Journal of Universal Computer Science, vol. 14, no. 18 (2008), 2953-2966
submitted: 1/3/08, accepted: 29/9/08, appeared: 1/10/08 © J.UCS

Crime Scene Representation (2D, 3D, Stereoscopic Projection) and Classification

Ricardo O. Abu Hana
(Pontifical Catholic University of Paraná – PUCPR, Curitiba-PR-Brazil
ricardohana@ppgia.pucpr.br)

Cinthia O. A. Freitas
(Pontifical Catholic University of Paraná – PUCPR, Curitiba-PR-Brazil
cinthia@ppgia.pucpr.br)

Luiz S. Oliveira
(Pontifical Catholic University of Paraná – PUCPR, Curitiba-PR-Brazil
soares@ppgia.pucpr.br)

Flávio Bortolozzi
(OPET College, Curitiba-PR-Brazil
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. This paper presents an experiment based on a stereoscopic projection that allows to experts analyze and take decisions about the crime scene and its dynamic.

Keywords: Classification, Neural Networks, SVM, Features, Crime Scenes
Categories: I.5.2

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 [TWGCSI, 00]. Any modification in the crime scene must be considered and

discussed by the experts. When the evidences are modified the dynamic of the facts are being modified too.

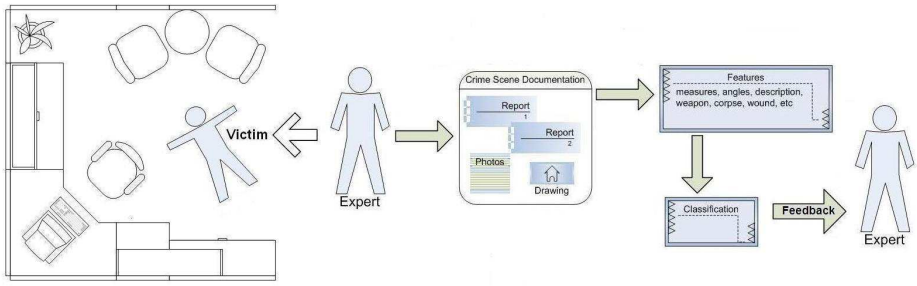


Figure 1: Crime scene documentation and classification.

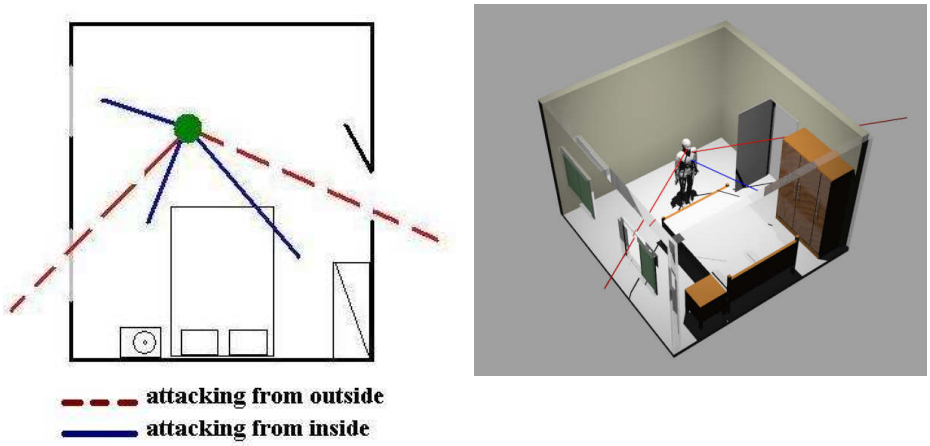
The experts use different technical procedures to provide a legal documentation about crime scenes such as annotation, drawing, measurement, photograph, and movies, as depicted in Figure 1. Every material is then analyzed by a group of experts. All these procedures are important to describe and document 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.

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.

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. Section 5 describes the stereoscopic projection experiment. In Section 6, our conclusion and a plan for future works are presented.



