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An Expert System of Crime Investigation Based on Mark-Theory to Reconstrcut Crime Scene

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ABSTRACT

There is enormous information in reference to evidence gathering, recording, and preservation. But little has been written pertaining the crime scene reconstruction which is the deriving job of the recognition and the locating of physical evidence[KLS91,KLS92,LCK92]. In our **CD Model**, there are two categories to check the value of any item as evidence. The first one is represented and applied in **Linkage Triangle** of figure one --"whenever two objects come in contact with one another, there will be an exchange of material from one to the other". The second one is by the use of a hypothetical walk through the scene which is really an exercise in deductive thinking that fits the properties of the modern technology of Expert System. It states in using CB[CD] Model that any item found includes the basic inference of Mark and Non-Mark theory evidence. There are three stages to **Criminal Behavior[CB]** :(1) **Pre-CB** (2) **In-CB** (3) **Post-CB**. Figure one gives you an explanation of transition state of occurring a crime.The criminal tries to hide his behavior during the stages of committing crime, but, still unveiling the signs of crime. We call it Non-Mark Theory evidence of crime investigation. We may inference it via using 5Ws[who,which,when,where, and what] to understand the level of suspect. This research does a contribute to the investigator at the last stage which is based on Mark Theory's evidence to reconstruct crime scene.

Because the firearms smuggling has been getting serious in the last decade, homicide, suicide, or accidental death occurring frequently in our city. In this paper, we mainly focus on the evidence of bloodstain with gunshots in the inference of **CD Model** to reconstruct crime scene via using the technology of Artificial Intelligence. We try to incorporate the domain knowledge of Mark Theory and the experiences of investigators to our Expert System, which helps both the investigators and qualified practitioners gain enough evidence of the crime scene. It is the most important that it offers the Mark Theory evidence to reconstruct the crime scene which is even possibly used to exculpate an innocent suspect of defendant.

Keywords: BloodStain, Crime Scene Reconstruction, Expert System, Mark Theory, gunshots

I. Introduction

There are two main trends in Crime Investigation: (1). Mark theory towards the gathering, analyzing, and inferencing of Physical Evidence; (2). Non-Mark theory focuses on the Crime Sign. It is possible either Mark or Non-Mark theory to increase the clues of crime detection and to high up the cleared rate of crimes. Both of them are insufficient research in the system of crime detection in our country. Crime Scene Reconstruction is the major concern within the crime detection[B91,K921]. We may get rid of unnecessary items in the scene. Physical Evidence only provides a direction of crime detection. Both Mark and Non-Mark theory in CD model explain the modern technology of crime detection. Figure 1 gives us detail explanation that both Mark and Non-Mark theory's evidence include the linkage triangle of scene, victim, and suspect. This paper presents a new solution to reconstruct crime scene via using the modern technology which is based on Mark theory as our approach.

GENERAL CONSIDERATIONS OF BLOODSTAIN EVIDENCE

The existence of blood circulation of human body, which causes the existence of bloodstain evidence. While the suicide or murder commits, it always spatters or spits on the clothes, weapons, and human body. It has two categories to consider bloodstain evidence: (i) examination of physical characteristics of bloodstain (ii) properties of bloodstains. There are seven items which are derived from the above two categories as follows:(a) distance between target surface and origin at the time blood was shed, (b) point(s) or origin(s) of blood, (c) type and direction of impact that produced bloodstains, (d) movement and directionality of persons and/or objects while they were shedding blood, (e) the number of blows, shots, etc. (f) position of victim and/or objects during bloodshed, (g) movement of victim and/or objects following bloodshed[D70].

GENERAL CONSIDERATIONS OF GUNSHOTS WOUNDS

According to the scene, the investigators may be confused as to what was the mechanism causing death. If it seems likely that gunshot wounds were the cause, he should try to determine four things[S77]:

1. Was death due to a gunshot wound or to an injury inflicted by some other instrument
2. If by a gunshot wound, from what distance was the firearm discharged
3. From what direction were the shots fired and what was the position of the body when hit
4. Was it an accident, suicide or murder

Let us see semantic network of the dead body in the crime scene as figure two.

