Computational Modelling for Law Enforcement Intelligence Analysis

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Abstract. The complexity of criminal behaviour generates growing demand for methods that enable intelligence analyst trainees and professionals to make sense of the criminal system under study. Computational modelling appears to offer methods for investigation of criminal behaviour and assessment of intervention strategies that would otherwise require long, expensive, and often ineffective analysis. In this paper, we explore the potential of computational models in the field of intelligence analysis. On the one hand, the discussion involves possibilities, challenges, and risks of applying computational modelling in the law enforcement domain, on the other hand the possible impact on law enforcement agencies strategic positioning, internal processes and the specific work environment. We propose a methodological approach that is based on modelling the interaction of criminal network dynamics, the civil society in the law enforcement area, and intervention strategic analysis embodied in a virtual analyst agent.

Keywords: Computational Modelling, Multi-Agent Simulation, Intelligence Analysis, Criminal Network Analysis, Law Enforcement

1 Introduction

The phenomenon of crime culminates a large number of factors that span the intrinsic behaviour of the criminal, environmental influences, the availability and behaviour of victims, and law enforcement impact. This makes a crime system complex and difficult to anticipate using standard methodology [1].

However, the occurrence of crime is not random and both research and practitioners attempt to identify properties and patterns exhibited by criminal behaviour. In their task to reduce crime numbers, law enforcement relies on an understanding of these properties in order identify opportunities to intervene effectively and efficiently given restricted resources.

The strategic dismantling and destabilisation of criminal behaviour has potential to reduce the harm of crime more effectively, however, there is a profound
need for an approach that would allow analysts to systematically reason about the dynamics of criminal behaviour in a law enforcement area and evaluate potential opportunities to disrupt those dynamics. Computational modelling has been applied in widely diverse tasks and specifically agent-based models promise to provide valuable insights in criminal patterns by modelling criminal behaviour dynamics on the micro level [2].

In this paper, we are interested in discovering and applying the ideas of simulation to augmenting traditional intelligence analyst training and work practice. The aim of this paper is to explore if and to which extent computational modelling, and agent-based modelling in specific, can help law enforcement in making better informed decisions on possible intervention strategies. More specifically, we want to investigate in which way simulation can capture domain specific as well as the intelligence analysts intrinsic approaches to rigorous strategic discovery of intervention opportunities, and how these interventions can be tested for their effectiveness using simulation techniques. How and to what extent there is space for such supplement or replacement is a difficult but potentially rewarding area of study.

In Section 2, we begin this article by introducing intelligence-led policing and law enforcement approaches to identifying intervention opportunities under a typical intelligence model. Section 3 then provides a brief introduction to agent-based modelling. In the following Section 4, we outline challenges for computational models in the intelligence analysis arena, and provide in Section 5 a discussion on these challenges as well as possible ways forward. In Section 6 we then give a short outline of our research approach. Section 7 addresses risks factors that we associate with our approach and computational modelling in the domain in general. We conclude with Section 8.

2 Strategic analysis of intervention opportunities

Interventions are crucial in our society in order to guarantee the functioning and operation of the system that provides us with resources which are only accessible in a collective and collaborative environment [3]. Attempts to control anti-social behaviour or reduce crime are one of the means of intervention in society [4].

An important trend in contemporary policing is the shift from traditional reaction and response to criminal activity towards proactive approaches of managing risks and targets. The result is a much closer integration of intelligence analysis into the policing business model that allows police to better understand problems and evaluate possible interventions to control crime [5]. Over the last decade, few policing methodologies have not emphasised the need for intelligence to provide necessary contextual information. There is also a strong argument for intelligence not only having to support decisions, but being an explicit part of the decision making process itself, integrated in a cycle of effects from intelligence analysis, towards decision making, and the criminal system on which interventions are applied and which feeds new information into the intelligence cycle [6]. Such approach emphasises the importance to include in the intelligence analy-
sis a direct link to an impact on the criminal environment rather than seeing intelligence analysis as simple dissemination of intelligence products.

