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Utilizing Simulation Tool for Crime Scene Analysis Visualization

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ABSTRACT

Crime scene reconstruction is one of the most important aspects of forensic investigation. It is the process of establishing the scientific facts of a case. Crime or accident scenes can be visualized to the viewer to help understand the situation and preserve the complex information. However, designing a visual system is the real challenge to clearly present information and improves the decision-making process. Many previous researches have proven that simulation modeling offers a great benefit in various fields. Simulation data can be interpreted by visualization into a displayable image. In this paper, we present a study for utilizing simulation tool to visualize crime scene analysis. Uncertainties situation in crime investigation process has been handled by numerical probability values from knowledge base system. The weight of probability is given based on the investigator expertise. The results are highly capable, demonstrating the potential of this model for both understanding processes behind crime.

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INTRODUCTION

Crime scene investigation is the application of forensic science within the context of the crime scene to the court (Chisum, Turvey, & Freeman, 2011; Millen, 2000; Thompson, 1998). Crime scene investigation often begins with a comprehensive hypothesis to explain the entire scene. Crime or accident scenes can be visualized to the viewer to help understand the situation and preserve the complex information. Visualizing data is an important development in the analysis and investigation area. Visualization is a computer-generated image providing an improved visual representation to gain understanding (Brown *et al*., 2006; Chittaro, 2001). It represents the image of a physical space or environment to assist interpretation. A visualization or graphic can be a potential aid to help interpret and express a large amount of complex information (Kelleher & Wagener, 2011). Meanwhile, the objective of data visualization is to examine information by mapping data onto graphical form for understanding (Haase, Strassner, & Dai, 1996; Lee, Butavicius, & Reilly, 2003). In many courtrooms, digital visual evidence presentation systems have already been used. These visual tools can be used to present evidence and illustrate hypotheses based on scientific data. 'What-if' scenarios and possible hypothesis can be analyzed and illustrate through digital reconstruction technology (Schofield, 2011). Investigation in crime scene scenario can be assisted by reconstruct the event and simulate the criminal human behaviour. Conventional illustrations, photographs, and verbal descriptions can be replaced by using computer animation techniques to reconstruct crime scenes (Dillon, Talbot, & Hillis, 2005).

Based on crime scene reconstruction, simulation model can be developed to provide decision support for investigators and visualize the crime scene. Simulation is a process of designing a model of a real system (Moreno *et al*., 1999). Experiments have been handled with this model to understand the behaviour and evaluate strategies for the operation of the system (Shannon, 1975). In simulation model, the operating behaviour of a system or problem entity has been imitated and analyzes (Crosslin, 1995; Harrel, Ghosh, & Bowden, 2012; Hsieh, 2002). Visualization technique can analyze raw data sets that result from computer simulation (Post, de Leeuw, Ari Sadarjoen, Reinders, & van Walsum, 1999; Tory, Kirkpatrick, Atkins, & Möller, 2006). Simulation and animation are commonly linked together to represent understandable form of real world. Thus, the relation among modeling, simulation and visualization is the simplification of a complex environment to assist understanding systematically (Brown, *et al*., 2006).

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Simulation environment is used as an analytical tool to clarify the investigation process and improve existing policies on the long run (Bosse & Gerritsen, 2010). The crimes event and the motivations can be modeled in time and space dynamically through a useful and prolific model of crime simulation (Brantingham, Wuschke, & Frank, 2003).

This study explores the potential use of such simulation tool as a visualization medium for crime scene analysis using ProModel. A test crime scene is selected and a simulation model of the crime scene scenario is developed. Numerical probability values from knowledge base system are added in the model to run the simulated visualization according to the expert evaluation. The objective of this paper is to describe the benefit of simulation tool in visualizing crime scene investigation. The paper is structured as follows. First, related work is discussed to review current simulation modeling and visualization in crime investigation. Then, crime scene investigation visualization using simulation tool is described. The experimental results come next, evidencing that the simulation model is indeed capable of generating result of probability values for visualizing crime scene. We conclude by describing the relevance of these findings.

