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Integrating Rational Choice and Subjective Biological and Psychological Factors in Criminal Behaviour Models

Tibor Bosse (tbosse@few.vu.nl) Charlotte Gerritsen (cg@few.vu.nl) Jan Treur (treur@few.vu.nl)

Vrije Universiteit Amsterdam, Department of Artificial Intelligence
De Boelelaan 1081, 1081 HV, Amsterdam, The Netherlands

Abstract

The Rational Choice Theory describes criminal behaviour as a form of means-end decision-making. In contrast, it is often argued that criminal behaviour involves subjective, personal biological and psychological aspects. This paper contributes an agent-based modelling approach for criminal behaviour integrating such subjective aspects with decision-making based on means-end analysis, and illustrates this for street robbery. The agent model developed is a combination of a BDI-model and a utility-based decision model in the context of such desires and beliefs. The resulting approach incorporates subjective, context-sensitive means-end analysis, where the context covers biological and psychological aspects as mentioned.

Introduction

A longstanding debate within Criminology is whether criminal behaviour is driven by a criminal's subjective, personal biological and psychological background, or is the result of a rational, calculated choice; e.g., (Moir and Jessel, 1995; Cornish and Clarke, 1986). Often the former is considered to happen to the subject with not much freedom of choice, whereas the latter is considered to be a more or less free choice. This debate has fundamental societal implications, for example, on policies with respect to punishment and treatment of criminals. An interesting question is whether in this debate an exclusive choice has to be made between two opposed viewpoints, or a synthesis can be obtained reconciling them. If this question is to be answered in the latter sense in a convincing manner, this requires a detailed account on how exactly the two viewpoints can be integrated. This indeed is the aim of the current paper. It is shown in detail that and how such an integration is possible, by means of a formalised computational model that incorporates both sides.

As a starting point, the agent model described in (Bosse, Gerritsen and Treur, 2007b) has been taken, which focuses on a case study about the Intermittent Explosive Disorder. This model addresses action generation based on beliefs, desires and intentions (BDI), and generation of desires and beliefs in opportunities. However, for the sake of simplicity, only one action per desire was assumed, so no decision making was covered involving a choice between different options for actions to fulfil a desire. The current paper presents a model for utility-based multi-criteria decision making (e.g., Keeney and Raiffa, 1976; Raiffa, 1982) within a BDI-setting and applied to street robbery. This decision model provides a formalisation of the Rational Choice Theory within Criminology; e.g. (Cornish and Clarke, 1986). This theory as informally discussed within Criminology describes crime as an event that occurs, for example, when an offender decides to take risk breaking the law, after considering his or her own need for money, personal values or learning experiences and how well a target is protected. The criminal assesses the chances of getting caught, the expected penalty, the value to be gained by committing the act, and his or her immediate need for that value.

In the decision model introduced in this paper, this process is modelled by introducing utilities for different possible intended actions. The utility of a certain (option for an) action is then assessed according to the extent to which it fulfils the subject's desire. In this way utilities are assessed with respect to a subjective measure focusing on a specific desire, which may be affected by the subject's specific biological and psychological background. In other words, for the individual agent, rational choice means the choice to fulfil its own desires in the best possible way. Thus, the model for desire generation based on the biological and psychological factors is integrated with a rational decision model for the choice of (intended) actions.

In this paper, the next section discusses a brief summary from the literature on the role played by biological and psychological factors in criminal behaviour. After that, the dynamical modelling approach is discussed. Next, the simulation model is presented and some simulation results are shown. Finally, the approach and its possible applications are discussed.

Biological and Psychological Factors

Since the BDI model (Georgeff and Lansky, 1987; Rao and Georgeff, 1991) does not prescribe a standard way to determine how desires are created, for a particular application usually domain-specific knowledge is used. For criminal behaviour, a number of specific biological and psychological aspects seem to play a role in the generation of desires. An extensive search has been performed into literature from areas such as Criminology and Psychology (e.g., Raine, 1993; Moir and Jessel, 1995; Delfos, 2004) for aspects to be incorporated in the model.

A *theory of mind* of a person (e.g., Baron-Cohen, 1995) describes other persons' minds by separate mental concepts, such as the person's own beliefs, desires, and intentions, and how those concepts play a role in the person's behaviour. Criminal actions are often performed by persons whose theory of mind is less developed. In recent years, more evidence is found that there often are biological reasons for this. For example, it has been found that many psychopaths have a damaged connection between the frontal lobes (concerned with conscience and remorse) and the limbic area, which generates feelings; cf. (Moir and Jessel, 1995).

