Caught in the Act: Investigating Crime by Agent-Based Simulation
Gerritsen, C.

2010

document version
Publisher's PDF, also known as Version of record

Link to publication in VU Research Portal

citation for published version (APA)

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:
vuresearchportal.ub@vu.nl
Part V –
Conclusions and Future Work

The main goal of the research presented in this thesis was to explore how approaches from the area of Artificial Intelligence (AI) can be used to make progress in (both theoretical and applied) research in the criminological domain. As pointed out in this thesis, various approaches from AI turned out to be beneficial for this purpose, among which population-based modelling and simulation, agent-based modelling and simulation, and mathematical modelling. To apply these approaches different modelling environments have been exploited, including LEADSTO, TTL, Matlab, Microsoft Excel and C++. To check whether the models behaved as expected both logical verification and empirical validation have been performed.

The mentioned approaches turned out to be beneficial because they could be used to gain more insights in criminological phenomena (that were not clear based on just an informal theory), without actually having to experiment with these phenomena in the real world. Further, simulation and modelling approaches turned out to be useful to test theories and to perform thought experiments. For example, what would happen if we used a different strategy for guardian surveillance? Or what would be the impact of altering school classes on the overall level of delinquency? The answers to these questions are not easy to find based on common sense reasoning; moreover, it is difficult to test this in reality because of ethical issues or costs (both time and money).

Below, the research presented in each of the parts of this thesis is discussed and possible directions for future work are mentioned for each part.

Modelling Biological and Cognitive Aspects of Violent Behaviour

Part II of the thesis is devoted to research on a rather detailed level of abstraction. We investigated biological, psychological and social aspects of three types of aggressive offenders, namely the violent psychopath, people diagnosed with an antisocial personality disorder and people diagnosed with an intermittent explosive disorder. The research presented is a first step in the development of an agent-based modelling approach for aggressive behaviour in which these aspects are integrated in one dynamical system. As shown in the different chapters, the approach provides the analyst more insight in how three specific types of violent behaviour (violent psychopath, intermittent explosive disorder, antisocial personality disorder) may result from an interaction between biological, cognitive and social factors.

We do acknowledge the fact that the model presented in this part is very specific and does not provide an approach that is directly applicable to all types of offenders. As mentioned earlier, different types of deviant behaviour are caused by different aspects. These aspects can be mainly biological, like the factors presented in this part, but there are also types of deviant behaviour that are mainly caused by, for instance, environmental influences. Thus, to be able to simulate these types of influences, the model would have to be significantly extended. Further, we also do not claim that the model is complete and includes all possible factors that lead to violent behaviour, but we included some main factors. So the model should be seen as a first explorative step to get insight in the underlying processes, but it is not expected to be fully accurate.
For future work the current model could be extended with more internal states with possibly more complex dynamics. The aspects that were used in the current model could be investigated in a more detailed manner (e.g. the notion of empathy, which is currently represented as one single state, could be represented using a complete dynamic submodel). Another possibility of future research is to extend the social/environmental aspects of the model. Among the factors that could be added are attractiveness and reputations of locations, informal social control by passers-by, and different surveillance strategies (e.g., random, planning-based, or area-based) of the guardians, as used in part IV. Such extensions of the model with both more details and more factors would make the model more generic. Also, in case appropriate empirical data would be available (e.g., from psychology or neuroscience), an interesting challenge would be to try to validate the model against these data.

Modelling Social Learning of Juvenile Delinquency

In Part III of this thesis, the aim is to develop and validate a model to simulate social learning of delinquent behaviour among adolescents. The model presented here simulates the development of delinquent behaviour of pupils within a class room. According to the literature, many aspects can have a contribution to this behaviour, among which some personality aspects, as well as characteristics of the school, parents and peers. We have developed different variants of the model to see which (combinations of) factors have the highest predictive value. The choice for these model variants was based on empirical data gathered in a longitudinal study by researchers from the NSCR. After the most relevant factors were determined and the model was validated, we performed ‘what-if experiments’ to see what would happen if we altered some situational parameters. For example, we investigated whether different class mates could decrease or increase a person’s level of delinquency.

