Case Analysis of Criminal Behaviour

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Abstract. In this paper, it is shown how behavioural properties can be specified for three types of violent criminals. Moreover, it is shown how empirical material in the form of informal descriptions of traces of crime-related events can be formalised. Furthermore, it is shown how these formalised traces and behavioural properties can be used in automated analysis, for example in order to determine which type of criminal can have committed such a crime. Moreover, an underlying dynamical model is presented that shows causal mechanisms behind each of the behaviours, and their dependencies on the characteristics of the type of criminal and inputs in terms of stimuli from the environment.

1 Introduction

Criminology is a multi-disciplinary area focusing on the analysis of criminal behaviour; e.g., [1, 9, 10, 14, 20, 22, 23]. Some contributions to the literature addressing formalisation and computational modelling of criminal behaviour are found in [2, 8, 17, 18]. This paper first presents a modelling and analysis approach for certain types of violent criminal behaviour against data available from crime cases. The paper addresses the question: given information about a committed crime, and a number of suspects, what can be said about the person who committed the crime? It is shown how also automated tools can be used to address this type of question. In particular, it is shown how dynamic properties can be specified that characterise the behaviour of certain types of criminals and how they can be automatically checked on formalisations of partially given traces of crime-related events.

Dynamic properties that characterise the behaviour of a criminal can be specified from an external or from an internal perspective. From an external perspective more complex temporal relationships between inputs and outputs over time have been expressed using the Temporal Trace Language TTL [6]. Dynamic properties from an internal perspective involve direct temporal or causal relationships between internal state properties and have been specified using the language LEADSTO [7]. This is an executable language that also can be used for simulation: given some input in terms of characteristics of a particular type of criminal and stimuli from the environment, the behaviour of this type of criminal in that particular environment can be simulated.

In Section 2 a brief overview of the types of criminals addressed is given. Section 3 addresses formalisation of partially given traces of crime-related events. Section 4 discusses the behavioural properties from an external perspective, and formal analysis

of these properties against formalised cases. Section 5 discusses dynamic properties formalising the mechanisms underlying the criminal behaviours as considered from an internal perspective. In Section 6 one of the generated simulation traces is shown. Section 7 is a discussion.

2 Three Types of Criminals

The case study made in this paper focuses on three types of violent offenders: the violent psychopath, the offender with an antisocial personality disorder (APD), and the offender who suffers from an intermittent explosive disorder (IED). Below, these types of criminals are briefly introduced and commonalities and differences between them are discussed, based on [11, 19, 20]:

- Violent psychopaths do not have feelings like the rest of us. They lack the normal mechanisms of anxiety arousal, which ring alarm bells of fear in most people. Their kind of violence is similar to predatory aggression, which is accompanied by minimal sympathetic arousal, and is purposeful and without emotion. Moreover, they like to exert power and have unrestricted dominance over others, ignoring their needs and justifying the use of whatever they feel compelling to achieve their goals. They do not have the slightest sense of regret.
- Persons with APD have characteristics that are similar to the psychopath. However, they may experience some emotions towards other persons, but these emotions are mainly negative: they are very hostile and intolerant.
- Persons with IED, in contrast, appear to function normally in their daily life. However, during some short periods (referred to as *episodes* from now on), their brain generates some form of miniature epileptic fit. Such episodes can be triggered by minor negative experiences. As a result, some very aggressive impulses are released and expressed in serious assault or destruction of property. After these episodes, IED persons have no recollection of their actions and show feelings of remorse.

