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Agent Based Simulation of Routine Activity Theory

Amrutha S

Department of Computer Science & Engineering, Royal College of Engineering and Technology, Thrissur, Kerala, India

Abstract: ***Routine activity theory states that criminal acts are caused due to the presence of criminals, victims and the absence of guardians in time and place. As the number of collision of these elements in place and time increases, criminal acts will also increase even if the number of criminals or civilians remains the same within the vicinity of a city. Street robbery is a typical example of daily crime and the occurrence of which can be predicted using routine activity theory. Agent-based models allow simulation of diversity among individuals. Therefore agent based simulation of street robbery can be used to visualize how chronological aspects of human activity influence the incidence of street robbery. The conceptual model identifies three classes of people- criminals, civilians and police with certain activity areas for each. Police exist only as agents of formal guardianship. Criminals with a tendency for crime will be in the search for their victims. Civilians without criminal tendency can be either victims or guardians. In addition to criminal tendency, each civilian in the model has a unique set of characteristics like wealth, employment status, ability for guardianship etc. These agents are subjected to random walk through a street environment guided by a Q – learning module and the possible outcomes are analyzed. The results include comparison of gang and single robberies, robberies made on kids and women and comparison of different guardian patrolling strategies.***

Keywords: Agent based modeling and simulation (ABMS), Routine activity theory (RAT), NetLogo, Q – learning, police patrolling strategies, crime simulation.

1. Introduction

Agent based simulation consists of agents, which are independent entities implemented using a software program and preferably has a learning module. They are better able to accommodate different dimensions in relationships that are frequently observable in complex and dynamic interactions. Agents are guided by the assumptions and the rules on which the model is based. ABMS increase understanding of how a process 'works' using the prescribed strategy.

Routine activity theory is a sub-field of rational choice and criminology, developed by Marcus Felson and Lawrence E. Cohen. Routine activity theory premise is that crime is relatively unaffected by social causes such as poverty, inequality, unemployment. According to RAT for crime to be committed, three aspects are needed: a motivated criminal, a suitable victim and the lack of capable guardian. Lack of a capable guardian can range to anything that would make a suitable victim easier to victimize. Street robbery is a daily crime which can be avoided with simple precautions. The incidents of street robbery constitute about 44% of all robberies. It can be violent or non-violent. It can happen to anyone under certain conditions defined by routine activity theory.

This simulation considers the occurrence and outcomes of typical street robbery and then by operationalizing routine activity theory. Unlike the previous works in the agent based simulation, this simulation has a learning module which guides the random walk of agents and their decisions. The simulation also experiments in the timing of crime. Several attributes of each person involving in a crime situation, social and individual effects on crime and several rules guiding to occurrence of crime are simulated using a multi-agent simulation toolkit NetLogo and results are analyzed.

2. Related Works

As it is written in, all criminal events result from the combination of criminal motivation, opportunity, victim characteristics and an environmental backcloth at a particular point in space-time. In addition, all agents which are somehow involved in the criminal event are influenced by a sequence of past events (e.g. if the victim decided to use the same street). Those past events are also influenced by the constraints of the environment. From this, we can deduce that there is high emphasis placed on the history of all the subjects.

a) Spatial dynamics of crime

One of the most important works in agent based simulation is. It deals with the relations between spatial dynamics and the criminal hot spots creation. Criminal hot spot is the place where the risk of crime is higher than at other places. It usually means that there were recently many crimes committed at the same place. Authors of created a model of criminality and of the creation of hot spots depending on the reputation and attractiveness of each place in the environment. The authors presented the environment as a graph of nodes connected with edges as the potential crime places and the roads which connect them together.

Agents are provided with information about whole environment. It means that environment is fully observable. The reputation assessment runs every step. There are two different types of reputation values. The first one is given by the count of crimes which were successfully committed at the node and the second one is given by the amount of criminals who were arrested by the guardians at the node. Agents in the model are divided into three groups: passengers, robbers and guardians. In, when a criminal successfully commits a crime, he is marked as "wanted" person. If he meets the guardian he is arrested. If he does not meet any guardian he becomes anonymous criminal who can't be recognized and he starts looking for

next victim. Authors of this discussed work observe how hot spots change the position as the time goes and they observe also how changes in simulation parameters can influence the simulation results.