(a) (b)

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

2 Crime Scene Representation and Visualisation

There are different ways to register a crime scene such as description, written notes, printed forms, 2D-drawing or scheme (Figure 3a), topography survey (Figure 3b), 3D-model (Figure 3c), photography (Figure 3d), and audio/videotapes [TWGCSI, 00]. The documentation is important to create a detailed record of the scene, evidence recovered, and actions taken during the search of the crime scene. The most important about the representation is the description of the dynamic acts occurred in 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.

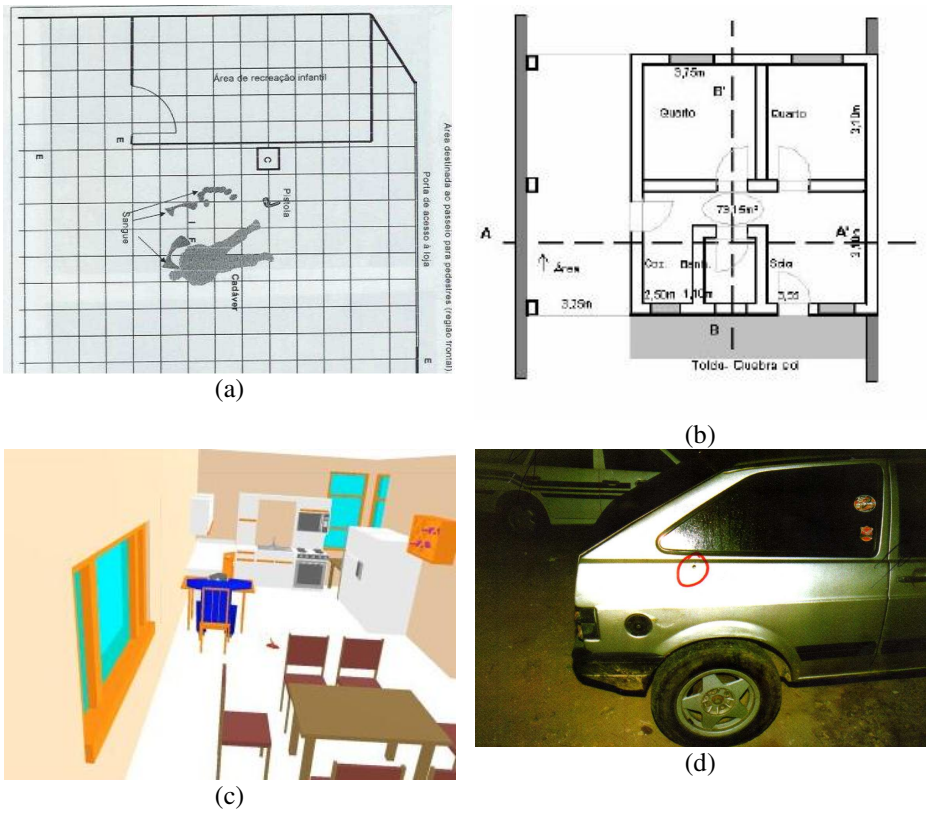
As the name indicates, description is about a document written of everything what the expert, policeman or coroner, could observe in the scene. To the first sight it could seem that this document is very subjective, but in the fact it does not occur. Two reasons for non subjective reports are training 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 drawings illustrate the description. There are some useful types of drawing to this purpose [TWGCSI, 00]:

- 2D-drawing or 2D-scheme: It is the most simple, schematically representation and does not include scale of some data of interest. For some elements already there is a convention: railroad, bridge, door, river, window, and others;

- Topographical survey: One is about special form of used drawing in the local register. This type of drawing demands some technical preparation of the expert. It is made in scale, having had ratio defined between the represented object and the representation;
- 3D-modeling: This kind of representation allows to the experts explore and analyse the scene from different points of view considering a lot of details. The objective is to help the experts understanding on the dynamics of the crime;

Photograph: Is widely used by the experts to register the crime scenes and their detail. There are different types of photograph to be used to collect information from the crime scene such as, simple, serial, metric photograph, and topographical survey.