Table 1. Overview of characteristics for the three types of violent criminals

	Anxiety threshold	**Excitement threshold**	**Theory of mind**	**Positive emotional attitude to others**	**Negative emotional attitude to others**	**Aggressive-ness**	**Impulsive-ness**	**Sensitive to alcohol**
Violent Psychopath	high	high	high	low	low	high	high	yes
Antisocial Personality Disorder	medium /high	high	low	low	medium	high	high	yes
Intermittent Explosive Disorder	normally: medium in episode: high	normally: medium in episode: high	normally: medium in episode: low	normally: medium in episode: low	normally: medium in episode: high	normally: medium in episode: high	normally: medium in episode: high	yes

These three types of criminals can be distinguished by taking a number of aspects into account (see also Table 1 for an overview); these are also the aspects incorporated in the model from an internal perspective.

Firstly, the *Anxiety Threshold* is a threshold that needs to be passed by certain stimuli, in order to make a person anxious. Thus, when a person's anxiety threshold is high, it is very difficult for this person to become anxious (and as a result, (s)he hardly knows any fear). This is the case for the violent psychopath and the person with APD: in these persons, a notion of fear is almost completely lacking. In contrast, persons with IED have a medium anxiety threshold. Nevertheless, under some special circumstances (i.e., during episodes) the anxiety threshold of a person with IED suddenly becomes much higher. Moreover, the *Excitement Threshold* needs to be passed by certain stimuli, in order to make a person excited. Thus, when a person's excitement threshold is high, it is very difficult for this person to become excited (and as a result, (s)he is often bored). This is the case for the violent psychopath and for persons with APD. Persons with IED have a medium excitement threshold, but under certain circumstances (during episodes) their excitement threshold becomes high, and they get bored very easily, which makes that they generate the desire to perform certain actions that provide strong stimuli (which are often criminal actions).

Theory of mind e.g., [3, 12, 15] refers to the understanding that others (also) have minds, which can be described by separate mental concepts, such as the other persons' own beliefs, desires, and intentions, and how they play a role in their behaviour. The violent psychopath has a theory of mind that is specialised in aspects that can contribute to his own goals, for example, to manipulate the other person. A person with APD has a less developed theory of mind. Persons who are diagnosed with IED normally have a medium theory of mind, but when they have an aggressive episode, their theory of mind decreases. *Emotional attitudes towards others* express the extent to which a person may have positive or negative feelings with respect to other persons' wellbeing. For the violent psychopath, both are low: these persons hardly show any emotion concerning other persons. For the criminal with APD, the situation is slightly different. Like the violent psychopaths, these persons do not have much positive feelings towards others, but they may have some negative feeling towards others. Finally, criminals with IED usually have a normal (medium) positive and negative emotional attitude towards others, but during the episodes of discontrol, all their positive feelings disappear, and substantial negative feelings arise.

Since this paper focuses on violent criminals, by definition all considered types of criminals are *aggressive*. However, the criminals with IED only become highly aggressive during a short period, whereas the other two types are always aggressive. *Impulsiveness* means that an action was not planned. All types of violent criminals mentioned in this paper are impulsive, but they differ in the type of impulsive action they perform. While the APD offender may lash out in disproportionate overreaction, the psychopath, with his emotional detachment, will impulsively take whatever course of action will supply him with the necessary gratification. Persons with IED normally have a medium impulsiveness, but when they have a seizure they become highly impulsive. For psychopaths and persons with APD, only a small amount of *alcohol or drugs* can become a compulsion and result in violent behaviour. Persons with IED can have episodes triggered by the smallest amount of alcohol.

3 Formalising Crime Cases

In this section, it is shown how partial information related to a crime case can be formalised, in order to characterise the type of person who committed this crime case. Below, two of such cases are shown, in the form of partially given traces (comparable to descriptions of real scenarios as reported by the police).