The research presented in this part led to several interesting insights, such as the tentative conclusion that school has an important influence but that class composition seems to have a relative low influence. Nevertheless, a difficulty with this approach is that it is not possible to predict behaviour with 100% certainty. This is an important fact to take into account when one wants to draw conclusions from the simulation. For example, once there exists a model that predicts with an accuracy of 76, what does this mean? If in 76% of the cases the prediction is accurate, this is a lot more than in the situation when a random guess is made (then there would be a 50% accuracy rate). However, when planning to make political decisions based on the model, 76% is perhaps not much. Hence, we are planning to further develop the model so we can obtain an even higher accuracy rate. One factor to consider is the possibility that part of the respondents could be life course persistent (see introduction part III) as opposed to adolescence limited offenders, which would mean that their delinquent behaviour is merely explained by other factors than social learning. Furthermore, the conclusion of Chapter III.3 is that the influence of school class composition does not appear to be very high. In future research we would like to examine this in more detail. Do we have the correct data to draw this conclusion in general? And what is the influence of other well-known contributors like school and parents or new media like Internet, videogames and music clips? Investigating these issues is also part of future work.
Modelling Spatio-Temporal Dynamics of Crime

Part IV focuses also on social aspects of crime, but here the focus is on the spatio-temporal dynamics. As explained in detail in the introduction of part IV, the Routine Activity Theory states that crime will occur when a motivated offender encounters a suitable target and no capable guardian is present. Obviously, this theory is quite broad and can be applied from different perspectives and to different domains. For example, within this thesis some aspects of the motivated offender have been investigated in part II. Here the causes for a certain desire are examined in detail, which in turn determine the level of motivation of the offender.

In this part we study the Routine Activity Theory (and in particular its consequences) in the domain of environmental criminology, to be more specific in the context of the spatio-temporal dynamics of crime. Criminal activities tend to concentrate around certain hot spots and these hot spots tend to shift over time. The dynamics of this process are the main research topic in this part. The method to investigate these questions was, again, (agent-based) simulation. First we studied a virtual society with static targets (e.g. houses) and dynamic guardians and offenders. In later research we also considered dynamic targets (e.g. passers by). We investigated the influence of different surveillance strategies of the guardians on the total amount of assaults and eventually we have also taken costs into account.

This research was fruitful because by using simulation we found a number of insights that were not obvious before. For instance, the use of ‘pure’ hot spot patrolling turned out to work better than area-based hot spot patrolling, unless the number of guardians is very high. Furthermore, concerning the allocation of guardians over different areas of the city, hybrid strategies combining reactive and anticipatory strategies turned out to be most effective when it comes to reducing the total amount of assaults. However, when costs are taken into account in the model we see that anticipatory strategies have the best cost-benefit ratio.

Nevertheless, also in this research, we are aware of the fact that we abstract from reality, and did not use empirical data. Instead, the main goal of this research is to help researchers in their theory building. As such, the presented models can be used as an analytical tool to see how certain aspects influence the spatio-temporal dynamics of crime. We are not aiming at a directly available tool for policy makers yet, but expect that in the future such models may become elaborate enough to indeed help policy makers make their decisions. Moreover, the model was set up in such a way that it is capable to deal with empirical data when it becomes available.

Also in this part, there are several possibilities to extend the model in the future. For example, it would be interesting to add ‘informal guardians’. These are guardians that are not officially delegated with the task to guard, but also have an important influence on crime. One can think of passers by as an example. If there are lots of people of the street, these people have an effect on the number of assaults just by their presence. In addition, also their reaction to criminal events is important. For example, if people encourage deviant behaviour, this will be performed more often, but when they condemn it this also will have an effect. One step further, also the influence of passers by on each other will be part of future research. In particular, the so-called ‘bystander effect’ could be studied: if someone watches a fight and does not do anything about that, then the persons standing next to this person might think that they should not interfere either. Other interesting directions for future work are making the offenders behave
more intelligently and creating some differences in the reaction time between the different types of agents.