(a) (b) (c) (d)

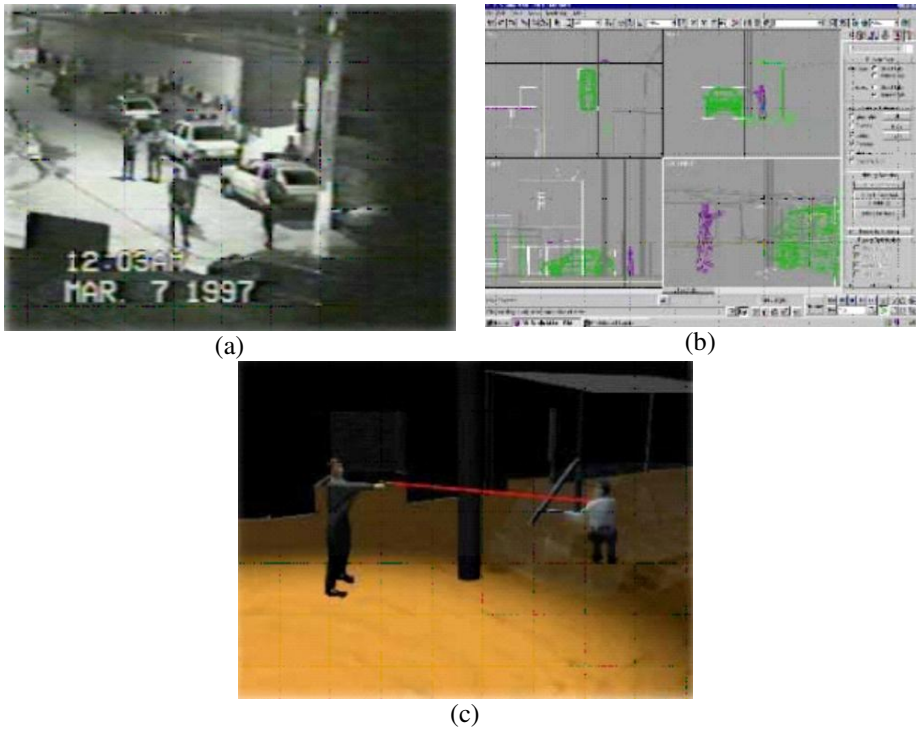
Figure 3: Crime scene registration: a) 2D-drawing, b) 3D-model, c) photo, .

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 [Cadesign, 97]. Based on the movie (Figure 4a), a 3D-model was created (Figura 4b). 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 (Figure 3c) [Cadesign, 97].

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.



(a) (b)

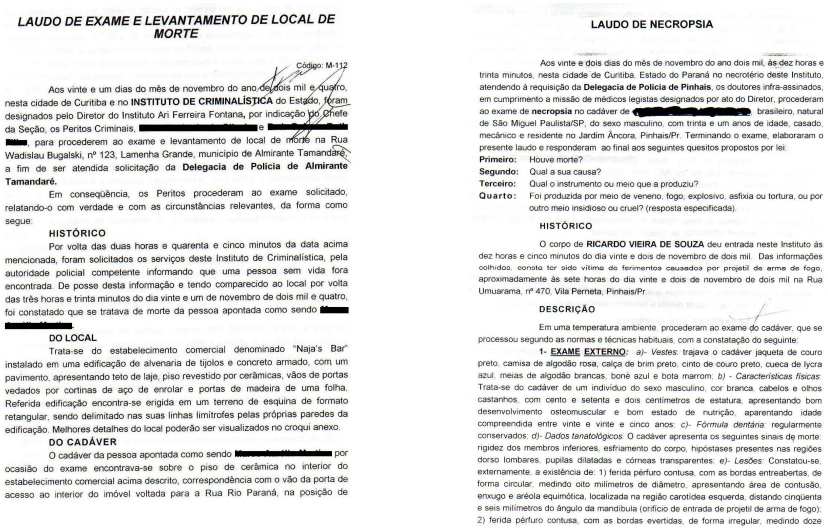
(c)

Figure 4: A Brazilian real case study - Favela Naval: a) movie, b) 3D-model, c) evaluation of the victim position.