The above notions give us the concepts to reconstruct the crime scene which is based on Mark Theory approach. We implement those characteristics and properties of bloodstain with gunshots wound to develop expert system. HARCSM not only helps attorney at law, but those investigators to reconstruct the crime scene. Expert System(ES) is the modern technology to solve fuzzy logic problems[BF82], in the field of crime investigation, we propose a new concept and solution to help police. It includes not only domain knowledge of blood and experiences of forensic on bloodstain interpretation, but the capabilities of gunshot wounds differentiation to its own Knowledge Base(KB). Because of the heavy work load of police, we make the most use of inference engine of ES to offer solutions to reconstruct the crime scene.

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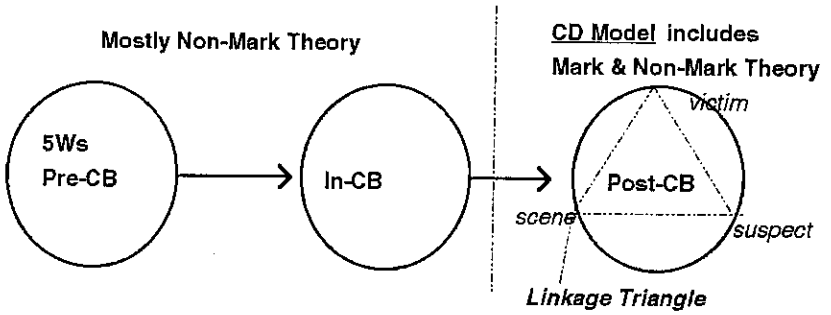

Figure 1. Transitive State Diagram for Criminal Behavior[CB Model]

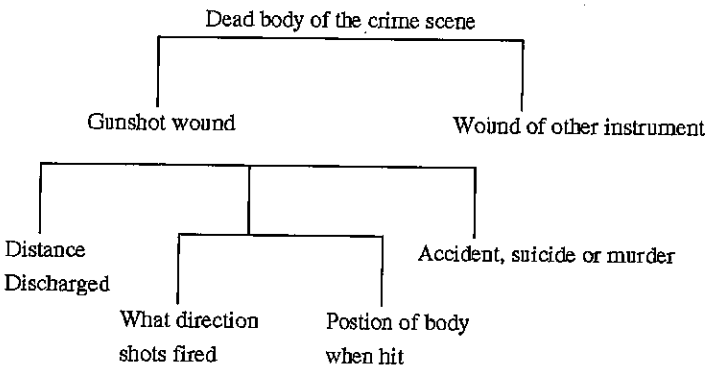

Figure 2. semantic network of the dead body of the crime scene

THEORY OF BLOODSTAIN INTERPRETATION IN CRIME SCENE

There are two components for our heuristic approach on Blood Stain Interpretation:They are used in the Forensic Science Laboratory[KLS91,KLS92].

(a). Identification

There are two major steps to test whether the evidence is blood or not as follows:

-1. Preliminary or Presumption Tests

Such as Benzidine, Phenophthalein, Leucomoalchite green, ortho-tolidine,tetramethyl benzidine, ortho-dianisidine, and luminol. We usually use Benzidine Test, and Phenolphthalein test. If the sample is blood, the resolution becomes light-green instantly. While it is negative, the color of the resolution will be changed after periods of time.

-2. Confirmatory or Conclusive Tests

It is possible that the bean oil, iron dust, oil, paints left on the scene, and they look like blood. We have to test to confirm it as using Takayama Test, if there is any crystal, it is blood.Takayama test is the confirmatory or conclusive test. If Benzidine test is positive and Takayama test is negative, then it is proved that the stain is blood.[TZ12]

(b). Individualization

To test whether the sample is human blood or not(Specia test). We propose anti-human serum precipitian method, if there exists crystaloid, it is positive, otherwise, it is negative, and it is not human blood. [C71]