This study explores the potential use of such simulation tool as a visualization medium for crime scene analysis using ProModel. A test crime scene is selected and a simulation model of the crime scene scenario is developed. Numerical probability values from knowledge base system are added in the model to run the simulated visualization according to the expert evaluation. The objective of this paper is to describe the benefit of simulation tool in visualizing crime scene investigation. The paper is structured as follows. First, related work is discussed to review current simulation modeling and visualization in crime investigation. Then, crime scene investigation visualization using simulation tool is described. The experimental results come next, evidencing that the simulation model is indeed capable of generating result of probability values for visualizing crime scene. We conclude by describing the relevance of these findings.

2. Related Works:

Variety of situations such as performance optimization, safety engineering, testing, training, education and video games has applied simulation. Crimes scene is one of the situations that can be modeled in simulation form. Furtado et. al (2009) has designed a bio-inspired multi-agent criminal model that imitate a real-life criminal behavior with some sociological studies. The model applies Ant Colony Optimization algorithm. A concept for integration of numerical simulation, expert system and artificial intelligence techniques is discussed in (Azadeh, Faiz, Asadzadeh, & Tavakkoli-Moghaddam, 2011) by developing an intelligent neural network-based simulation environment for optimization of the performance of queuing systems. Agent based approach has caught many attention from researchers in their works regarding crimes simulation modeling. The question on how the emergence of criminal hot spots can be predicted and prevented have made Bosse and Gerritsen (2009) present an agent based simulation approach to compare crime prevention strategies. The results show that the model may be very valuable input for policy makers, in order to generate efficient strategies. Malleson, Heppenstall *et al.* (2010) presents the construction and application of an agent-based model (ABM) for simulating occurrences of residential burglary at an individual level. They represent the first working example of integrating a behavioural framework into an ABM for the simulation of crime.

In visualizing crimes, a combination of 3D virtual reality technology with intelligent agents to maximize the use of knowledge available during forensic investigation is presented (2000). They developed an intelligent environment using an expert knowledge base with multi-user collaborations and scenario testing. In training mode for police and investigator, a concept for visualizing an interaction log in a virtual crime scene investigation learning environment called OPENCRIMESCENE is presented (Brennecke, Schlechtweg, & Strothotte, 2007). Within visual review log, user can step back and take over a more objective perspective on how his or her behaviour has been. An application of how data from 3D photogrammetry is processed and integrated to generate a forensic surface representation of accident victims is presented by Ehlert, Salah and Bartz (2006). The objective of this application is to provide additional means for the documentation of surface injuries inflicted by fall, shock, or by a blow. The possibilities of reconstructing an accident with software ‘Poser4’ in reconstruction of accident and crime scenes has been investigated by Neis, Fink, Dilger and Rittner (2000). It allows a reconstruction of crime or accident scenes with realistic posing of the actors in a virtual environment.

Davies, Mehdi and Gough (2004) described research on developing an application for constructing a 3D virtual scene that can be manipulated and viewed from any angle in real time without having to be pre-rendered. This enables investigators to evaluate and eliminate different hypotheses much more rapidly. To date, most crime scene simulation or reconstruction systems provide adjustable 3D views of computer aided design (CAD) models, rendered using standard local illumination techniques. While such systems can be of substantial benefit to investigators, they are not primarily concerned with creating reconstructions that attempt to be data centric and intelligent based.

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4. Crime Scene Investigation Visualization Using Simulation Tool:

In this study, numerical probability value from the knowledge base system (KBS) is considered as the input for visualization process (see Figure 1). The KBS is a part of our whole research. However, we only focus on the visualization part in this paper. A simulation software ProModel is used as a tool to generate visualization. The visualization process of the crime scene includes tasks of entities processing and routing, 2D visualization and hypothesis result. Entities processing and routing require the numerical probability input to generate the movement of the visualization based on the logic rule. The output of the process is a range of reconstructed crime scene scenarios.