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, as presented in Figure 5a. The second is the autopsy report which is about the victim or corpse, depicted in Figure 5b. 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 [Howard, 00]. 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.



LAUDO DE EXAME E LEVANTAMENTO DE LOCAL DE MORTE

Código: M-112

Aos vinte e um dias do mês de novembro do ano de dois mil e quatro, nesta cidade de Curitiba e no **INSTITUTO DE CRIMINALÍSTICA** do Estado, foram designados pelo Diretor do Instituto Ari Ferreira Fontana, por indicação do Chefe da Seção, os Peritos Criminais, [redacted] e [redacted], para procederem ao exame e levantamento de local de morte na Rua Wadislau Bugalski, nº 123, Lamenha Grande, município de Almirante Tamandaré, a fim de ser atendida solicitação da **Delegacia de Polícia de Almirante Tamandaré.**

Em conseqüência, os Peritos procederam ao exame solicitado, relatando-o com verdade e com as circunstâncias relevantes, da forma como segue:

HISTÓRICO

Por volta das duas horas e quarenta e cinco minutos da data acima mencionada, foram solicitados os serviços deste Instituto de Criminalística, pela autoridade policial competente informando que uma pessoa sem vida fora encontrada. De posse desta informação e tendo comparecido ao local por volta das três horas e trinta minutos do dia vinte e um de novembro de dois mil e quatro, foi constatado que se tratava de morte da pessoa apontada como sendo [redacted].

DO LOCAL

Trata-se do estabelecimento comercial denominado "Naja's Bar" instalado em uma edificação de alvenaria de tijolos e concreto armado, com um pavimento, apresentando teto de laje, piso revestido por cerâmicas, vãos de portas vedados por cortinas de aço de enrolar e portas de madeira de uma folha. Referida edificação encontra-se erigida em um terreno de esquina de formato retangular, sendo delimitado nas suas linhas limítrofes pelas próprias paredes da edificação. Melhores detalhes do local poderão ser visualizados no croqui anexo.

DO CADÁVER

O cadáver da pessoa apontada como sendo [redacted] por ocasião do exame encontrava-se sobre o piso de cerâmica no interior do estabelecimento comercial acima descrito, correspondência com o vão da porta de acesso ao interior do imóvel voltada para a Rua Rio Paraná, na posição de

(a)

LAUDO DE NECROPSIA

Aos vinte e dois dias do mês de novembro do ano dois mil, às dez horas e trinta minutos, nesta cidade de Curitiba, Estado do Paraná no necrotério deste Instituto, atendendo à requisição da **Delegacia de Polícia de Pinhais**, os doutores infra-assinados, em cumprimento a missão de médicos legistas designados por ato do Diretor, procederam ao exame de **necropsia** no cadáver de [redacted], brasileiro, natural de São Miguel Paulista/SP, do sexo masculino, com trinta e um anos de idade, casado, mecânico e residente no Jardim Âncora, Pinhais/Pr. Terminando o exame, elaboraram o presente laudo e responderam ao final aos seguintes quesitos propostos por lei:

Primeiro: Houve morte?
Segundo: Qual a sua causa?
Terceiro: Qual o instrumento ou meio que a produziu?
Quarto: Foi produzida por meio de veneno, fogo, explosivo, asfixia ou tortura, ou por outro meio insidioso ou cruel? (resposta especificada).

HISTÓRICO

O corpo de **RICARDO VIEIRA DE SOUZA** deu entrada neste Instituto às dez horas e cinco minutos do dia vinte e dois de novembro de dois mil. Das informações colhidas, consta ter sido vítima de ferimentos causados por projetil de arma de fogo, aproximadamente às sete horas do dia vinte e dois de novembro de dois mil na Rua Umuarama, nº 470, Vila Perneta, Pinhais/Pr.