b) Agent based simulation of burglary

One of the most important works in crime simulation is. Agents in the model only go to work and have a rest at their home. Environment is a grid of cells representing the individual positions. Each cell represents either, the road which is used by agents for movement, or the building where the agents live or work, or just the blank cell which is inaccessible. The day cycle of ordinary citizens is modelled in the way that people sleep over the night and they work over the day. They just move from one building where they live to other building where they work. The difference between ordinary citizens and criminals is that the criminals do not have any full-time job. Hence, they are not able to earn enough money to satisfy their desire for money and they are made to commit the crime in order to substitute the source of income. The criminal chooses the building to burgle from his cognitive map which was created during his travelling. The model explores different crime prevention strategies.

3. Proposed Model

Agents in the model are of three types- criminals, civilians and police. All the agents are implemented using a reinforcement algorithm. In order to reduce the complexity of the simulation to a manageable level, the following assumptions based on routine activity theory is been made before formally presenting the model. Unlike the previous models, the proposed model concentrates on routine activity theory and proof of the theory. The existing models did not use any learning algorithms. The proposed model uses a reinforcement algorithm called Q-learning which guides the random walk and criminal behavior of agents. The proposed model added a number of attributes to each agents like wealth, fear factor, and ability to fight criminals.

1) *Type of street robbery*

Since our requirement of modeling is to study routine activity theory, the simulation will include property crime i.e. no violent behaviors are modeled.

2) *Scale of simulation*

The simulation does not need an area that is larger than several blocks in city.

3) *Routine activity selection*

Routine activities are going to work, walking. Some agents commit crime during these activities. For a criminal to commit crime, needs crime propensity and a suitable victim. The victim selection depends on wealth, age, gender etc.

4) *Rational choice assumption*

A civilian walk randomly, by avoiding the criminal who robbed him before. For a criminal, the first civilian with wealth is a suitable victim. If the victim has fear factor he will become more suitable.

5) *Agents in simulation*

a) Criminal agents

Motivation of criminal is an important factor for a crime event to occur. Also criminal learning and adaptation from past experience affects future crime rate. Learning function is defined for criminals to develop motivation. Criminals want to maximize their average crime commitment success rate. Another important attribute for criminal is crime factor which defines the criminal propensity of a criminal.

b) Civilian agents

For a typical crime simulation, a no: of victim agents need to be created and released to the street network to be robbed by a criminal. Victim desirability and guardian capability are two properties of victims. Victim desirability is how much a criminal expects to get from victim through crime and guardian capability is the ability to protect him-self.

c) Police agents

Police agents are not build with any adaptation capability. They have only one activity in the simulation- executing routine activity (walking). The effect of police agents on a crime event is that when a police agent is present at a given place, a crime event will not occur.

6) *Learning from experience*

All agents are provided with the memory and ability to learn from experiences. This learning issue could be classified as reinforcement learning because criminal agents are supposed to maximize the reward they earn by the choice of the crime commitment. Q-learning is a learning approach for solving reinforcement learning problem. Q-learning is a model free reinforcement learning technique that works by learning an action-value function that gives the expected reward of taking a given action in a given state and following a fixed rule thereafter.

7) *Q – Learning algorithm*

The problem model consists of an agent, states S and a set of actions per state A. By performing an action $a \in A$, the agent can move from state to state. Each state provides the agent with a reward. The goal of the agent is to maximize its total reward. It does this by learning which action is optimal for each state. For a single episode routine activity, the following algorithm can be applied

- Initialize cognitive map with uniform float value say 0.1
- Initialize agent with random position
- Agent updates the least cost value using equation,
  $U(s) \leftarrow U(s) + \alpha [r + \max U(s') - U(s)]$
  Where U(s) is utility value of each agent, α is the learning rate and 'r' is the reward value. The max U(s') allows an agent to choose from maximum value of actions and use it to update the value of next action.
- Agent moves a step according to crime event rules
- Go to step 2

8) *Criminal agents and learning*

Criminals are agents that travel around the city and commit crimes. There are several circumstances which can influence choice of the crime place like, presence of police, number and type of civilians, presence of other criminal, gang formation among criminals etc. After a few crimes with the help of gang, the criminal will be able to do crime without forming gangs. Each criminal gets a fixed reward after crime.