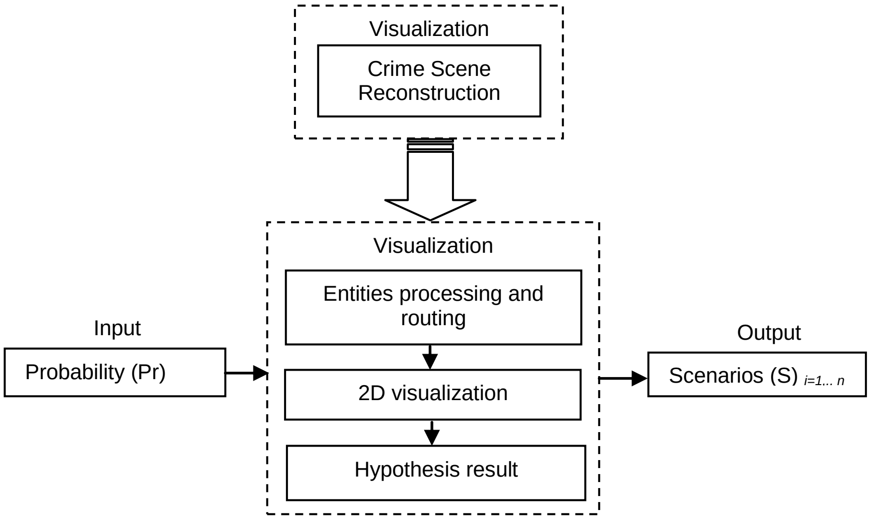

Fig. 1: Visualization of Crime Scene.

The algorithm to generate a visualization of hypothesis probability is described by the input and output as follow:

i. $P(E_i|H_n)$ = Probability of the chosen evidence exist, E_i that cause the hypothesis H_n.
ii. P(Ex)= Probability given by experts for routing in visualization.
iii. H[i] = attribute of hypothesis type
iv. VH[i] = the variable of hypothesis

Algorithm: Generate Visualization of Hypothesis Probability:

```
Input: P(Ei|Hn), P(Ex)
Output: Visualization, VH[i]
Begin:
Step 1: Setup simulation environment of location, entities, resource, attribute, arrivals and external file
Step 2: Set distribution weight for routing, P(Ex).
Step 3: Read P(Ei|Hn)
Step 4: Declare array, H[i] to keep the attribute of hypothesis type
Step 5: Declare array, VH[i] to keep the variable of hypothesis
Step 6: Define logic rule of process and routing:
            for (i = 1 to n, i = i++)

while (n > 0) do {

Begin
If P(Ei|Hn) < P(Ex) then {
                        Begin
                                Inc H[i]
                                Inc VH[i]
                        End
                        n-- }
                End
}
Step 7: Run visualization
End.
```

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Keppens and Schafer (2006) explained that crime scenes are described within scenarios context. Scenarios describe events and situations that may have occurred in the real-world. Formulation of hypothetical crime scenario will form description of the available evidence and support considered hypotheses. To develop the model, a crime scene is needed. For this work it was chosen to use a fictional scene from several research articles. There are no legal implications in using a fictional scenario to develop a prototype. Real data can be used once the model is completely developed. Hypotheses are given by the expert based on their experience in investigating crimes. We use commercial simulation modeling software of ProModel. Therefore, we began by analyzing a crime scene case and identify the related evidence in the scenario. Based on the analysis and identified evidence, we develop hypothesis of the case. The hypothesis is developed by combining evidences that mostly support the hypothesis. Then, we map the scenario in conceptual model into simulation software, ProModel

Test crime scene:

A dead body of a man named Johndoe is found in his house. His dead body is hanging and some evidences are found at the scene:

i. Johndoe's hanging dead body.
ii. Signs of petechiae on Johndoe's eyes.
iii. Medical report indicating that Johndoe's cause of death was asphyxiation cause by hanging.
iv. Cutting instrument was found near Johndoe.
v. Johndoe's body has defensive injuries.
vi. Johndoe has a severe injury on the head.