In this tradition, we define the aim of intelligence analysis to identify weaknesses in criminal structures in form of opportunities which could be exploited by law enforcement. Assessment at Force and local policing levels aims at monitoring the implementation of strategies and the successful adaptation to change. This comprises in line with Force strategic priorities the identification of short and medium term risks and harm for the community, the identification of opportunities to improve its well-being, and the evaluation of intervention strategies. Fig. 1 illustrates a typical cyclic process that is used by law enforcement agencies that implement the widely used National Intelligence Model [7] in order to tackle the challenges posed by the rapid changes in law enforcements’ operating context.

![Fig. 1. Cyclic approach to intelligence-led policing](image)

The initial phase involves the identification of the greatest threats to the community in terms of volume, trends, harm, and vulnerability. Several criteria are available to define a problem, for example offences having significant impact on a Region or a small number with still significant harm to victims. Employing the set of given priorities, a review of current and available intervention strategies then identify the greatest opportunities for the Force to reduce harm to the community. Often, these interventions will be tailored based on a review of the problem triangle, whereas a general rule is to eliminate at least one part of the problem, i.e. offender, victim, or location. This step also needs to take into account the allocation of appropriate operational activity given the available resources.
Finally, impact of interventions is evaluated and taken into account in the next cycle. In defining appropriate measures, law enforcement traditionally relies on measures such as crime rates, arrests and citations, clearances, and response times to define their priorities and evaluate police performance. Since then, focus in policing has included community policing, but traditional measures remain an important facet in analysis and benchmarking of policing activities. Due to the broadening scope of policing, their isolated use is, however, perceived inadequate as they ignore large parts of police activities that have an impact on quality of life in the community [8]. Not surprisingly, a plethora of performance measures such as response time, citizen satisfaction, or fear of crime have been developed (see [9] for an overview) that intend to address the need for broadening the benchmarking approach.

Due to limited resources, law enforcement agencies aim to ensure that sufficient quality intelligence is available on the anticipated effects of interventions. For example, imprisoning one offender may not have an effect on the actual crime rate while the same intervention on another offender may significantly impact the number of crimes saved. Understanding the underlying processes and dynamics in criminal behaviour as well as the effects implied by the intervention itself is a necessity if one wants to bring about effective change. As a result, the improved intelligence will ultimately lead to targeted strategies and resources being allocated more effectively.

Allocated behavioural change mediated through an intervention aims to interact with the existing system, hopefully to manage the intervention most intelligently. With increasing complexity, one must take into account complicated processes and various situated consequences in terms of the resulting effects, side-effects and human affects of interventionist strategies [10]. In the ongoing pursuit to reduce crime, law enforcement can resort to several classes of intervention strategies:

1. Offender management in line with priorities;
2. Crime and disorder hot spot management;
3. Crime prevention strategies, e.g. closed-circuit television (CCTV), lighting schemes, community action initiatives.

The search for appropriate interventions can prove an elaborate task. Firstly, because in many cases our understanding of the target system can be too ambiguous, uncertain, imprecise, or just too complicated to draw simple causal relations between observed behaviour and suitable intervention [11]. Secondly, with respect to the number of available interventions in most of the domains, a thorough investigation of each candidate intervention may well be an infinite task [12, 13]. Finally, it would be beneficial to possess the predictive ability to anticipate effects and side-effects of the intervention on the target system. A review of current literature, however, reveals only little research on the evaluation of law enforcement interventions.