Another important aspect in crimes is *aggressiveness*. Research has pointed out that there is a correlation between aggressive behaviour and the level of testosterone. In fact, 89% to 95% of all crime is performed by males (Moir and Jessel, 1995). In addition, the use of alcohol or drugs may increase the violence of behaviour.

A third aspect involved in criminal behaviour is the *desire to act*, which can be related to a high level of adrenalin. If a person's adrenalin level becomes too high, (s)he somehow has to cope with this; acting decreases the adrenalin level. Thus, if the desire to act is high, then a criminal act more easily occurs. The specific types of actions that are chosen depend on another factor, the *desire to act safely*. This factor correlates with a high level of oxytocine, a hormone mainly produced by women. Persons with a high level of oxytocine have a higher tendency to cope with their desire to act by performing 'safe' actions (e.g., taking care of the 'nest') than persons with less oxytocine; they will rather perform 'less safe' actions (e.g., fighting) (Delfos, 2004).

In addition, crimes are often committed by persons who are looking for a thrill. These persons in general have a high excitement threshold, which means that it is very difficult for them to become excited (Moir and Jessel, 1995; Raine, 1993). As a result, they are often bored, so that they generate a *desire for actions with strong stimuli*. Such actions may become criminal actions, such as stealing, joyriding, or assaulting other people. Only by performing these actions, their desire for strong stimuli is fulfilled, and they become less bored.

Furthermore, a significant amount of committed crimes can be described as *impulsive*. They are not planned, but rather triggered by occasional opportunities. An important factor causing impulsive behaviour is a low level of blood sugar, which in turn is caused by a high insulin level and a low serotonin level (Moir and Jessel, 1995).

A next factor that may affect the types of (criminal) actions that persons may perform, is the extent to which they have (positive or negative) feelings with respect to another person's wellbeing. When someone has a low amount of *positive feelings towards others*, (s)he does not really care about the other. Likewise, when someone has many *negative feelings towards others*, (s)he may wants to cause harm towards someone else. For example, in psychopaths, both attitudes are low: these persons hardly show any emotion concerning other persons, so for them, both the positive and the negative emotional attitude towards others are low (Moir and Jessel, 1995).

The last two factors chosen to incorporate in the model are the *desire for high gain* and the *desire for low loss*. These concepts were chosen on the basis of the Rational Choice Theory (Cornish and Clarke, 1986). According to this theory, to determine their actions, persons will try to minimise their expected loss or penalty (e.g., being caught, getting hurt) and maximise their gain (e.g., money, status). The theory states that criminals will make a serious decision before committing a crime, weighing pros against cons.

Modelling Approach

Modelling the various aspects in an integrated manner poses some challenges. On the one hand, qualitative aspects have to be addressed, such as beliefs, desires, and intentions, certain brain deviations, and some aspects of the environment such as the presence of certain agents. On the other hand, quantitative aspects have to be addressed, such as testosterone and serotonin levels, and utilities.

The modelling approach based on the modelling language LEADSTO (Bosse, Jonker, Meij, and Treur, 2005) fulfils these desiderata. It integrates qualitative, logical aspects and quantitative, numerical aspects. This integration allows the modeller to exploit both logical and numerical methods for analysis and simulation. The basic building blocks of LEADSTO are so-called *executable dynamic properties*, by which direct temporal dependencies between two state properties in successive states are modelled. Their format is defined as follows. Let α and β be state properties of the form 'conjunction of ground atoms or negations of ground atoms'. In LEADSTO, the notation $\alpha \twoheadrightarrow_{e,\, f,\, g,\, h}\, \beta$, 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 of the language LEADSTO, see (Bosse, Jonker, Meij, and Treur, 2005). The overall simulation model has been built by composing two models:

1. a model to *determine desires* incorporating various biological and psychological aspects and their interactions
2. a model for reasoning about *beliefs, desires and intentions*, using a BDI-model based on *utility-based decision making*

These models have both been implemented in LEADSTO. They are described in more detail the next sections.

Determining Desires

To determine desires, a rather complex submodel is used, incorporating dynamical system elements for the biological and psychological aspects as mentioned earlier, varying from qualitative aspects, such as anatomical aspects concerning brain deviations (e.g., the absence of certain connections) to quantitative aspects, such as biochemical aspects concerning testosterone levels. Some example LEADSTO specifications (called Local Properties, LPs) are given below (both in informal and in formal notation)[1]:

LP9 A certain level of current testosterone will lead to a corresponding level of aggressiveness.

∀x:SCALE chemical_state(testosterone,current,x) $\twoheadrightarrow_{0,\,0,\,1,\,1}$ desire_for_aggressiveness(x)

[1] See (Bosse, Gerritsen, and Treur, 2007b) for the complete model.