The question now is to find the cause of death of Johndoe whether it is suicide, homicide or accident. Based on the given test crime scene, we have developed a simulation model that requires the probability value from the KBS. A conceptual model that relates the evidence with the hypothesis is developed before the simulation model. Figure 2 shows the layout of the visualization.

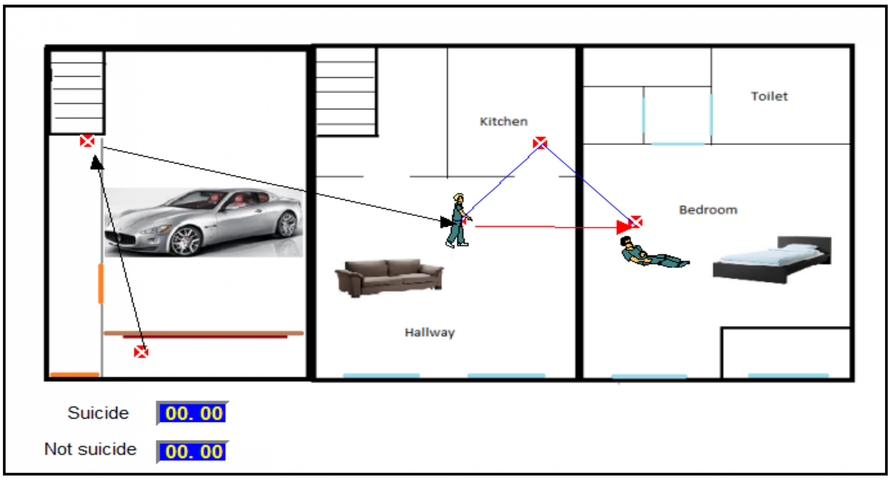

Fig. 2: Layout of the Visualization.

Firstly, we define locations of the movement of the murderer and the victim (see Figure 3). In this case, there are five locations which are garage door, upstairs, hallway, bedroom and kitchen.

```
********************************************************************************
*                                  Locations                                   *
********************************************************************************

  Name        Cap      Units Stats       Rules      Cost
  ----------- -------- ----- ----------- ---------- ------------
  garage_door 1        1     Time Series Oldest, ,
  upstairs    1        1     Time Series Oldest, ,
  hallway     INFINITE 1     Time Series Oldest, ,
  bedroom     1        1     Time Series Oldest, ,
  kitchen     1        1     Time Series Oldest, ,
```

Fig. 1: Location.

Then, we define an entity which is a murderer if the cause of death of Johndoe is not suicide (see Figure 4).

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```
********************************************************************************
*                                   Entities                                   *
********************************************************************************

  Name       Speed (fpm)  Stats       Cost
  ---------- ------------ ----------- ------------
  murderer   10           Time Series
```

Fig. 4: Entities.

There are two types of resources which are dead Johndoe and live Johndoe (see Figure 5). This the possibility condition of the victim whether Johndoe is dead or still alive.

```
********************************************************************************
*                                   Resources                                  *
********************************************************************************

                                    Res      Ent
  Name         Units Stats    Search   Search Path       Motion         Cost
  ------------ ----- -------- -------- ------ ---------- -------------- -----------
  dead_JohnDoe 1     By Unit  None     Oldest            Empty: 150 fpm
                                                         Full: 150 fpm

  live_JohnDoe 1     By Unit  Closest Oldest Net1        Empty: 150 fpm
                                             Home: N1    Full: 150 fpm
```

Fig. 5: Resources.

Variables are typically used for making decisions or for gathering data. We define four types of variables which are suicide, not_suicide, percentage1 and percentage2 (see Figure 6). Suicide and not suicide are variables for gathering data of numerical probability from KBS. Percentage1 and percentage2 are input for the probability routing.

```
********************************************************************************
*                              Variables (global)                              *
********************************************************************************

  ID          Type         Initial value Stats
  ----------- ------------ ------------- -----------
  suicide     Real         0             Time Series
  not_suicide Real         0             Time Series
  percentage1 Integer      0             Time Series
  percentage2 Integer      0             Time Series
```

Fig. 6: Variables.

Attributes are placeholders similar to variables but are attached to specific entities or locations. It usually contains information about that entity or location. Attributes are changed and assigned when an entity executes the line of logic that contains an operator, much like the way variables works. In this case study, we define three types of attributes which are a_Hyptypes, percentage and aPt_ID (see Figure 7).