> ***Case 1*** *Person 1 is walking down the street. Person 2 approaches him and asks for a light for his cigarette. Person 1 answers that he does not have a lighter and continues his walk. After a couple of minutes, person 1 meets person 3 and assaults this person 3. He hits him over 10 times in his face and stomach. For the assault he uses a large stick that he found on the street. During the assault, person 1 constantly calls person 3 names.*

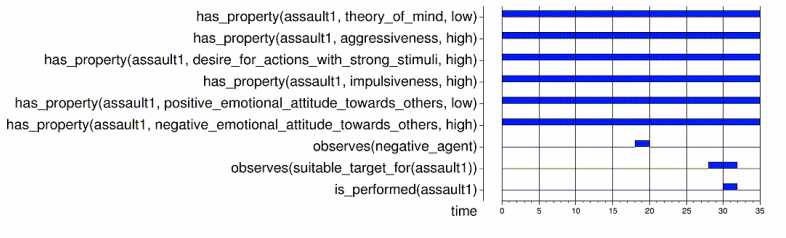

Fig. 1. Example partial trace for Case 1

Using a formal ontology, the dynamics as described by Case 1 can be formalised and visualised as shown in Figure 1. Here, assault1 stands for the assault as described in the story. Moreover, the encounter with person 2 is assumed to be a 'negative experience', which might be sufficient for persons with IED to cause an episode; this is formalised by state property observes(negative_agent). Moreover, observes(suitable_target_for(assault1)) formalises that the agent observes an opportunity for a crime of type assault1. In addition, some atoms of the form has_property(...) are shown. These atoms do not represent events in the scenario, but rather describe some useful common background knowledge (e.g. the fact that hitting someone in the face is a highly aggressive act). Similarly, the dynamics as described by Case 2 below are visualised in Figure 2.

> ***Case 2*** *Person 1 is walking down the street. He is on his way to the ATM because he needs some money for the groceries. However, an old lady is standing in front of the ATM. She is not very fast and it takes her some time to get the money. Person 1 sees a stick lying on the ground, picks it up and hits the old lady. She steps away for the machine because it really hurts. Person 1 walks past her and uses the ATM.*

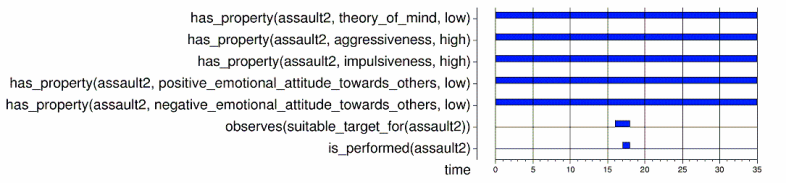

Fig. 2. Example partial trace for Case 2

4 Formalising Criminal Behaviour: External Perspective

In this section it is shown how dynamic properties can be specified to characterise the types of criminals discussed earlier from an external perspective. Moreover, it is discussed how these dynamic properties can be automatically checked against the example traces to find out which type of criminal performed the crime. To analyse traces as discussed in the previous section, the following dynamic properties have been specified in the Temporal Trace Language TTL [6] to characterise, from an external perspective, the different types of violent criminal behaviour considered. To characterise an assault by an IED criminal, two properties are used. The first property checks whether a negative person has been encountered just before the assault (which might have caused an episode); the second property checks whether the assault itself corresponds to some typical characteristics for crimes by persons with IED.

Intermittent Explosive Disorder

a) The assault was performed by a person that first met a negative agent, and later met a passer-by.

IED1(γ:TRACE, t:TIME, a:ACTION) ≡

∃t',t'' [t' < t''< t &
state(γ, t') |= observes(negative_agent) &
state(γ, t'') |= observes(suitable_target_for(a)) &
state(γ, t) |= is_performed(a)]

b) The performed assault is characterised by a high aggressiveness, a high impulsiveness, a low positive emotional attitude towards others, and a high negative emotional attitude towards others.