The majority can be found in the area of spatial simulations, specifically situational crime prevention incorporating into the model spatio-/temporal dynamics of criminal behaviour and hot spot evolution [1,2,14]. Other studies focus
on the social or psychological aspects of criminal behaviour as part of its social structures. Several studies such as [15] model the learning of criminal behaviour for adolescence-limited delinquency through a social learning process. Another approach that is increasingly popular both in research and law enforcement is to analyse criminal behaviour from the perspective of criminal networks [16]. Criminal network analysis has proven an effective way to describe criminal structures from one of the most important points of view: that most crime is a group phenomenon. Social network analysis techniques have been applied in order to track groups of street gangs, organised crime and other types of criminal organisations and is used by law enforcement to determine current strategic and tactical priorities, and appropriate intervention strategies on a daily basis. Some effort has been dedicated to identifying vulnerabilities in criminal networks and dismantling them. The majority use static measures from social network analysis to analyse structural features of criminal networks [17]. Some employ simulation techniques to test the structural robustness of networks as a result of sequential removal of nodes [18, 19]. Most approaches, however, ignore the mechanisms of social and cognitive processes through which, over time, people and their assets co-evolve [20]. Due to those dynamics, for each network, a different strategic approach regarding the type, intensity or time of intervention may have to be taken in order to achieve maximum impact [21].

Despite the possible benefits for law enforcement, little attention has been paid to supporting law enforcement to systematically explore available intervention strategies and the factors that influence their effectiveness in the context of criminal behaviour dynamics. At the same time, the criminal network perspective seems to be an essential part in structuring and understanding criminal behaviour in order to develop effective intervention strategies. To better understand processes and drivers behind certain behaviour in the target system, side-effects and affects of the intervention, as well as expected performance and latency effects, agent-based models seem suitable for theory building and testing.

3 Agent-based modelling

Computational models, specifically agent-based models, can be found in a wide range of application areas (see [22] for an overview). Individuals in a system are modelled as agents who make decisions, react to changes, or interact with other agents based on certain criteria. Depending on the specification, agents are also able to learn and adapt. Over a specific period, behaviour of a group or organisation emerges from the actions of agents.

Agent-based models are characterised by a variety of attributes. This list is not complete, but provides us with some of the more obvious and notable attributes:

- Focus on the process and intermediate solutions (non-equilibrium);
- Utilisation of a mix of simulated and real data as opposed to being completely algorithmic;
• Ability to handle more complexity such as a greater number of interacting parts and higher levels of non-linearity in relationships.
• Theory testing in a safe, constructed environment that mimics a real world scenario.
• Analysis of the dynamics on the micro level while producing the important emerging patterns on the macro-level.
• Model parameters may be manipulated in a way that would be too expensive or even impossible in reality, for economic, ethical and logistic reasons (e.g. data belonging to individuals that might be subject to data protection law)
• Ideal for measuring the outcomes of changes in the behaviour of individuals

Some of these attributes are true for all computational models and agent-based models may not necessarily be the best choice to investigate a specific problem. Moreover, not all agent-based models are created or implemented with having all of those attributes in mind.

4 Challenges

Unlike many of the fields in which agent-based models have been used, intelligence analysis has some unusual attributes that present unique demands. These may make it particularly challenging to apply modelling techniques to intelligence analysis.

4.1 Accommodating analyst diversity

While analyst tasks involve mining and preparation of raw data for decision makers, the central analytical tasks involve identification of vulnerabilities, threats and opportunities from a breadth of intelligence, knowledge on the internal workings of the intelligence cycle and co-produced intelligence products. Analysts must also hold specialist knowledge on the contexts of crime, demographics, politics, and the community.

Intelligence analysts come from various backgrounds. Some may have come through the police ranks and some may have military experience with respective domain experience, while others are civilians. Individuals’ education spans from science degrees to liberal arts. Analysts are also trained to different levels of expertise. All over Europe, there is a structured hierarchy of training courses, undertaken dependent upon the need or profile held by the individual. However, while training is given to develop the skills needed to use software and existing analytic tools, capabilities of effective reasoning and the use of professional instincts highly depends on the individual.

The same variety as for analyst backgrounds applies to their approaches in investigations [23–25]. One common strategy lays out possible hypotheses and maps respective data to each hypothesis to identify whether the data supports, counter-indicates, or is irrelevant. In other situations, it might be beneficial to skip the creation of any preconceptions and let the data prove and suggest itself
in order to avoid fitting of data to favoured hypotheses. Yet another approach entails a strategy of investigating the four specific areas of access, intent, motivation, and capability from the perspective of the offender and explores what the information presents regarding those categories.