DESCRIÇÃO

Em uma temperatura ambiente, procederam ao exame do cadáver, que se processou segundo as normas e técnicas habituais, com a constatação do seguinte:

1- EXAME EXTERNO: *a)- Vestes:* trajava o cadáver jaqueta de couro preto, camisa de algodão rosa, calça de brim preto, cinto de couro preto, cueca de lycra azul, meias de algodão brancas, boné azul e bota marrom; *b) - Características físicas:* Trata-se do cadáver de um indivíduo do sexo masculino, cor branca, cabelos e olhos castanhos, com cento e setenta e dois centímetros de estatura, apresentando bom desenvolvimento osteomuscular e bom estado de nutrição, aparentando idade compreendida entre vinte e vinte e cinco anos; *c)- Fórmula dentária:* regularmente conservados; *d)- Dados tanatológicos:* O cadáver apresenta os seguintes sinais de morte: rigidez dos membros inferiores, esfriamento do corpo, hipóstases presentes nas regiões dorso lombares, pupilas dilatadas e córneas transparentes; *e)- Lesões:* Constatou-se, externamente, a existência de: 1) ferida pérfuro contusa, com as bordas entreabertas, de forma circular, medindo oito milímetros de diâmetro, apresentando área de contusão, enxugo e aréola equimótica, localizada na região carotídea esquerda, distando cinquenta e seis milímetros do ângulo da mandíbula (orifício de entrada de projetil de arma de fogo). 2) ferida pérfuro contusa, com as bordas evertidas, de forma irregular, medindo doze

(b)

Figure 5: A Brazilian real case - Favela Naval: a) movie, b) 3D-model, c) evaluation of the victim position.

Gibson and Howard present a reconstruction system through photographs and consider that is can be used in the documentation of crime [Gibson, 00]. Wang and Oliveiras describe a similar system that tries to solve the problem of occlusion, found very often in approaches based on 3D-modeling [Wang, 02]. 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, Flamingo and Eyeswitness.

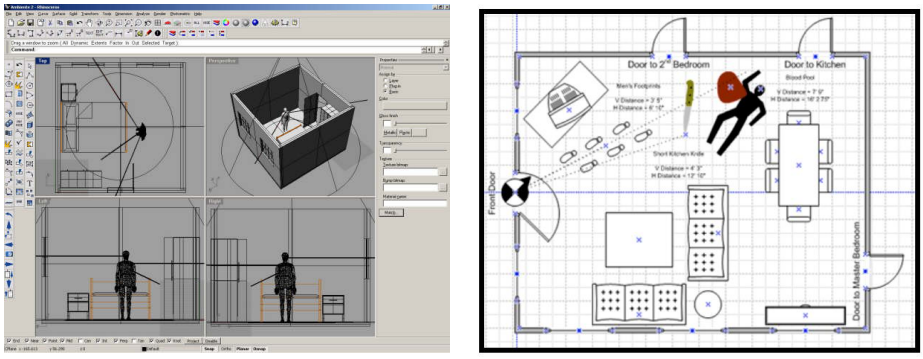
From conceptual design through drafting and detailing, the software CAD can create, visualize, document, and share the drawings and designs. Eyeswitness is PC-

based 3D visualization software designed specifically for the law enforcement community. It can provide a crime scene recreation, traffic accident documentation, and pre-raid planning. Other positive attributes of this software are: accurate measurements can be made on the screen from point to point; the expert can draw and include in a scene an element that can be provided in their 3D-objects library and scenes can be adjusted for the proper location and angle of the sun. However, this software is a commercial product not allowing customization or interchangeable formats. Figure 6 illustrates two different scenes using the softwares: Eyeswitness and Rhinoceros.