9) *Civilians agents and learning*

Civilians are agents who walks around the street and gets robbed by criminals. Civilians can be of three types – people with age > 14, kids and women. People consume the wealth they have and when they have wealth less than a defined value, they go to work and gain money. When people get robbed, they lose money and writes the criminal who robbed them in their memory. The next time when they are near that criminal, they flees from the spot, or they move to a proper guardian and thus saving them from robbery.

10) *Police agents and patrolling strategies*

Police agents are not using any learning methods. They move randomly in the environment. But the proposed model added several patrolling strategies to them. If there is any civilian who has not robbed yet near to them, police move to them so that they remain protected. If the robbery rate in a particular area increases, police considers it as a hotspot of crime and patrols that area rigorously.

11) *Crime event rules*

Routine activities bring people together, and interaction of people generates crime events. To model these interactions, crime event rules are needed. Police are reasonable guardian for victims. However, the most important guardians are ordinary people on the street. If robbery rate of simulation increases to a particular value, police patrolling becomes more efficient. Based on crime event evaluation, the crime event rules can be formulated from a criminal perspective. They are,

- If no victims are present at current place, no crime events occur.
- Criminal does a vision test within neighborhood. If there is one or more police agents are present, no crime will occur.
- If wealth of near victim is zero, no crime occurs.
- If more than one criminal are present near a suitable victim, the criminal with maximum criminal propensity gets the chance to commit crime.
- If more than one civilian are present at crime scene, and all civilians are either kids or women, crime occurs,
- If civilians have a fear factor towards crime, crime occurs, if one of civilians has the ability to fight, no crime occurs.
- Criminals can be light or heavy according to criminal propensity. Light criminals are amateurs, and need a companion to commit crime. They form gangs and commit crime. They share wealth earned and criminal propensity of them increases with each crime. As time goes by, they become heavy criminals and won't need gangs anymore.

12) *Commit crime module*

This module contains a sequence of decisions in committing crime. Figure 1 shows those steps. Initially, criminal agent checks for a suitable situation of robbery according to crime event rules. If the criminal is a light criminal, crime factor value will be less than a threshold value and criminals make a gang for robbery. Then it checks for presence of guardians and different civilian agents. Women and kids are comparatively easy to rob. Therefore they will the preys at the initial stage of simulation. After some iteration, criminals earn a high value for crime factor and they separate from gang and start to commit crime individually.

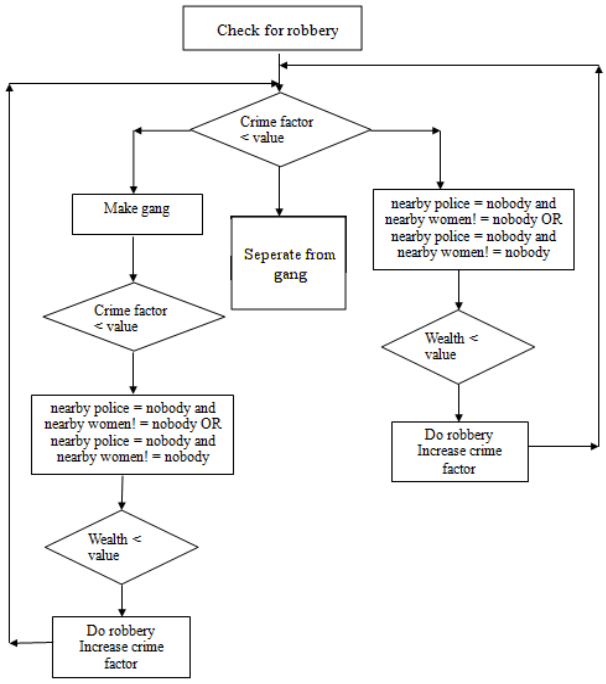

Figure 1: Sequence of decisions in committing crime

13) *Patrolling strategies*

In every street crime police patrolling plays an important role. Since routine activity theory considers presence of guardian as an important factor, two types of patrolling strategies are designed. Both of the strategies consider presence of a hotspot. A hotspot can be a place where a crime occurred previously or a place where the density of criminals are high. The first strategy considers hotspot as a place where a crime occurred previously. The police will move to the hotspot. In the second strategy police will follow the criminals where they form large groups. These strategies are specified in police patrolling module.