Due to the variety in their background, experience and training, analysts all bring their own expectations, work styles, and doctrines. Designing an appropriate human computer interface will be a complex and inherently conflicted endeavor. This also applies to developing computational models that need to reflect the variety in the analytical approaches.

4.2 Intelligence Data

Criminals do not want to be identified and it is in their own interest to avoid contact with law enforcement agencies. Therefore membership in a particular network and links between people may be missing from data. Bayesian approaches have, for example, been proposed to predict covert network structures from the existing network [26].

Another influential factor is the general data quality issue in law enforcement which requires domain knowledge in order to create a clear picture of what data is available and how to access it. Data held within law enforcement can contain incorrect or dated identity information due to either intentional deception by criminal when brought into custody or human error during the manual data entry process. Thus, intelligence data can be frequently vague and the validity of data may be uncertain. Moreover, we cannot expect that data is always easily identifiable through global unique identifiers (e.g., a serial number). Some systems would record a person as Johnny D. Smith, other as John Daniel Smith, each with a different nominal identifier. Additional information such as birth dates and addresses may be inconsistent. Thus, the question is how many unique John Daniel Smiths there are in the system. Finally, it is a challenge for law enforcement analysts to decide, in the face of ever more data stored in disparate datasets, which data is relevant and useful for the current problem.

Consequently, conclusions produced by analysts that are based on law enforcement data will carry uncertainty. This makes the use of computational models ideal, as their applicability in contexts of uncertainty has been proven.

4.3 Crime

Throughout history, the research of criminology has provided several fundamental theories, some of them listed below:

- Social learning theory explains deviancy by combining variables which encourage delinquency (e.g., the social pressure from delinquent peers) with variables that discourage delinquency (e.g., reaction by parents on their childs delinquency or school initiatives).
- Differential association theory proposes that criminal behaviour is learned from the interaction with others.
- Social control theory proposes that exploiting the process of socialisation and social learning builds self-control and reduces the inclination to indulge in behaviour recognised as antisocial.
- Rational choice theory adopts a utilitarian belief that man is a reasoning actor who weighs means and ends, costs and benefits, and makes a rational choice. Thus, one, although much debated, way for society to prevent crime is by the threat of punishment.

A theory that intends to culminate several of the individual, environmental and social factors is Routine Activity Theory [27]. Stemming from environmental criminology, it proposes that crime opportunity requires elements to converge in time and place including (1) a motivated offender (2) suitable target or victim (3) lack of a capable guardian. It becomes clear that, in order to model and explore the dynamics of crime, a thorough understanding of a crime system is required. An occurrence of crime is the result of a culmination of a very large number of factors that include the motivations and behaviour of the criminal, the influence of the physical surroundings and the behaviour of the victim and others.

4.4 Criminal networks

It is well-established that the source of crime is located in the intimate social networks of individuals. Indeed, delinquents often have friends who have themselves committed several offences, and social ties among offenders are seen as a means whereby individuals exert an influence over one another to commit crimes. In fact, not only co-offenders but also the structure of social networks matters in explaining individuals own delinquent behaviour.

While most research is based on the analysis of static network representation, interest is now turning towards the dynamic and flexible nature of criminal networks as an indicator for both strength and vulnerability in their structure [28]. This is believed to have its origin in the great inner pressures (e.g. through trust or the lack of it) and environmental influences that drives the network towards finding a balance between efficiency in the collaboration of its parts and the security needed to evade detection and disruption for example from and policing interventions. Thus, criminal networks are not static, hierarchical objects, but more likely represent organic structures that are evolving over time due to social dynamic processes. As a result, the removal of one node may not have the same effect as the removal of another. Instead, unwanted and unexpected effects could be observed. Scenarios are common in which a leader is replaced by another offender, in which the removal attracts new network participants, or that a network might even work more effectively. In this case, a model must be able to capture the dynamics that lead to one offender gaining more power, and when and in which way new participants attach to the network.