The AutoCAD is the software for creation of drawings that makes possible the use of DXF files (Interchangeable Format of Drawing), whose format is opened and consists of ASCII file with diverse properties. DXF files can be manipulated by other programs, in contrast of archive DWG files that is the format standard of the AutoCAD. The QCAD is the most popular CAD systems for Linux being a good option to a few free applications for architecture and engineering mechanical designs. 3D Studio (Autodesk Architectural 3D Studio Max) is the software for the treatment of 3D-objects, images and textures, allowing create complex surfaces and volumes. The Rhinoceros (Rhinoceros Solid Modeler 3.0) is the software for 3D-surface modeling and it works in addition to Flamingo software, which is the software for the treatment of images and textures from Rhinoceros.

The Maya 3D, is widely sufficiently used in the creation of effect and animation in 3D, is sufficiently used in the production of videos and films beyond serving in the development of computer games. Creating models of excellent quality it is not simple, and then these softwares are more useful in areas as engineering and architecture, in which the professionals develop 3D object models, constructions and environments.

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.



(a) (b)

Figure 6: Software: a) working space in the Rhinoceros; b) Eyeswitness.

3 Feature Set

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 7a);
- x_3 and x_4 = angles of the wound: in relation to the horizontal and the vertical axis (Figure 7e-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 7b-c);
- x_9 = distance between victim and window or door (Figure 7d);
- 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 [Jain, 00]. One of distinct properties of the conventional MLP architecture is that all the *K*-classes share one large network [Jain, 00] [Oh, 02] [Zhang, 00]. Based on this and other works we have done [Freitas, 07] [Kapp, 07] we have chosen this architecture for our experiments. Moreover, experimental results were obtained applying SVM [Vapnik, 98].