IED2(γ:TRACE, t:TIME, a:ACTION) ≡

state(γ, t) |= is_performed(a) ∧
has_property(a, aggressiveness, high) ∧ has_property(a, impulsiveness, high) ∧
has_property(a, positive_emotional_attitude_towards_others, low) ∧
has_property(a, positive_emotional_attitude_towards_others, high)

Here state(γ, t) |= X denotes that within the state state(γ, t) at time point t in trace γ state property X holds, with the infix predicate |= within the language denoting the formalised satisfaction relation. Similarly, state(γ, t) |≠ X denotes that X does not hold. See [6] for more details of TTL. Next, the following property characterises an assault by a violent psychopath:

Violent Psychopath

The performed assault is characterised by a high aggressiveness, a high impulsiveness, a low positive emotional attitude towards others, and a low negative emotional attitude towards others.

psychopath(γ:TRACE, t:TIME, a:ACTION) ≡

state(γ, t) |= is_performed(a) ∧
has_property(a, aggressiveness, high) ∧ has_property(a, impulsiveness, high) ∧
has_property(a, positive_emotional_attitude_towards_others, low) ∧
has_property(a, positive_emotional_attitude_towards_others, low)

These dynamic properties have been checked automatically for the cases 1 and 2 described above (see also Figure 1 and 2) using the TTL checker tool [6]. For case 1 it turns out that IED1 and IED2 hold and psychopath does not hold. For case 2 psychopath holds and IED1 and IED2 do not hold. This indicates that the first case the criminal may

be of IED type and in the second case a violent psychopath. Thus, using these checks, it indeed turned out possible to assign certain types of criminals to certain (partial) traces.

5 Formalising Criminal Behaviour: Internal Perspective

In this section, it is shown how criminal behaviour is formalised from an internal perspective. A dynamical system model for the underlying mechanisms that has been developed is briefly described. This model was developed within the LEADSTO environment, see [7]. In LEADSTO, direct temporal dependencies between two state properties in successive states are modelled by *executable dynamic properties*, defined as follows. Let α and β be state properties of the form 'conjunction of ground atoms or negations of ground atoms'. In the LEADSTO language the notation $\alpha \rightarrow\!\!\!\rightarrow_{e, f, g, h} \beta$, means:

if state property α *holds for a certain time interval with duration g,*
then after some delay (between e and f) state property β *will hold*
for a certain time interval of length h.

Here atomic state properties can have a qualitative, logical format, such as an expression desire(d), expressing that desire d occurs, or a quantitative, numerical format such as an expression has_value(x, v) which expresses that variable x has value v. For more details, see [7]. The dynamical system model has been built by composing three submodels:

1. a *BDI-model* to determine actions based on beliefs, desires and intentions
2. a submodel *to determine desires*, used as input by the BDI-model.
3. a submodel *to determine beliefs in an opportunity*, as input for the BDI-model.

The *BDI-model* bases the preparation and performing of actions on motivational states such as beliefs, desires and intentions e.g., [13, 16, 21]. It uses as input desires and beliefs in opportunities, generated by the other two submodels. In this model an action a is performed when the subject has the intention to do this action and it has the belief that the opportunity to do the action is there. Beliefs are created on the basis of stimuli that are sensed or observed. The intention to do a specific type of action a is created if there is a certain desire d, and there is the belief that in the given world state, performing this action will fulfil this desire.

desire(d) $\wedge$ belief(satisfies(a, d)) $\rightarrow\!\!\!\rightarrow$ intention(a)
intention(a) $\wedge$ belief(opportunity_for(a)) $\rightarrow\!\!\!\rightarrow$ to_be_performed(a)

Assuming that beliefs in reason for intentions are internally available, what remains to be generated in this model are the desires and the beliefs in opportunities. Generation of desires often depends on domain-specific knowledge, which also seems to be the case for criminal behaviour. Beliefs in opportunities are based on the Routine Activity Theory by [9].