LP20 Observation of a stimulus with an excitement level that is lower than the excitement threshold will lead to boredom.
∀s1,s2,y:INTEGER observes_stimulus(s1,s2) ∧ excitement_threshold(y) ∧ s2<y $\twoheadrightarrow_{0, 0, 1, 1}$ boredom

LP29a A low blood sugar level leads to high impulsiveness.
chemical_state(blood_sugar, low) $\twoheadrightarrow_{0, 0, 1, 1}$ desire_for_impulsiveness(high)

The variety of biological and psychological aspects that were found relevant in the literature (such as Moir and Jessel, 1995; Raine, 1993; Bartol, 2002; Delfos, 2004) and are taken into account in this model, are those described in the second section above. Different combinations of these elements lead to different types of (composed) desires; e.g., 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 following LEADSTO rule generates a composed desire out of the different ingredients mentioned earlier:

LP30 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, positive and negative emotional attitude towards others, and desire for high gain and low loss leads to a specific composed desire, represented as d(has_value(theory_of_mind, s1), …, has_value(desire_for_low_loss, s10)).
∀s1,s2,s3,s4,s5,s6,s7,s8,s9,s10:SCALE
theory_of_mind(s1) ∧ desire_for_aggressiveness(s2) ∧ desire_to_act(s3) ∧
desire_to_act_safely(s4) ∧ desire_for_actions_with_strong_stimuli(s5) ∧
desire_for_impulsiveness(s6) ∧ emotional_attitude_towards_others(pos,s7) ∧
emotional_attitude_towards_others(neg,s8) ∧ desire_for_high_gain(s9) ∧
desire_for_low_loss(s10) $\twoheadrightarrow_{0, 0, 1, 1}$
desire(d(has_value(theory_of_mind, s1), ...,
has_value(desire_for_low_loss, s10)))

Utility-Based Reasoning about Intentions

As in (Bosse, Gerritsen and Treur, 2007b), part of the model for criminal behaviour is based on the BDI-model, whichbases the preparation and performing of actions on beliefs, desires and intentions (e.g., Georgeff and Lansky, 1987; Rao and Georgeff, 1991). In this model an action 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 observed. The intention to do a specific type of action is created if there is a certain desire, and there is the belief that in the given world state, performing this action will fulfil this desire. The BDI-model was specified by:

LP31 Desire d combined with the belief that a certain action a will lead to the fulfillment of that desire will lead to the intention to perform that action.
∀d:DESIRE ∀a:ACTION desire(d) ∧ belief(satisfies(a, d)) $\twoheadrightarrow_{0, 0, 1, 1}$
intention(a)

LP32 The belief that there is an opportunity to perform a certain action combined with the intention to perform that action will lead to the performance of that action.
∀a:ACTION belief(opportunity_for(a)) ∧ intention(a) $\twoheadrightarrow_{0, 0, 1, 1}$ performed(a)

However, to assess and compare different options, and select a best option, as an extension to this basic BDI-model utilities are to be assigned and combined, addressing the degree to which an action satisfies a desire. The notion of utility to be used requires some reflection. Sometimes this may be considered a rational notion with an absolute, intersubjective (or objective) status. For two agents with a kind of standard internal functioning, considered rational, this intersubjectivity may be a reasonable assumption. However, if the internal processes are different it is less reasonable. One agent may have preferences different from those of the other agent, and hence be satisfied with a situation that is not satisfactory for the other agent. As an example, multi-attribute negotiation aims at exploiting such differences in preferences between agents in order to the benefit of both; e.g., (Keeney and Raiffa, 1976; Raiffa, 1982; Jonker and Treur, 2001; Bosse, Jonker and Treur, 2004). This shows that the meaning of utility can be subjective and personal. In particular, for a criminal subject, due to his or her specific biological and psychological characteristics, a desire can be quite deviant from what is commonly considered as the rational norm. For this subject the utility of a certain action a is assessed according to the extent to which it fulfils this personal desire. This shows how utilities are assessed with respect to a subjective measure focusing on a specific desire d, which is affected, or even largely determined by the subject's specific biological and psychological background. According to this perspective, the utility-based decision model was set up as follows:

1. Aspect Utility Value Representations
For any aspect x_i with value s_i, introduce an aspect utility v_i for any possible action a by

has_aspect_utility(a, has_value(x_1, s_1), v_1)
…
has_aspect_utility(a, has_value(x_k, s_k), v_k)

where v_i is based on a closeness measure for each aspect x_i of the considered option a to value s_i, normalised between 0 (least close, minimal utility) and 1 (most close, maximal utility). For example,

has_aspect_utility(fight,
has_value(desire_for_aggressiveness, high), 0.9)

indicates that the action of fighting contributes much to a high value for aggressiveness.

