$ is known as kernel function and maps the sample space to a higher dimension. In this way, samples that are not linearly separable can become linearly separable (in the higher dimensional space). The most common kernel functions are: linear, polynomial, Gaussian, and tangent hyperbolic. In this paper, linear and polynomial kernels were considered in the SVMlight software.

5. EXPERIMENTAL RESULTS

The database used in the present work is composed of 400 crime scenes. This database was divided into three subsets, called: Training (60%), Validation (20%) and Testing (20%). Table 1 summarizes the results of applying a MLP classifier. We can observe from this table two kinds of error (Type I – when the attack is from inside being classified as outside attack and Type II - when the attack is from outside being classified as inside attack). The Type II Error is more expressive than the Type I and it can be explained based on the existence of evidence of ticket of the projectile for some bulkhead (x_{10}) in the crime scene. The Type I Error could be observed in the crime scenes which the distance of the weapon in relation to the victim (x_2) was in the boundary of 1 meter but the distances of victim for the window or doors (x_9) indicated that could be an outside attack.

Table 1. Crime Scene classification: MLP-NN.

Error Type I (%)	Error Type II (%)	Total Error (%)
3.8	26.5	30.3

Table 2 presents the results applying the SVM classifier. Comparing the classifiers we observed that SVM performs better than MLP. It is interesting to observe that linear kernel presented better results for outside attacking classification and polynomial kernel achieved better results for inside attacking classification. In general, the polynomial kernel achieves better results than linear kernel and MLP. The Type I Error can be explained by the distance between victim and window or door (x_9), because this distance can represent an ambiguous value.

Table 2. Crime Scene classification: SVM.

Kernel					
Linear			Polynomial		
Error Type I (%)	Error Type II (%)	Total Error (%)	Error Type I (%)	Error Type II (%)	Total Error (%)
12.5	10.3	22.8	7.2	12.2	19.4

The last experiment we have performed was related to the size of the training database. We start with few samples and then we increase the size of the training set to observe the impacts on the testing set. Table 3 reports the results of these experiments. As expected, the more training cases are used, the better the classification works. The Error Type II, though, does not decrease after 80 samples. This corroborates to the need of acquiring more data for further experiments, which is not an easy task due to the nature of the problem.

Table 3. Crime Scene classification: SVM-polynomial.

Training Set	Error Type I (%)	Error Type II (%)	Total Error (%)
20	15.9	17.8	33.7
40	10.3	18.8	29.1
80	10.9	11.5	23.5
160	9.7	12.8	22.5
320	7.2	12.2	19.4

6. CONCLUSION AND FUTURE WORKS

In this paper we presented a study of crime scenes and their features used in criminal investigations and criminal documentation made by the experts. Since the crime scene provided a large set of features, we presented a methodology to classify the violent crime considering 2-classes: attacking from inside or attacking from outside of the scene. The experimental results reveal error rate of 30.3% (MLP), 22.8% (SVM-linear) and 19.4% (SVM-polynomial) using a database formed with 400 crime scenes demonstrating that this approach could be considered as a tool to build reliable crime scene classification systems to help the expert's report and training. Future work will provide an automatic or semi-automatic feature extraction from the crime scene. Other works will investigate feature selection applying PCA (Principal Component Analysis) or ICA (Independent Component Analysis) and different classifiers.

7. ACKNOWLEDGMENTS

The authors wish to thank the students Tayana Castilho (PUCPR, Architecture School, PIBIC/CNPq), Renata Schefer, Giulliano Facin, and Tassia Erbano (PUCPR, Law School, PIBIC/PUCPR) which have collaborated to this work. This work has been supported by CNPq (Proc. No. 471604/2004-6).

8. REFERENCES

[1] Cadesign, CAD e animação ajudam a esclarecer o caso de Diadema (CAD and computer animation help to solve Diadema case). CADDESIGN, (27), 1997.

[2] C. O. A. Freitas, L. S. Oliveira, F. Bortolozzi, S.B.K. Aires, “Handwritten Character Recognition Using Non-Symmetrical Perceptual Zoning”, International Journal of Pattern Recognition and Artificial Intelligence, IJPRAI, Vol. 21, No. 1, 2007, 1--21.

[3] S. Gibson, T. Howard, “Interactive reconstruction of virtual environments from photographs, with application to scene-of-crime analysis”, Proc. of the ACM Symposium on Virtual Reality Software and Technology, Seoul, Korea, 2000, 41--48.

[4] T. Howard, S. Murta, “Virtual Environments for Scene of Crime Reconstruction and Analysis”, Advanced Interfaces Group, Manchester, 2000.

[5] A. K. Jain, R. P. W. Duin, J. Mao, “Statistical Pattern Recognition: A Review”, IEEE Transactions on Pattern Analysis and Machine Intelligence, 22, 2000, 4--37.

[6] M. N. Kapp, C.O.A. Freitas, R. Sabourin, “Methodology for the design of NN-based month-word recognizers written on Brazilian bank checks”, International Journal on Image and Vision Computing, vol. 25, No. 1, 2007, 40--49.