The *submodel to determine desires* is a rather complex submodel, incorporating various aspects. To model these, both causal and logical relations (as in qualitative modelling) and numerical relations (as in differential equations) have been integrated in one modelling framework. This integration was accomplished, using the LEADSTO language as a modelling language. The variety of aspects that were found

relevant in the literature, such as [4, 11, 19, 20] and are taken into account in this submodel, are: (a) use of a *theory of mind* (e.g., understanding others), (b) desires for *aggressiveness* (e.g., using violence), (c) desires to *act* (no matter which type of action) and (d) to *act safely* (e.g., avoiding risk), (e) desires for *actions with strong stimuli* (e.g., thrill seeking), (f) desires for *impulsiveness* (e.g., unplanned action), and (g) social-emotional *attitudes with respect to others* (e.g., feel pity for someone). Note that these aspects are derived on the basis of (but not exactly equal to) the characteristics as described in Table 1. Different combinations of such elements lead to different types of (composed) desires, for example:

- the desire to perform an exciting planned nonaggressive nonrisky action that harms somebody else (e.g., a pick pocket action in a large crowd)
- the desire to perform a exciting impulsive aggressive risky action that harms somebody else (e.g., killing somebody in a violent manner in front of the police department)

The following LEADSTO property (LP) is used to generate a composed desire out of some of the ingredients mentioned above; here the x1, x2, x3, x4, x5, x6, x7, x8 are qualitative labels (e.g., high, medium, low) or numerical values (integer or real numbers):

LP24 A combination of values for theory of mind, desire for aggressiveness, desire to act, desire to act safely, desire for actions with strong stimuli, desire for impulsiveness, emotional attitude towards others(pos) and emotional attitude towards others(neg) will lead to a specific composed desire, represented as d(x1, x2, x3, x4, x5, x6, x7, x8).

$\forall$x1,x2,x3,x4,x5,x6,x7,x8:SCALE
theory_of_mind(x1) $\wedge$ desire_for_aggressiveness(x2) $\wedge$ desire_to_act(x3) $\wedge$
desire_to_act_safely(x4) $\wedge$ desire_for_actions_with_strong_stimuli(x5) $\wedge$
desire_for_impulsiveness(x6) $\wedge$ emotional_attitude_towards_others(pos,x7) $\wedge$
emotional_attitude_towards_others(neg,x8)
$\twoheadrightarrow$ desire(d(x1, x2, x3, x4, x5, x6, x7, x8))

Due to space limitations, the parts of the submodel to determine each of the ingredients (a) to (g) cannot be described in detail. To give an impression, a rough sketch of part of this submodel is given. Stimuli are labeled with two aspects, indicating the strength with respect to anxiety (risk), and with respect to excitement (thrill), respectively. For both aspects, thresholds represent characteristics of the person considered. The excitement threshold depends on other aspects in the model, such as sensitivity for and use of drugs and alcohol, and basic sensitivity to stimuli. A stimulus with excitement strength below the excitement threshold leads to being bored, and being bored leads to a desire for an action with strong(er) stimuli. Similarly, a stimulus with anxiety strength above the anxiety threshold leads to internal alarm bells, which (depending on another characteristic, the tendency to look for safety) leads to the desire to take into account anxiety.

The *submodel to determine opportunities* is based on two of the three criteria as indicated in the Routine Activity Theory by [9]. The third criterion of the Routine Activity Theory, the presence of a motivated offender, is indicated by the intention in the BDI-model. This way, the presence of the three criteria together leads to the action to perform a criminal act, in accordance with [9]. More specifically, the notion of opportunity is based on the presence of a suitable target, and the absence of social control (guardian). This was specified by the following property in LEADSTO format:

LP34 When a suitable target for a certain action is observed, and no suitable guardian is observed, then a belief is created that there is an opportunity to perform this action.

$\forall$a:ACTION
observes(suitable_target_for(a)) $\wedge$ not observes(suitable_guardian_for(a))
$\twoheadrightarrow$ belief(opportunity(a))

6 Simulated Criminal Behaviour from an Internal Perspective

The model described in the previous section has been used to generate a number of simulation traces for the different types of violent criminals addressed. In Figure 3, an example trace is depicted, which addresses the case of the criminal with IED. In this picture, time is on the horizontal axis; state properties are on the vertical axis. A dark box on top of the line indicates that the property is true during that time period, and a lighter box below the line indicates that the property is false. The lower part of the picture depicts some quantitative information: the thresholds for anxiety and excitement, and the strength of the world stimuli.