II. Crime Scene Reconstruction

In this paper, we focus on the reconstruction of crime scene via analyzing the blood of the crime scene, and differentiation of gunshot wounds. Owing to the speedily advanced computer technology, we try to bring in the expert system to police science. Expert System is a computer program that emulates the behavior of a human expert within a specific domain of knowledge. It has the ability to perform at the level of an expert, the representation of domain-specific knowledge in the manner in which the expert thinks, and the incorporation of explanatory mechanisms and ways of handling uncertainty into the repertoire of the system[JDD89,R85]. An expert system consists of three parts:a dialogue, an inference engine, and a knowledge base[JDD89]. The knowledge base is a set of facts and heuristics(rules of thumb) about the particular domain. It is important for the expert system to consist of both facts and rules of thumb derived from an expert's experience. It can be seen in the legal field. Bellord, N.J. shows that another form of relevant legal knowledge may be tactics. Thus, the knowledge of who is going to judge a particular case and what the judge's reaction usually is to a particular kind of murder may be of far greater importance than anything to be found in a book[B82]. This suggests that besides having "book knowledge"(facts in expert system), it is just as important to have heuristics obtained from the expert lawyer. That means, the knowledge base of the expert system thus has both facts and heuristics. According to the above notions, we want to make the most use of inference engine and knowledge base in expert system. Owing to the complex domain knowledge and experiences in police science, we try to implement expert system to crime investigation. HARCSM is our new approach to solve the reconstruction problem of crime scene via using the expert system.

III. Expert System

(a). What is Expert System

Expert systems deal with knowledge rather than data and the files they use are often referred to as knowledge bases. The rules that the program uses are IF-THEN-ELSE type rules[E88,BE84]. A rule is

made up of a list of IF conditions(normal English sentences or algebraic expressions) and lists of THEN and ELSE conditions(more sentences) or statements about the probability of a particular choice being the appropriate solution to the problem. If possible, the program will derive information from other rules rather than asking the user such as backward or forward chaining[JDD89]. This ability to derive information allows the program to combine many small pieces of knowledge to arrive at logical conclusions about complex problems[BE84]. The rule editor allows the rules to be easily modified, added or deleted. The final goal of an expert system is to select the most appropriate solution to a problem based on the data input by the user. If more than one solution is possible the program will provide a list of the possible solutions arranged in order or probability. Essentially all of the instruction necessary to run an expert system knowledge base is provided by the program and all output is in normal English. Little or no training is required to run an already developed knowledge base. We choose EXSYS as an Expert System Shell to construct HARCSM.

(b). Why build an expert system

There are many reasons that have been given for building expert systems. Some of the reasons are valid, but unfortunately not all are. Expert systems are not the solution to all problems[JDD89,E88,W84,W86]. It is important to understand why you want to build an expert system, to understand what type of system it must be and how it must work. The main reasons for building an expert system are: 1. It is urgent and time is not enough to get a new expert even the experiences and time is increasing 2. Disseminate problem solving knowledge(not just facts)with minimal training of users 3. Free a human expert from repetitive, routine work to do work an expert system can not do
4. Modelling a problem solving technique for future users and education 5. Provide a safe and effective training tool 6. Allow the problem solving skill of several people to be combined

HARCSM is going to be used by police, investigators, and attorney at laws, etc. To evaluate the current situation of Taiwan's environment, and to ease the work load of police, to reconstruct the crime scene, and to reconsider the above six reasons, so we develop our expert system.

(c). How to select an appropriate problem---feasible for our system

In theory, any decision-making process can be converted to an expert system[BF82,HK85]. However, in practice many problems can not effectively be converted into expert systems. The most important first step in developing an expert system is to pick an appropriate problem. While not all problems can be solved, there are an enormous number that can. Often, even if a large problem can not be solved, part of the problem can be solved.

There are several factors to consider in selecting a problem to solve with an expert system:

1. Does a human know how to solve the problem ?

If there is no human expert that can solve the problem, it will not be possible to develop rules describing the solution to the problem[J86]. Our investigator is able to solve those problems about blood stain interpretation, and gunshot wounds differentiation to reconstruct crime scene. But, owing to the heavy work load of police, sometimes, they can not keep them in spirit-up to solve every problem. That is why we develop HARCSM to help them.