**Comparison of Papers**

When comparing all papers presented in this thesis with each other, various commonalities and differences can be found. In Table 1 an overview is presented of elements that are present in this thesis. Here the different chapters are represented in the columns and the rows represent important aspects. The first row indicates what types of theories from the literature were used as inspiration for the chapter. Here, BL = Literature from Biology, RC = Rational Choice Theory, SL = Social Learning Theory, RAT = Routine Activity Theory. The next row indicates whether the chapter focuses on biological, cognitive, or social aspects of delinquent behaviour. The third row indicates which modelling approach was used (ABM = Agent Based Modelling, PBM = Population Based Modelling, MM = Mathematical Modelling). The fourth row indicates which modelling environment was used in the chapter. The abbreviations in that row stand for the following: LT = LEADSTO, ML = MatLab, C = C++, EX = Microsoft Excel, TTL = Temporal Trace Language. The fifth row indicates whether logical verification was applied and the last row indicates whether empirical validation was performed.

<table>
<thead>
<tr>
<th>theories used</th>
<th>IL.1</th>
<th>IL.2</th>
<th>IL.3</th>
<th>IL.4</th>
<th>IL.5</th>
<th>II.1</th>
<th>II.2</th>
<th>II.3</th>
<th>IV.1</th>
<th>IV.2</th>
<th>IV.3</th>
<th>IV.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>domain</td>
<td>BL</td>
<td>BL</td>
<td>BL</td>
<td>BL</td>
<td>BL</td>
<td>SL</td>
<td>SL</td>
<td>SL</td>
<td>SL</td>
<td>RAT</td>
<td>RAT</td>
<td>RAT</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>C</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>modelling</td>
<td>ABM</td>
<td>ABM</td>
<td>ABM</td>
<td>ABM</td>
<td>ABM</td>
<td>ABM</td>
<td>ABM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
</tr>
<tr>
<td>approach</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
<td>MM</td>
</tr>
<tr>
<td>modelling</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>LT</td>
<td>EX</td>
<td>ML</td>
<td>LT</td>
<td>LT</td>
</tr>
<tr>
<td>environment</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>TTL</td>
<td>ML</td>
<td>ML</td>
<td>C</td>
<td>ML</td>
</tr>
<tr>
<td>logical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>verification</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>empirical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>validation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 1. Overview of the aspects addressed in the chapters*

The table illustrates that the chapters were inspired by different theories, address different aspects of criminology (biological, cognitive and social), and exploited different modelling approaches and environments. Nevertheless, they all have in common that they took criminological literature as a basis, and formalised this literature in order to create computational models that can provide more insight in the dynamics of the process under investigation.

Moreover, when comparing the three parts of this thesis one can notice that each of them has a slightly different methodological aim, which can be summarised as combining, predicting and analysing. In Part II theories from multiple disciplines (namely biology and psychology) are combined, thereby creating an integrated perspective on different factors underlying violent behaviour. In Part III, the main goal
is to exploit existing literature to develop a model that is able to predict the development of juvenile delinquency, and Part IV mainly attempts to analyse the consequences of the Routine Activity Theory under particular circumstances. We found that each of these methodologies requires some specific preconditions that need to be met. For combining different theories, clearly, at least two theories need to be available, which are described at a sufficient level of detail. Predicting dynamics is only possible when a validated model and sufficient (empirical) data are available. Finally, to analyse the consequences of a theory one needs to have a theory, but no other theory or (empirical) data are needed. For future research, these considerations can be explored in more detail. For example, an interesting challenge is to develop a general framework that prescribes which methodology can be applied in which situation.

Based on the research presented in this thesis we can thus conclude that AI approaches, and in particular modelling and simulation approaches, can be useful in the domain of criminology. Although the research presented is just a first step in a long process, some interesting results have been revealed already. Extending the research with the plans presented above could enhance the opportunities for understanding and fighting crime even further.