14) *Summary of proposed model*

A typical street robbery simulation consists of a no: of criminal, civilian, police agents and an environment of street network. The agents interact and generate crime pattern for analysis. The goal of simulation is to explore the agent interactions and adaptations on crime patterns.

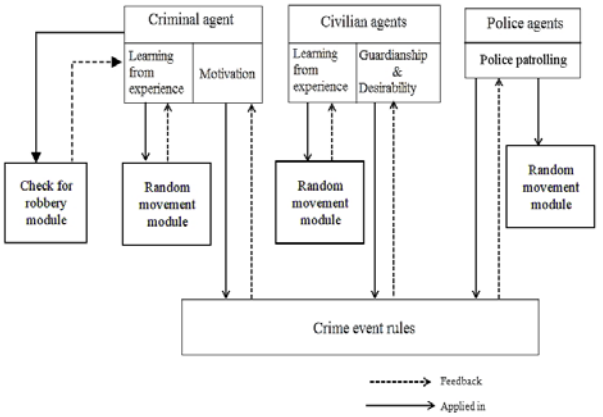

Figure 2: Proposed model

Figure 2 shows interaction and feedback relationship among crime event and components of a crime event. Dark lines mean being applied in and dotted lines mean feedback. For example, the arrow from criminal motivation to crime event rules shows that criminal motivation contributes to crime event possibility.

The criminal always check for the possibilities of a robbery using 'commit crime' module. If there are favorable conditions according to crime event rules, criminal agent commits crime and experience of criminals and civilians is updated along with the wealth exchanged and fear factor of civilians. Police agent only has an attribute called patrolling strategy, which is changed time by time.

All agents have a 'random movement' module. Every agent starts in a random position and move in different direction and speed. The decision about taking diversions is random choices for each agent. Thus the proposed model added a learning module for all agents. It provided several attributes like fight, fear factor to civilians and crime factor for criminals. It also added patrolling strategies for policemen.

4. Implementation Details

4.1 Tool used - NetLogo

Agent-based simulation can be done using general-purpose software or programming languages, or it can be done using specially designed software and toolkits that address the special requirements of agent simulation. NetLogo is a multi-agent programming language and modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems evolving over time. Modelers can give instructions to hundreds or thousands of independent "agents" all operating concurrently. This makes it possible to explore relation between micro-level behaviors of individuals and macro-level patterns that emerge from their interactions.

As a language, NetLogo adds agents and concurrency to Logo programming language. Mobile agents called "turtles" move over a grid of "patches", which are also programmable agents. All of the agents can interact with each other and perform multiple tasks concurrently. NetLogo also includes a third agent type, the "observer". There is only one observer. Different "breeds" of turtle may be defined and different variables and behaviors can be associated with each breed. Some models use the patch world just as a lattice. But the patches are not just lattice sites - they are square sections of a continuous two-dimensional space. Turtle coordinates are floating point values, so a turtle may be positioned anywhere within a patch. The time in the world created by NetLogo is measured in 'ticks' which cannot be compared to physical world time

4.2 Environment

Environment in the model is quite simple. It represents a street. The street consists of roads in which agents walk randomly. There are no means of public transport in the street or any other possibilities how the movement could be accelerated. There are also buildings in the street. The time referred in the environment is not comparable to physical time.

5. Results Achieved

Figure 3 shows the interface of simulation. A road with several blocks and agents at random positions are set up. The blue ones are civilians, pink are women and orange ones are criminals. Policemen can be identified easily because of their uniform.

Fig 3: Screen shot of simulation

Experiments conducted

No: of police is less than criminals

In the first experiment police help is not provided and no: of police is also low. As a result within 1 minute and 4 seconds (1750 ticks), total robbery became 21 (12 gang robberies and 9 single robbery). The figure 4 shows the chart of experiment. This proves routine activity theory.

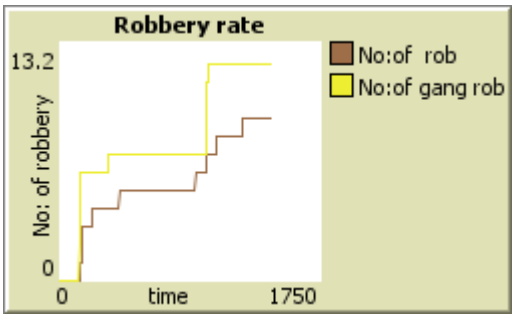

Figure 4: Chart of gang robbery vs. single robbery

5.1.2 Performance of criminal

The next experiment was based on the performance of criminal. The global variables to represent the successful and failed attempts of criminals were plot against time. The winning rate of criminals was comparatively low when learning rate of civilians was increased, which means as the precautions taken by civilians' increases, chance of robbery decreases. Figure 5 shows the chart of performance of criminal by time.