2. Does the problem have a definable solution ?

If there is no way to specify all of the possible solutions, it will be very difficult to write rules to solve the problem. There are some problems that can be handled that have a very large numbers of solutions-configuration problems are a good example-but there is always a definable set of possible solutions. The technology of blood stain interpretation is mature enough, there exists possibly enough solutions to solve those crime scene problems[TZ12].

3. Is the level of understanding and scope appropriate ?

HARCSM is really a deep level of understanding in Expert System. Because it focuses on a specific problem about bloodstain with gunshot wounds which needs more innovation[JDD89,E88,K92,KLS92]. According to the deep level of understanding, we have to make HARCSM more easy to use via the well-developed user-interface.

IV. System Development

There are many recommendations to develop expert system, we propose five steps to develop HARCSM[JDD89,R85,KLS92,K92]. Those steps are as follows :

1.Definition

To clarify our problems, to collect and to analysis our information to construct expert system, and to scope our problem which is about general or specific. Bloodstain Interpretation is a kind of specific problem. It needs not only domain knowledge, but experiences to reconstruct the crime scene, which means we need more heuristic approach on it. It should be noted that when blood leaves a body by spatter or drop, its behavior will follow laws of physical sciences, specifically that of ballistics-the science of projectiles in motion. Therefore, interpretation of the significance of bloodstain evidence should be accompanied pathologist with physical scientist. Because the pathologist does the job of identification, and individualization, the physical scientist does the job of reconstruction. It clarifies what kind of domain experts we need in our expert system.

2.Conceptualization

In this step, we have to describe prototype, and to take care of domain knowledge. Sometimes, we even need to inherit knowledge via using some advanced technology such as decision-tree, etc.

IDENTIFICATION, INDIVIDUALIZATION OF BLOODSTAIN

The first job to be done with suspected dried blood evidence is to identify it. The sample must be proved to be human's blood. A variety of chemical tests are used for this purpose. Those kinds of tests are used to detect the presence of blood may be divided into two categories:(i). preliminary, or presumptive tests and (ii). confirmatory, or conclusive tests. Benzidine test is the preliminary or presumptive test.[CN64]

Takayama test is the confirmatory or conclusive test. If Benzidine test is positive and Takayama test is negative then it is proved that the sample is not blood. If Benzidine test and Takayama test are both positive then the stain is blood. Once a specimen has been identified as blood, it is necessary to find out whether it is human's or not. To determine the species of the blood specimen is done by the anti-human serium precipition method. If the result of this method is negative then it is animal origin, not human origin. If the anti-human preciption method is positive and there are not two potential problems with the test: (i) false reactions because of incorrect dilutions and (ii) cross-reactivity of antisera, then the blood stain is human origin.

We may include above notions as using RULE 4 in HARCSM:

RULE 4:

IF Question 1: Benzidine test is positive
and Question 2: Takayama test is positive
and Question 3: The result of the anti-human serum preciption method is positive
THEN The blood stain is human origin.

GUNSHOTS OR OTHER INSTRUMENT CAUSED THE DEATH

When a bullet strikes and passes through a body, the wounds of entrance and exit will have certain characteristics which will vary with the following conditions[S77,K92]:

1. The type of ammunition
2. The distance from which it was fired
3. Whether or not the bullet first strike some other object(ricochet)
4. Whether or not it passed through clothing
5. Whether or not it struck a bone in its course through the body

WOUNDS OF ENTRANCE

When a bullet strikes the skin, it first produces simply an indentation of the skin due to the fact that skin is both tough and elastic and the tissues underneath are not resistant[S77]. Due to the fact that the skin is stretched by the bullet in its passage through, it then returns to its former position and the size of the wound of entrance appears to be smaller than the diameter of the bullet which made it. Typical wounds of entrance are neat round holes with an even gray ring around them and from which emerges comparatively small quantities of blood much greater than in wounds of entrance.

RULE 60:
IF Question 1: the size of the wound of entrance appears to be smaller than the diameter of the bullet
and Question 2: it is neat round holes with an even gray ring around them, and small quantities of blood

and Question 3: the wounds of exit are much larger than the bullet, are ragged, torn, and generally the escape
of blood is much greater than in wounds of entrance
THEN It is gunshot wound.