At last, the dynamics in criminal networks are also a direct reaction to interventions applied by law enforcement. Reference [29] suggests that law enforcement intervention itself is an integral part in identifying weaknesses in the
criminal network structure as the measurement of dynamics implies that some action has been undertaken to change the robust criminal structure. This goes in accordance with Complex Adaptive System (CAS) theory, whereas an intervention should be seen as part of the environment itself rather than an exogenous constant. Thus, intervention testing cannot be seen as a static set of action but a strategic set of strategies of how to change actions in response to an environment.

This all suggests that a mix of both structural properties and social dynamics should be taken into account to better understand criminal behaviour and access the effectiveness of interventions strategies. Strategic alignment of law enforcement agencies heavily depends on understanding those dynamics, for example their evolution, the context of an affected community, as well as the effects as a result of policing activity [30]. Topological measures can be deceiving if used in isolation, as the conception of what a key player is very often does not only rely on the network structure but additional individual offender attributes and law enforcement priorities. Structural measures alone are not able to provide many of the individual differences in offender behaviour which can be crucial in identifying critical offenders and intervening strategically. Specifically, one should also take into account individual weights and priorities that stem from law enforcement internal intelligence cycle.

Finally, most current approaches to criminal network analysis treat networks as a single isolated instance [31], despite the fact that law enforcement needs to manage a number of simultaneously active networks operating in a law enforcement area. Criminal networks are tightly integrated into the fabric of the society they operate in, both in their evolution and the harm that offenders evoke, which makes the boundaries of such networks difficult to determine [32].

5 Discussion

Criminal behaviour has been shown to exhibit dynamics originating from the internal processes between criminals and external pressure, dynamics which we can observe for example through criminal structures that are continuously evolving. Taking some of them into account has already shown to produce very different results compared to static approaches. Depending on factors such as strength and timing of interventions, criminal structures and criminal networks specifically have been shown to be very resilient to certain types of intervention, with some strategies even increasing their resilience [28,33]. This reflects their flexibility and capability for rapid adaptation in a volatile and adverse environment [20]. Ignoring dynamics may negatively impact the effectiveness of intervention strategies when put into operation [21].

This suggests that no quick fix will be available in the attempt to dismantle and destabilise them. When treating criminal structures dynamically, for example to anticipate behavioural reactions in response to an intervention, changes the focus of analysis from static intelligence analysis to a much more open-ended, contextualised, proactive problem solving process which strategies to use, identification of dynamic patterns, comparisons of different outcomes, and so on.
In the last decades, law enforcement has been equipped with modern technology such as data warehousing which makes data more readily available. Tools for the automated extraction and analysis of data have been shown to support analysts in their daily tasks (e.g. criminal network analysis [34]). This development has, however, not necessarily led to improved policing efforts, and a gap between intelligence analysis and operational policing efforts can be identified [35]. Explanations for this gap span from a lack of intelligence-led organisational culture, lack of understanding of each others work practices and culture, or generally different approaches to problem-solving [36]. Reference [37] observed these problems impacting sufficient information sharing with ultimately affecting strategic planning. Similarly, [38] identified the under-utilisation of intelligence-led policing benefits as the most pressuring issue.

The evolution from reactive policing towards such a proactive approach inherently has brought about uncertainty for decision makers in strategic planning and priority setting [39]. The question remains to what extent one can plan and anticipate future criminal behaviour. Reference [40] argue that, while actual prediction of criminal behaviour is currently impossible, decision makers can align strategic plans and priority settings through anticipation. Such approach would allow intelligence products to be recognised as part of a strategy to reduce uncertainty that arises through environmental complexity of the crime phenomenon [41]. In this context, current intelligence approaches have been criticised for their lack of imagination, poor contextual understanding and the over use of dated, historically-based pattern analysis [42]. Moreover, a number of researchers have indicated a shortfall in the ability of intelligence professionals to grasp a full picture of the operating context and its complexities [43].

Consider a large set of criminal networks that are currently active in a law enforcement area. Those exhibit, through both the amount of available information as well as related theories around crime and their dynamics, such complexity that it is not at all obvious where to begin looking and how to approach intervention tests. Do I look at the edges where things are simpler, in the central places where the most connections are, or should we start the search from something that we already know? Which interventions are available and the most suitable given a specific context?