The initial state properties that have been set to model the person with IED are as follows (see time point 0): low preparedness to look for safety, low psychological self, high potential aggressiveness, medium potential positive and negative emotional attitude towards others, medium potential anxiety and excitement threshold (both value 5), a low potential sensitivity for stimuli (value 3) and (s)he drinks alcohol and is sensitive for it. Later, at time point 25, (s)he encounters a negative agent and generates an episode, which has some important consequences. Because of the episode, the person with IED generates a desire (at time point 29) that is characterised by the following elements: low theory of mind, high aggressiveness, high desire to act, low desire to act safely, high desire for actions with strong stimuli, high impulsiveness, low positive emotional attitude towards others, high negative emotional attitude towards others. As a result, the criminal generates an intention to perform a specific type of assault (denoted by assault1), and, as soon as the opportunity is there, actually performs the assault. As a result, the stimuli of the world increase, which satisfies the desires of the criminal. Note that, in order to classify these kinds of simulation traces, they can also be verified against the properties shown in Section 4. This has been performed successfully, using the TTL checker.

7 Discussion

For the analysis of criminal behaviour computer support is more than welcome, but almost inexistent. As one of the ways to address this, a formal method to analyse crime cases against known types of criminal behaviour was presented. As a case study, this method has been applied to three types of violent criminals. It was shown how the temporal language TTL [6] can be used to specify dynamic properties that characterise the behaviour of different types of criminals from an external perspective. Moreover, it was shown how crime cases, for example as reported by the police, can be formalised. Furthermore, it was shown how the automated TTL checker