FROM WHAT DISTANCE WAS THE FIREARM DISCHARGED

There are three zones of the distance from classified which a firearm was discharged[S77,K92];
1. Those in which the muzzle of the place was held directly in contact with the skin or practically so.
2. Those in which the muzzle was held from about 2 to 18 inches away.
3. Those in which the muzzle was held from 18 inches or more.

RULE 61:
IF Question 1:there are flame & expanding gases produced by the burning powder on the skin
and Question 2:the wound is larger than the diameter of the bullet
and Question 3:the skin edges are ragged & torn
and Question 4:there is actual charring of the tissues due to the tremendous heat from the muzzle blast
THEN It is contact wounds

RULE 62:
IF Question 1:the smoke & the soot from the burned powder were deposited around the wound of
entrance,producing a'dirty, gimmy appearance
and Question 2:it is simply deposited on the surface of the skin & can be wiped off with a cloth
THEN It is 2 to 18 inches shot

3.Knowledge Base(KB) and Knowledge of Representation(RoK)
There are many RoKs been proposed to represent knowledge such as Semantic Network[for the novice designer], Rule-based, Frame-based, Object-attribute value, and hybrid representation, etc[W86,K92]. We prefer hybrid representation [rule & frame-based] to develop HARCSM. We also include those related knowledge to port to our KB. Figure 3 is our RoK which comes from the testing results of bloodstain interpretation[D70].

In this semantic network, we represent the relationships about diameter and its corresponding fallen distance, length to width ratios and its corresponding angle of impact degree.

4.Prototyping
We choose EXSYS as an expert system shell to develop our system. According to the structure of expert system[W86,JDD89,J86,KLS91,KLS92,K92]. Because we already have inference engine, and man-machine interface, so we have only to construct KB. We usually pick small knowledge as prototype.

Figure four is the structure of HARCSM. You will see the EXSYS is our expert system shell. The knowledge may be ported by using knowledge acquisition subsystem of EXSYS. The dialogue window offers a good user-interface between man and machine. The inference engine does the job of thinking to derive facts & rules in KB.

5. Test and Feedback
In this step, we should consider the practical problem. Let's see detail in figure 5 for going thru step 1 to step 5.

To validate our system is necessary to check the KB and the ES as a whole. Validation can be achieved by running the KB on past problems whose solutions are known or accepted. It can also be confirmed by other expert's knowledge in the problem domain. Testing is important, because, when the expert system finally runs, it typically produces a variety of unexpected results[FPJ80]. In order to correct "bugs", the KB must be refined and then maintained. Toward these goals, iterative refinements of KB thru knowledge acquisition, knowledge representation, knowledge programming, and knowledge testing are conducted until user expectations are met. The above steps from 2 to 5 are iterative. If one of them is not correct, we have to refine it and to do the whole steps again. The following case gives us real explication: Blood dropping to a flat surface that is not horizontal will produce an elliptical rather than a circular stain. The degree of circular distortion is indirectly proportional to the angle of incidence. That is, as the angle decreases from 90 to 0 degrees, the stain becomes more elongated. Plotting the length to width ratios of blood spots against their respective impact angles of incidence produces a reasonably good working curve. Let's see the RULE NUMBER 13 first,

RULE NUMBER 13
IF: Question 1: Benzidine test is positive
and Question 2: Takayama test is positive
and Question 3: The result of anti-human serum precipition method is positive
and Question 4: The shape of blood is elliptical or exclaimation

and Question 5: Length to width ratios of stain is 1.00-1.02
THEN: The angle of impact is 80-90 degrees.

See another case as follow: When spot diameters of over 16mm are observed it may be concluded that the blood drops were of normal volume since smaller drops could not possible produce so large a stain.

RULE NUMBER 9
IF: Question 1:Benzidine test is positive
and Question 2: Takayama test is positive
and Question 3: The result of the anti-human serum precipition method is positive
and Question 4: The shape of blood is round & scallops around the edge
and Question 5: Diameter of a bloodstain from a single drop is 16-17 mm
THEN: The distance which the blood fell is 2.4-4 feet.