```
********************************************************************************
*                                  Attributes                                  *
********************************************************************************

  ID         Type         Classification
  ---------- ------------ --------------
#
#define hypothesis type of cause of death
  a_Hyptypes Real         Entity
  percentage Real         Entity
  aPt_ID     Integer      Entity
```

Fig. 7: Attribute.

The movement of the entity and resources are determined by the defined process and routing (see Figure 8). We have defined logic rule for entity to operation. We define an ID as an external file in order to read the value of numerical probability from the text file. The values are assigned as variables of percentage1 and percentage2.

```
**********************************************************************************
*                                   Processing                                   *
**********************************************************************************

                                 Process                   Routing

Entity   Location    Operation            Blk  Output   Destination Rule    Move Logic
-------- ----------- -------------------- ---- -------- ----------- ------- ------------
murderer garage_door READ (file,percentage1)
                     READ (file,percentage2)

                     IF percentage1 < 0.4 THEN
                     Begin
                     a_Hyptypes=1
                     INC suicide
                     End

                     ELSE IF percentage2 < 0.6 THEN
                     Begin
                     a_Hyptypes=2
                     INC not_suicide
                     End


                     INC aPt_ID
                     aPt_ID=aPt_ID        1    murderer upstairs    FIRST 1

murderer upstairs                         1    murderer hallway     FIRST 1
murderer hallway     USE live_JohnDoe FOR 3 min
                                          1    murderer bedroom     FIRST 1
                                                                            MOVE WITH live_JohnDoe THEN FREE
murderer bedroom                          1    murderer EXIT        FIRST 1 GRAPHIC 1
                                                                            MOVE WITH dead_JohnDoe
```

Fig. 2: Process and Routing.

Entity arrivals define the time, quantity, frequency and location of entities entering the systems. We defined the arrivals of a murderer at location of garage_door as the murderer arrives at the first location point (Figure 9).

```
**********************************************************************************
*                                   Arrivals                                     *
**********************************************************************************

 Entity   Location    Qty Each   First Time Occurrences Frequency  Logic
 -------- ----------- ---------- ---------- ----------- ---------- ------------
 murderer garage_door 1                     INF
```

Fig. 3: Arrival.

External files are used to read data directly into the model or to write output data from the model. External files are also used to store and access process sheets, arrival schedules, shift schedules, bill of material, delivery schedule and so forth. We use external file to read the probability values from the KBS that have been written in a text file (Figure 10).

```
**********************************************************************************
*                                External Files                                  *
**********************************************************************************

 ID         Type              File Name                                      Prompt
 ---------- ----------------- ---------------------------------------------- ----------
 file       General Read      D:\Wana\PhD Works\CHILD\Prolog forensic\int.txt
```

Fig. 10: External File.

RESULT AND DISCUSSION

This study has demonstrated the visualization model for crime scene investigation by utilizing simulation tool, ProModel. The numerical value of probability from knowledge base into the simulation model has been applied. The simulation model is developed by defining locations, entities, attributes, variables, resources, arrivals, process and routing and external file. The external file is defined as an ID to read numerical value from text file. Each piece of evidence has a probability value that supports the given hypothesis, where the probability weight is determined by experts based on their experience in investigating crime scenes. The numerical probability can be referred to as a supportive element in decision-making among experts, especially in uncertain conditions when one piece of evidence could lead to many hypothetical conclusions. The 'what-if' element in the KBS will allow the expert to construct multiple scenarios of evidence combinations where they can add or delete any evidence element based on their findings to create a scenario. Visualization of crime scene and the movement of the entity will be generated by the simulation model according to the defined process and routing. Based on this scenario, experts can also develop an effective investigation strategy that will optimize crime scene investigation.

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