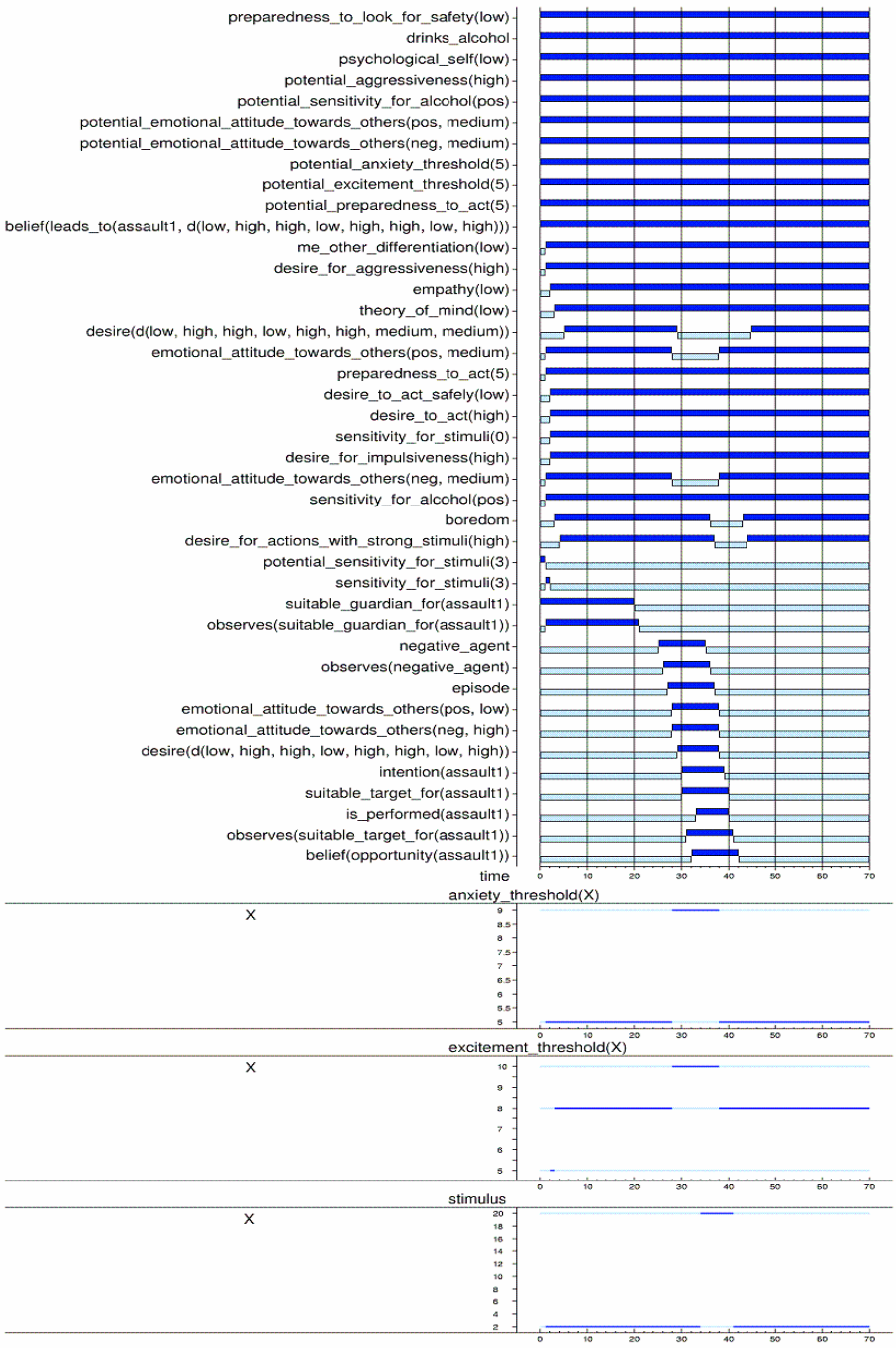

Fig. 3. Example simulation trace for a criminal with IED

can be used to verify the behavioural properties for the formal (partial) traces describing specific crime cases. Note that the properties addressed in this paper and the two cases considered are only meant as an illustration of the approach, and are therefore not too complex. However, the expressivity of TTL allows it to handle more complex properties and cases (involving, e.g., real values, or more time points). Thus, in the future the approach will be applied to such more complex realistic cases and properties as well.

In addition, from an internal perspective a model has been developed that describes the dynamics of the basic mechanisms underlying the criminal behaviour types considered. This executable model can be set with characteristics of any of these three types of criminals and used to simulate behaviour. It has been shown that, if the right characteristics are set, the model indeed shows the behaviour as known for the corresponding type of criminal.

The presented modelling approach integrates qualitative, logical aspects and quantitative, numerical aspects. This integration allows the modeller to exploit techniques from both areas, such as automated methods for logical analysis and possibilities to simulate dynamical systems using numerical methods, also incorporating qualitative elements. The model was validated by comparing it to patterns described in criminological literature.

In comparison to existing work in the formalised analysis of criminal behaviour, an important distinction is that the research presented here focuses on the dynamical aspect of criminal behaviour. Most approaches to the analysis of criminal behaviour that have been proposed are basically static and usually based on profiling. In contrast, the work reported here (1) takes the dynamical systems perspective on behaviour as a point of departure, which considers behaviour as emerging from a dynamic interplay of various components and aspects, and (2) exploits and integrates qualitative and quantitative techniques developed to model such complex dynamical systems. This is shown, for example, in the simulation of a criminal with IED, where personal characteristics may change dramatically due to events that are encountered.

Similar to the current paper, [5] also incorporates formal methods applied to criminal behaviour. However, that paper focuses only on the IED criminal, whilst the current paper addresses three types of violent criminals. Moreover, [5] does not concentrate on crime case analysis but on simulation and evaluation of simulated traces with respect to environmental properties, including some probabilistic properties.

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