Reference [44] believe that social network analysis still provides the way to bridging the gap between intelligence and operational policing and provide better intelligence products to decision makers. Their reasoning is to position the intelligence analyst between the data perspective and the activity on the street by using tools that allow to see the data as it functions in theatre. Here, computational modelling could prove to be a unique opportunity to both further the understanding of the processes and dynamics of an underlying system, i.e. criminal and law enforcement activity on the street, and examine the assumptions and knowledge on which intelligence products are based. One effective way to view testing of intervention strategies and tactics through computational modelling is as what-if simulations. The analyst may explore how known facts may be affected. For example:
What if we apply this type of crime hardening techniques on a block of houses?
What if we isolate this specific offender tomorrow?
What information could we retrieve if we infiltrated this network for the next two weeks?

The ability of testing multiple sequential or parallel intervention opportunities, examine their effects in a secure and safe environment, and decide which to pursue further, is the ideal scenario for simulation models. Analyst would benefit from such a multi-dimensional, non-linear and complex view of criminal networks in their community context, created from otherwise static and uni-dimensional data. To that end, computational modelling combines the intelligence analysis with computer supported social science approaches for the analysis of criminal behaviour and issues most vital to the law enforcement domain and the respective community/society. Indeed, one of the most attractive elements of computational models is the ability to experiment under different crime theories before the implementation of crime reduction policies.

To accommodate for the variety of analysts and analytical approaches implies that analysts are enabled through a suitable UI to adapt models based on their personal understanding (framing) of a criminal network in its environment [45]. At the same time, automated agent-based simulations must cover the available intervention space, i.e. include different theories and possibly model compositions, while providing transparent results and their provenance. Evaluation of relative tendencies and patterns of behaviour in such environment can help the diverse group of analysts to identify appropriate and unsuitable law enforcement interventions given a specific framing of context and the system under study. Even possible solutions that so far have not been considered through other methodology might be identified. Similar to games, this might mitigate biases, for example confirmation bias, by supporting an opposite conclusion or belief.

Over time and combined with other intelligence, ideally, analysts should be able to provide generalisations and recommendations, i.e. continuously grasp a full picture of current criminal activity in the system under study as well as intervention opportunities by: 1) suggesting general factors that make groups adaptive or maladaptive; 2) being able to make general statements on the efficacy and effectiveness of different strategies. Taking such an approach will help to shift the analytical focus from reactively targeting concrete offenders to detecting opportunities and weaknesses in structural processes, which may not always be visible to police organisations, but pose significant security risks if left unattended.

Intelligence analysts can be expected to benefit from simulations also in other ways: When integrated with the data collection and preparation process [34,35], they can further foster the ability to collect and structure knowledge. In essence, to think like an analyst is a natural outcome of some strategic modelling. We can expect such integrated models to better suit the needs of analysts. Abreast of the shear amount of data, it is certainly useful for the analyst to have a
better understanding of the situation in which raw data is available, and, with little costs, simulation may be able to provide context that they could use to gain a greater understanding of the information. Thinking ahead, analysts could also, through daily practice and the growing experience in the use of a what-if simulation system provide valuable input into the improvement of intelligence analysis and the tools themselves.

While environmental simulations have made some progress over the recent years, the study and integration of suitable network dynamics is still in its infancy, and practical examples of law enforcement models outside the research arena are rare, due to the challenges that have been outlined above, but also the risks that are attach to modelling (see also Section 7). Despite the outlined challenges, intelligence analysis has large communalities with other areas in which computational modelling has been applied. Some issues have, for example, been addressed in economics and military game-theory [46], and examples can be found in which network structures have been explicitly used to model behaviour of agents in their context [47]. However, analysis and modelling of dynamics in other contexts such as terrorist network analysis has not sufficiently been addressed and similar issues seem to arise for all types of criminal structures, for example in the focus of analysts on simplistic topological network measures [17]. We might also question if the organisational paradigm applied in the analysis of some crime types applies to structures such as co-offending networks. Additionally, law enforcement on a daily basis seldomly have the resources to collect information on metadata of offenders and their relations that is often available in the long term study of terrorism. At least for well-known prolific offenders, the question remains if this is a pure data collection and sharing problem in that intelligence such as offender profiles remains clustered amongst several investigations or tacit amongst a small group of insiders in the law enforcement unit.