In rule number 9, and rule number 13, about the distance and angle of impact, we have to contact with experts while we are doing validation thru testing. Because they are kinds of domain knowledge about blood stain. It is possible that we did not do the right thing about semantic network because of misunderstanding of analysis and conceptualization.

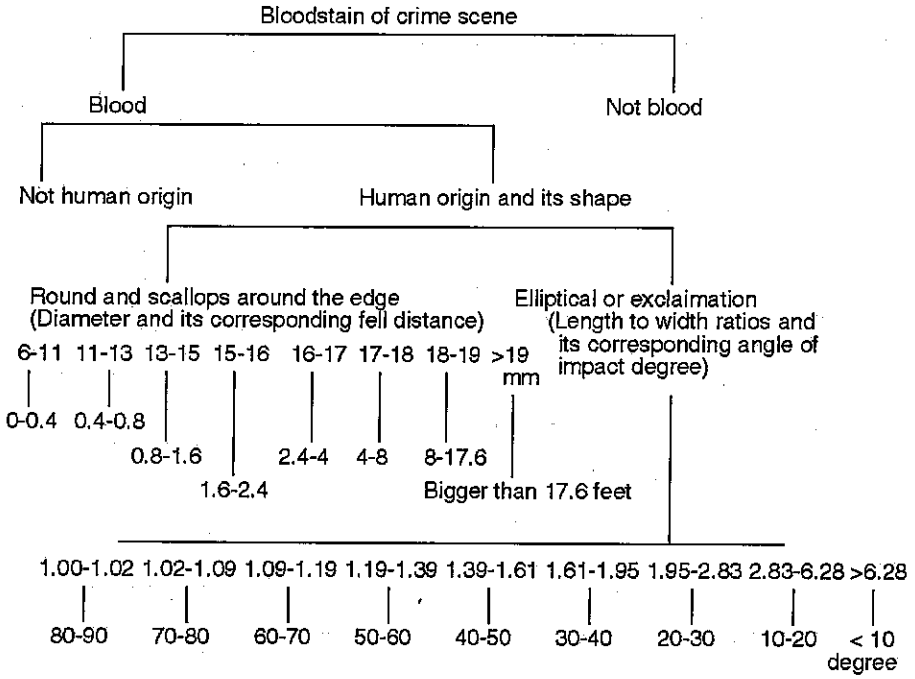

Figure 3. Semantic network for Initial RoK of Bloodstain Interpretation

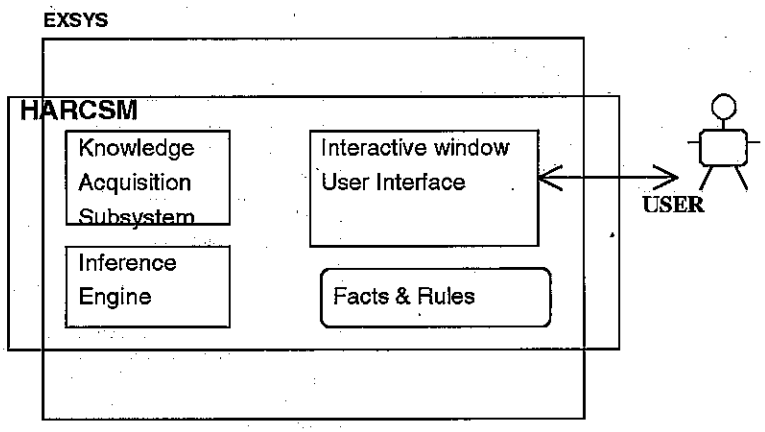

Figure 4. System Structure of HARCSM

6. Finish

While step 1 thru step 5 are completed, the whole expert system is finished. We offer rule 1 thru rule 5, and rule 70,75 to illustrate our expert system.

RULE NUMBER 1
IF Question 1: Benzidine test is negative
THEN: The stain is dye or something.

RULE NUMBER 2
IF Question 1: Benzidine test is positive
and Question 2: Takayama test is negative
THEN: The stain is dye or something.

RULE NUMBER 3
IF Question 1: Benzidine test is positive
and Question 2: Takayama test is positive
and Question 3: The result of the anti-human serum preciption method is negative
THEN The bloodstain is animal origin.