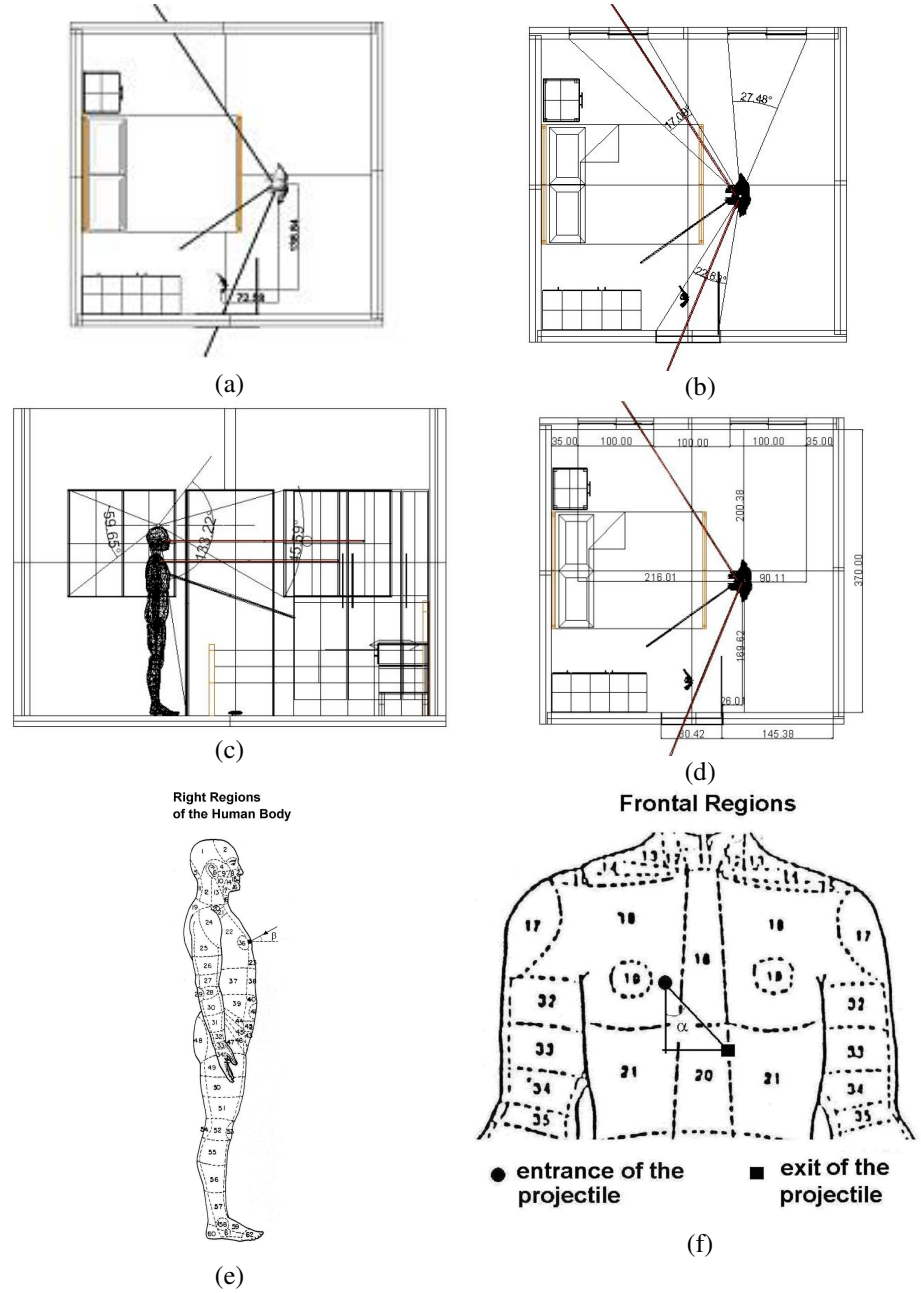


Figure 7: Feature set from crime scene: a) distance of the weapon in relation to the victim, b) horizontal angles between the victim and the extremities, c) vertical angles between the victim and the extremities, d) distance between victim and window or door, e) horizontal angle of the wound, and f) vertical angle of the wound.

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 18,000 cycles.

Support Vector Machine (SVM) is a supervised learning method used for classification and regression proposed by Vapnik [Vapnik, 98] 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 [Vellasques, 06]:

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

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 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.

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.

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

Table 1: Crime Scene classification: MLP-NN.

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

Table 2: Crime Scene classification: SVM.

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

Table 3: Crime Scene classification: SVM-polynomial.