We believe that computational modelling could prove a valuable addition to the intelligence cycle. New simulation tools as a complementary source for exploring the intervention space and as a consistent, continuous, and defensible approach could support law enforcement in creating better intelligence products on effective ways for disrupting criminal activity and reducing the impact of criminal activity on the community. A solution would be exploratory and modelling different facets of criminal behaviour remains a challenging task, and it is impossible for a single project to take into account all critical factors. However, models used to simulate the dynamics of criminal behaviour can serve as an effective tool for exploring and reasoning about criminal structures.

When thinking about applications of simulation in law enforcement, one should be careful, though, in proposing just yet another technological solution. As argued by [48], problems in the intelligence cycle will not be solved by technology alone, but in complementing the analyst in daily analysis tasks. The National Intelligence Model or new developments following the Organised Crime Strategy [49], for example, can be seen as a step in the direction of an integrated
intelligence-led law enforcement culture, and technology should aim to integrate with existing intelligence cycles.

6 Proposed research test bed

We propose a computational methodology for simulating criminal networks in the context of physical environment, socioeconomic influences and evaluating alternative law enforcement interventions. We aim to provide an agent-based network model for the co-evolution of criminal networks in a law enforcement area and a virtual intervention analyst. Figure 2 presents the simplified modelling approach. The criminal network represents autonomous agents that negotiate opportunities for crime and react to the pressures that are applied on the network. Based on an environmental crime model, the environment presents the context of manifested crime in the wider civil society and opportunities to commit crime.

![Fig. 2. Proposed modelling approach, adapted from [46]](image)

The complex dynamics involved in crime systems has been widely recognised, yet, many interventions often fall short. Our solution aims to allow interventions through different framings that analysts may have about criminal systems and their context in which these networks are active. To allow discovery of new patterns and mitigate biases and the key hole problem, we take a rigorous and systematic approach to intervention testing as outlined in Figure 3.

The virtual analyst holds plans and law enforcement priorities representing an instance of analysts tacit knowledge and an intrinsic approach to hypothesis testing while testing the intervention space. The analyst is thereby governed by a domain specific intelligence framework rather than specific test inputs. The analyst is further equipped with a set of intervention strategies which are dynamically applied as appropriate measures of their temporality and provencance.
Intervention strategies comprise a mix of crime hardening and criminal network destabilisation tactics that aim at the network or the environmental level. The evaluation of intervention effectiveness will be based on a mixture of network performance and law enforcement impact measures regarding the civil society. Important is how the factors of time, space and strength of an intervention impacts the evolution of criminal behaviour in the law enforcement area and how different criminal structures respond to different interventions or a combination of them.

We believe that the proposed research can make a considerable contribution in advancing traditional analyst training and work practices as well as computational support systems by offering a consistent, rigorous and defensible approach to intelligence support of decision making.

7 Risk factors

There are several additional risk factors that may hinder the use of agent-based models for our purpose, in whole or in part, that have not been fully discussed in the prior sections, but should be taken into consideration in a potential modelling project.

7.1 Inaccuracy

Analysts need to make an assessment about potential futures taking into account several sources with varying degrees of uncertainty. An understanding must be created though that, while computational models reflect social science research and knowledge on criminal behaviour, there is a risk is that simulation outcomes may not reflect reality as much as anticipated, but in such a subtle way that
analysts do not realise the mismatch and nonetheless go on to create intelligence products that have a higher confidence level than they deserve. Furthermore, computational models can only give estimates of possible outcomes in terms of expected behaviour or effectiveness of interventions, whereas actual assessment based on evidence will need to wait until events have occurred [36].