RULE NUMBER 4 [The inference of human origin starts here]
IF Question 1: Benzidine test is positiveand
Question 2: Takayama test is positiveand
Question 3: The result of the anti-human serum precipition method is positive
THEN The bloodstain is human origin.

RULE NUMBER 5
IF Question 1: Benzidine test is positive
and Question 2: Takayama test is positive
and Question 3: The result of the anti-human serum precipition method is positive
and Question 4: The shape of blood is round & scallops around the edge
and Question 5: Diameter of a bloodstain from a single drop is 11-13mm
THEN: The distance which the blood fell is 0.4-0.8 feet.

RULE NUMBER 70
IF Question 1:around the entrance of wound is the scorching fur
and Question 2:the wound of entrance is out of the range of hand touch
THEN Purely Commit Suicide - Probability=0/10 & Purely murder -Probability= 7/10

RULE NUMBER 75
IF Question 1:around the bullet wound there is the socrching fur, or the smolder, or the powder article
and Question 2:the number of deadly shot is not less than two
THEN Purely commit suicide - Probability = 1/10
and Purely murder - Probability = 10/10
and be shot accidentally - Probability = 1/10

V. Discussion and Conclusion

(a). Discussion

HARCSM uses many techniques to test its premises and justify its conclusions. Expert system that "reason about their reasoning" employ metaknowledge. The metaknowledge is defined by Waterman[W86] as "Knowledge about the use & control of domain knowledge in the expert system". Hayes-Roth[HLW83] stated the functions of metaknowledge as follows:(i). Selects rules after checking their legality,(ii). Records the necessary facts about the objects,(iii). Justifies rules by explaining "how" and "why" the conclusion is made.

In HARCSM program, expert system checks the legality of each premise through identification and individualization tests. The blending function of the program ensures that as more information about the object becomes known, the knowledge becomes less "fuzzy". The more new confidence comes in, the higher the confidence factor because the object is evolving to a less uncertain state. The expert program explicates "how" and "why" through its consultation facility. It explains how it reaches its conclusion by printing the object-value couplet that lead to conclusion. It shows solutions why the user has been asked a question by stating that no conclusion could be reached about the selected goal.

(b). Summary

The objectives of this research were to show the capabilities of an expert system. The advantages of using an expert system technology instead of using traditional programming techniques are as follows:(i). Heuristics of expert on the optimization of search methodology,(ii). Solutions to fuzzy logic,(iii). Machine Learning[Automatic Self-Modification],(iv). To do self-evaluation during critical points of the process[HKM80]. HARCSM is capable of offering the above advantages. The KB of HARCSM was heuristically derived from knowledge about bloodstain interpretation, and wounds of gunshot differentiation. We bring in the techniques of heuristics in setting up the IF/THEN statements, the problem is solved efficiently instead of doing blind search and uncertain investigation. A victim on the scene which is caused by the gunshot, and usually bothers the investigators to differentiate them from commiting suicide, murdering, or being shot accidentally. This system really give investigators a good guide to dig it up. The goal of this paper has been to represent the concept and implementation of fuzzy subset theory to aid in the problem of mainly reconstructuring the crime scene via using bloodstain interpretation, and gunshots differentiation. This prototype meets our initial requirements, but we still have to do some modifications and improvements as follows: (i). To port the capability of chinese text to HARCSM, (ii). To get more domain and metaknowledge from investigators and police, then port those knowledge to our system, (iii). To integrate our system to police investigative system.

Evidence	Approach	Knowledge Type
Mark Theory	Expert System	Static Knowledge
Non-Mark Theory	Neural Net or Fuzzy Set	Dynamic Knowledge

Figure 5. Comparison of Mark Theory & Non-Mark Theory Evidence

(iv). Figure five will show us clear view about the further study of crime investigation tool. According to our CB Model, we want to expand our system to include not only Mark theory evidence, but Non-Mark theory evidence also. The former one can be constructed by the technology of expert system, the latter one can be solved by the theory of fuzzy and neural network[KLS91,KLS92,LCK92,LLC92,K92].

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