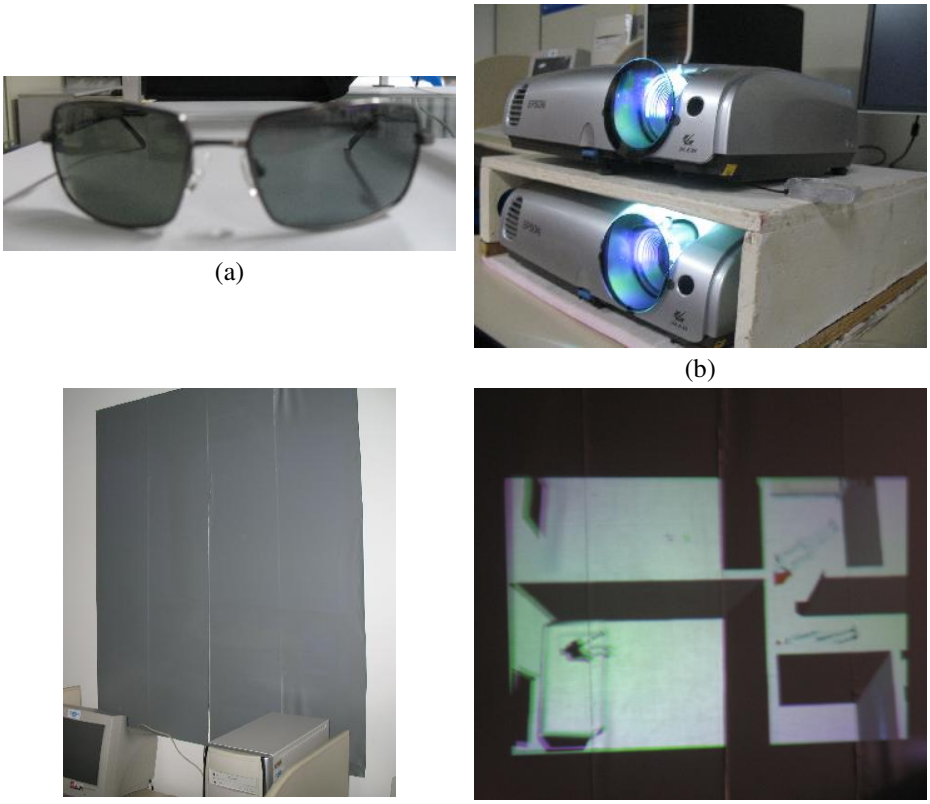
6 Stereoscopic 3D Projection

A crime scene can be analyzed using a stereoscopic 3D presentation. The use of stereopsis can provide a several improvements to a presentation, such as add visual impact and improved crime scene understanding. However, this kind of presentation is rarely used in crime scene representation or visualization because of the added difficulty involved in generating the presentation in 3D and organizing the necessary environment. We organized in laboratory the software and hardware tools necessary to provide this kind of projection.

The laboratorial experiment considers as presented in [Woods, 00] that the most effective way to project stereoscopic images is to orthogonally polarise the left and right images. Polarised projection allows for the projection of full-colour stereoscopic images to a large audience and the per unit cost of the glasses (with polarised lens) is low (Figure 8a). Thus, we need have two video projectors applyng a pair of orthogonal polarised lens, which are placed at output of the two projectors, as presented in Figure 8b. Then, the video projectors are focused at a silvered screen (polarisation preserving screen), as depicted in Figure 8c. The audience must wear the polarised glasses, because these glasses provide the appropriate view of the crime scene. An important detail must be observed: the left eye sees images from the left projector and the right eye sees images from the right projector, so the orthogonal polarised lens must be combined. Taking into account these considerations, the hardware needed to make feasible to interface the computer to the projector stereo-pair was a graphical driver nVidia FX550.

7 Conclusion and Future Work

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.



(a) (b) (c) (d)

Figure 8: Stereoscopy 3D presentation: a) glasses with polarised lens, b) projectors and polarised lens, c) silvered screen and d) stereoscopic projection.

Acknowledgements

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/CNPq) which have collaborated to this work. This work has been supported by CNPq (Proc. No. 471604/2004-6).

References

[Cadesign, 97] Cadesign, CAD e animação ajudam a esclarecer o caso de Diadema (CAD and computer animation help to solve Diadema case). CADDESIGN, (27), 1997.

[Freitas, 07] 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.

[Gibson, 00] 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.

[Howard, 00] T. Howard, S. Murta, "Virtual Environments for Scene of Crime Reconstruction and Analysis", Advanced Interfaces Group, Manchester, 2000.

[Jain, 00] 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.

[Kapp, 07] 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.

[Oh, 02] I-S. Oh, C. Y. Suen, "A class-modular feedforward neural network for handwriting recognition", Pattern Recognition, 35, 2002, 229--244.

[TWGCSI, 00] Technical Working Group on Crime Scene Investigation - TWGCSI, Crime Scene Investigation, Technical report, U.S. Department of Justice, 2000.

[Vapnik, 98] Vapnik, V., Statistical Learning Theory, Wiley, N.Y., 1998.

[Vellasques, 06] Vellasques, E., Oliveira, L. S., Britto Jr., A. S., Koerich, A. L., Sabourin, R. Modeling Segmentation Cuts Using Support Vector Machines. 10th International Workshop on Frontiers in Handwriting Recognition, La Baule, France, 2006, 41--46.

[Wang, 02] J. Wang, M. M. Oliveiras, "Improved scene reconstruction from range images", Proc. of Eurographics 2002, Vol. 21, 2002.

[Woods, 00] A. Woods, Stereoscopic Presentations: Taking the Difficulty out of 3D. 6th International Workshop on 3D Imaging Media Technology, Seoul, Korea, 2000, 1--6.

[Zhang, 00] G.P. Zhang, Neural network for classification: A survey, IEEE Trans. On System, Man and Cybernetics, 30(4): 2000. 451-462.