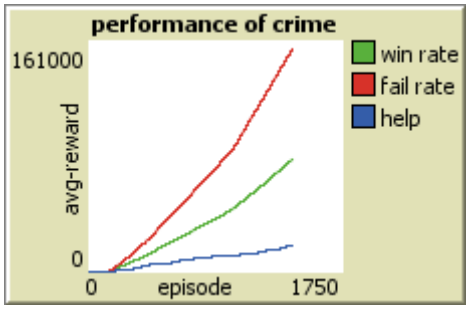

Figure 5: Chart showing performance of criminal

The 3d view of simulation is shown in figure 6. The red spots show the hotspots of crime. The major observations obtained through running the model are described in the table 1.

Patrolling strategies

Strategy 1: police randomly visited the hotspots where densities of criminals were high.

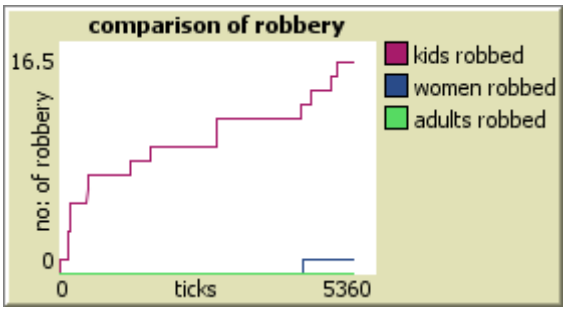

Figure 6: Chart showing rate of robbery in strategy 1

Strategy 2: police concentrates on the areas where crime rate is high (hotspots). As we can see strategy 1 is more effective in reducing crime.

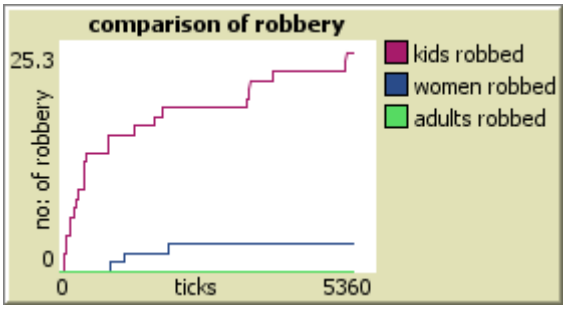

Figure 7: Chart showing rate of robbery in strategy 2

Table 1: Observations of simulation

Experiment name	*Parameters*		*Observations*
	No: of agents	Learning rate of civilians	
Rate of robbery	Less no: of police compared to criminals	Very less	Civilians will have a fear towards crime and more people are robbed
	Adequate no: of police	moderate	Police helps civilians by patrolling
	Adequate no: of police	High	Civilians take precautions E.g: they form gangs and walk together

6. Conclusion

Agent based simulation of routine activity theory was aimed to model a street robbery scenario and thus proving the truth of routine activity theory. The proposed model tried to incorporate human attributes like fight or flight behavior towards crime and learning of crime in criminals. The model used patrolling strategies for policemen and tried to make it real. With the help of agent simulation and NetLogo a clear picture of street robbery and outcomes of street robbery were observed. Using agent based simulation the unique characteristics and micro level behavior of each individual can be represented more meaningfully. The experiments conducted shows rate of robbery and performance of a random criminal. Thus the proposed model proved routine activity theory. There are several possibilities of future work in this model like- adding emotionally intelligent agents who show a social learning behavior, and how the system of justice and punishment may influence the behavior of a criminal etc.

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Author Profile

Amrutha S is an Assistant Professor at the department of Computer science, Royal college of Engineering & Technology, Thrissur, Kerala. Her research interest is in the area of Agent based modeling and simulation. She is an assistant member of IETE. She is a post graduate in Software Engineering from the Department of Computer Science, Cochin University of Science & Technology, Kerala.