[7] I-S. Oh, C. Y. Suen, “A class-modular feedforward neural network for handwriting recognition”, Pattern Recognition, 35, 2002, 229--244.

[8] Technical Working Group on Crime Scene Investigation, Crime Scene Investigation, Technical report, U.S. Department of Justice, 2000.

[9] Vapnik, V., Statistical Learning Theory, Wiley, N.Y., 1998.

[10] Vellasques, E., Oliveira, L. S., Britto Jr., A. S., Koerich, A. L., Sabouri, R. Modeling Segmentation Cuts Using Support Vector Machines. 10th International Workshop on Frontiers in Handwriting Recognition, La Baule, France, 2006, 41--46.

[11] J. Wang, M. M. Oliveiras, “Improved scene reconstruction from range images”, Proc. of Eurographics 2002, Vol. 21, 2002.

[12] G.P. Zhang, Neural network for classification: A survey, IEEE Trans. On System, Man and Cybernetics, 30(4): 2000. 451-462.

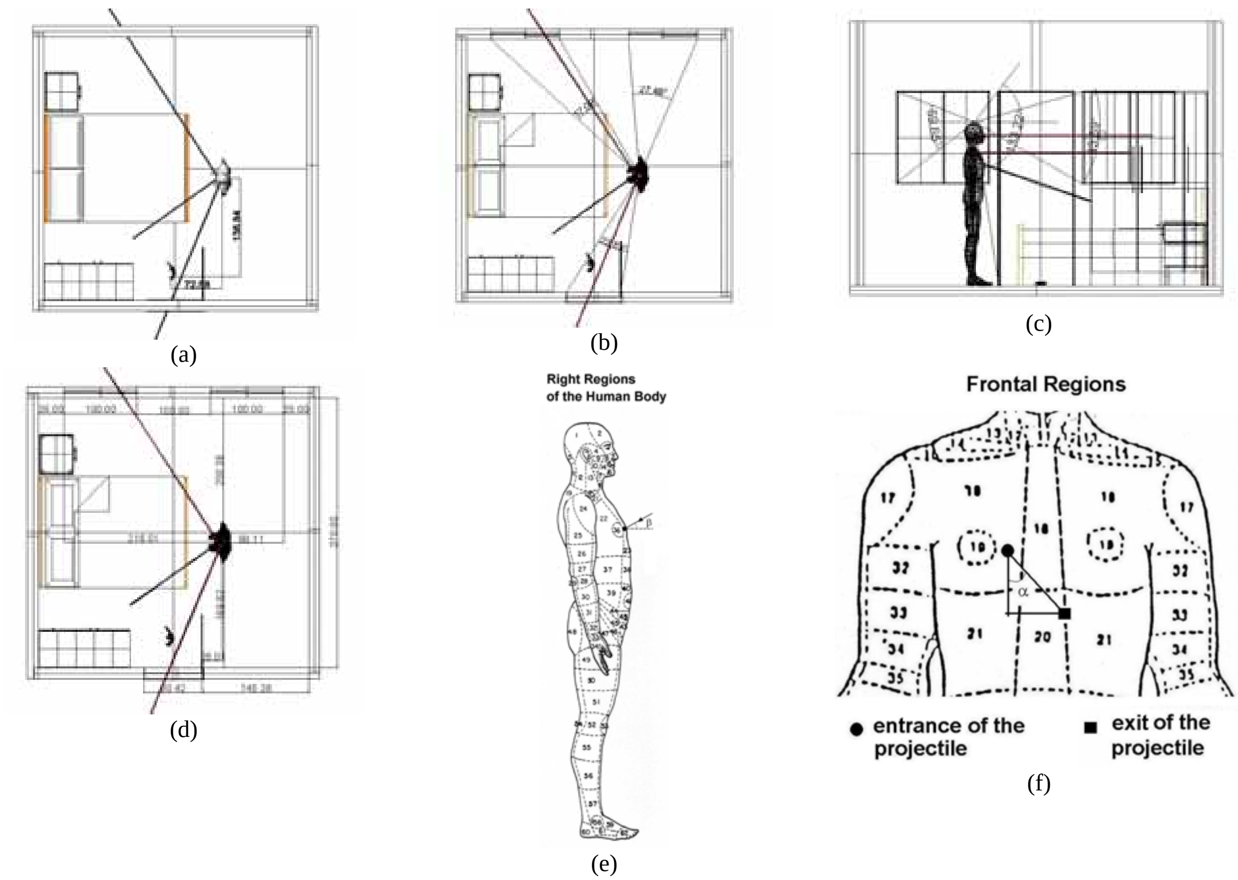

Figure 4. Feature set from crime scene: a) distance of the weapon in relation to the victim, b) horizontal angles between the victim and the extremities, c) vertical angles between the victim and the extremities, d) distance between victim and window or door, e) horizontal angle of the wound, and f) vertical angle of the wound.