7.2 Acceptance

Traditionally, analysts do not receive a large amount of training in the use of IT tools and the methodologies used "under-the-hood". Using simulations to assist in the rigorous assessment of intervention strategies may sound superficial and might not receive the necessary support by domain experts. Nevertheless, the research in computational models has been documented there possible benefits [22] and there is widespread support from decision makers in the improvement of intelligence gathering and evaluation to improve Policing effectiveness and efficiency. While no guarantee can be given that all the promises behind computational models will ever become true, specifically their use as a complementary tool is very likely to raise the likelihood of positive results.

Another aspect is that the willingness to work with new methodologies and technologies may decrease with age. This may put in question the acceptance of a new methodology by policy makers who are generally older as well as by the older analyst generation. When combined with the background of exactly this generation, simulations offer a greater chance to improve intelligence products, whereas their rejection may hinder the success of this new methodology in the long term.

Finally, automated black-box systems are unacceptable, as analysts must at all times be aware of the provenance of intelligence to argue for or against hypotheses and in order to turn intelligence into evidence.

7.3 Public support

In the same way as analysts rely on full transparency and provenance, there exists the latent risk of reliance on computational methods, or the public perception that this is the case, which can easily outweigh economical and operational benefit. This is especially critical when large amounts of (sensitive) data is passed to a computer for automatic analysis with the impression that offenders, or even worse suspects are automatically categorised and passed on into the judicial system.

7.4 Tacit knowledge

Analysts, also due to their above mentioned disparate backgrounds, possess tacit knowledge that they might employ in pursuing a certain type of hypothesis test or intervention strategy. It must be clear that, with computational models, the analyst has the ability to use tacit knowledge in order to conduct both exploratory studies and rigorous hypothesis tests on a large intervention space,
and such approach may even provide the analyst with previously unconsidered strategies. Rather than looking at automating analysts’ thought processes, simulation tools should be seen complementary inside an already well-organised, professional, organisational setting, existing processes and work tasks. Automation would not only be unrealistic, but also increase transparency issues which in turn decrease chances for acceptance.

7.5 Hype and overpromising

A final concern is that of hype which can lead to overpromising on what computational models can deliver. Computational models are used in a variety of application areas, however, their history is still very young and experience mostly limited. It is, yet, tempting to make substantial claims, for example for marketing purposes, which exceed the actual power of the employed models in current practices. Such claims should be tempered so that early failures do not lead to early abandonment that is premature. The question that should be answered is: Does the development and deployment of computational models result in greater effectiveness and efficiency at lower costs when compared with the usual practice in intelligence analysis? The lack of suitable studies on this topic leaves a void and makes this question impossible to answer at the moment.

8 Conclusion

Despite recent advances, intelligence-led policing requires decisions on strategic planning and priority setting in an environment characterised by growing uncertainty. Literature seems to suggest a better integration and alignment of intelligence into the intelligence cycle in order to improve support for decision makers. Currently, a clear gap can be identified between intelligence analysis and operational policing, which might be caused by a lack of communication and understanding of each others work places and the opportunistic use of technology which is seldom immediately applicable inside law enforcement agencies and the deployed intelligence models. Other indications point to intelligence professionals having issues due to the outlined complexities of criminal behaviour in grasping a full picture of the operating context and applying a structured process in the identification of interventions.

We have argued that computational modelling, and agent-based simulation in specific, may support intelligence professionals and decision makers to anticipate relative development of criminal behaviour and reduce surprise. To date, computational modelling and simulation techniques have seen a limited take up by law enforcement for the purpose of intelligence analysis. Yet, there seems potential for this technology to supplement current analyst training or analysis tasks when integrated into the intelligence cycle. Thus, it is worth to further explore and experiment with computational models in the law enforcement domain.

We have outlined our current research goals and see opportunities in integrating different approaches in computationally evaluating law enforcement
interventions by taking into account domain specific intervention strategies and performance measurements, and combining them with the analysis of criminal structure dynamics such those inside criminal networks and the effects of all onto the community. We have also pointed to the challenges and risks that need to be taken into account when attempting to model interventions on criminal behaviour as part of the intelligence analysis.

References