2. Aspect Weight Factor Representations
Introduce weight factors w_1, …, w_k for the different aspects x_i, normalised so that the sum is 1, and introduce relations weight_factor(x_i, w_i) stating that aspect x_i has weight factor w_i.

3. Combination of Aspect Utilities to Option Utilities
Combine the option aspect utility values v_1, …, v_k for a given composed desire to an overall option utility taking into account the weight factors w_1, …, w_k, according to some combination function $f(v_1, …, v_k, w_1, …, w_k)$.

The combination function in **3.** can be formalised in a number of manners; two common possibilities are:

- Euclidian Distance**:** $f(v_1, …, v_k, w_1, …, w_k) = \sqrt{(w_1v_1^2 + … + w_kv_k^2)}$
- Manhattan Distance**:** $f(v_1, …, v_k, w_1, …, w_k) = w_1v_1 + … + w_kv_k$

The LEADSTO property for combination is:

LP41 ∀a:ACTION ∀x_1,...,x_k:ASPECT ∀s_1,...,s_k:SCALE ∀v_1,...v_k,w_1,...w_k:REAL
belief(has_aspect_utility(a, has_value(x_1, s_1), v_1)) ∧ … ∧
belief(has_aspect_utility(a, has_value(x_k, s_k), v_k)) ∧
weight_factor(x_1, w_1) ∧ … ∧ weight_factor(x_k, w_k) $\twoheadrightarrow_{0, 0, 1, 1}$
belief(has_utility(a, d(has_value(x_1, s_1), ..., has_value(x_k, s_k)),
f(v_1, …, v_k, w_1, …, w_k)))

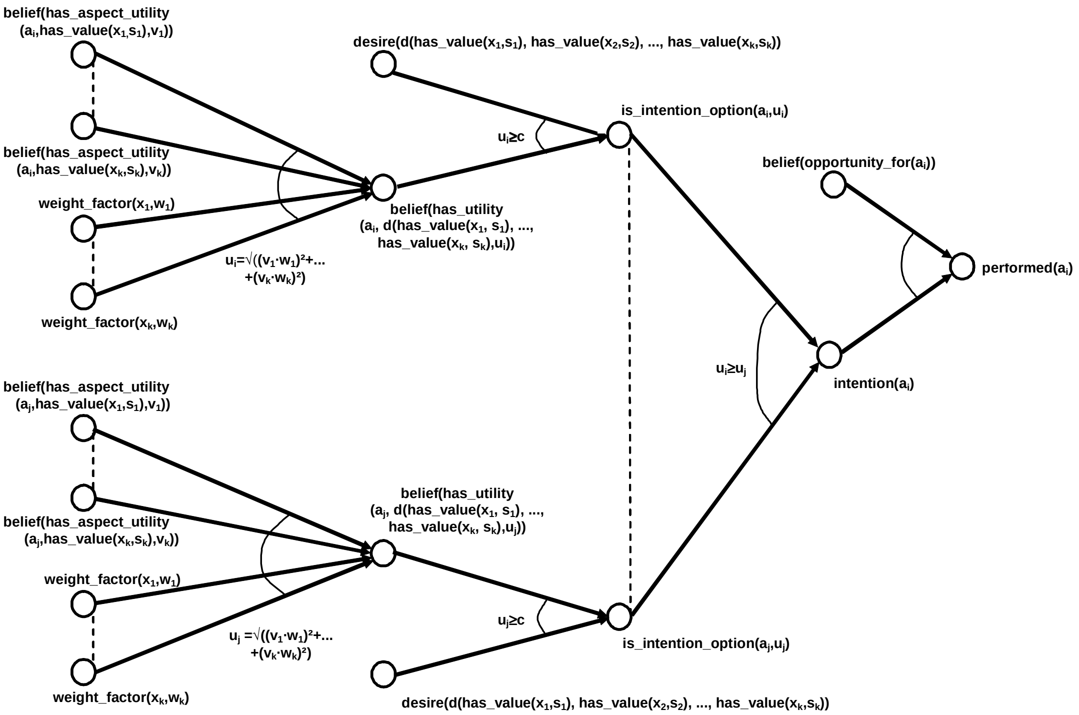

Figure 1: Utility-Based BDI-model

Next, the choice process is formalised. This is done in two steps. First, LP31 is replaced by LP31a, LP31b, and LP31c:

LP31a Desire d combined with the belief that a certain action a will lead to the fulfillment of d with utility u (≥c) will lead to the consideration of a as a possible intention option.
∀d:DESIRE ∀a:ACTION ∀u:REAL desire(d) ∧ belief(has_utility(a, d, u) ∧ u≥c)
$\twoheadrightarrow_{0.2, 0.2, 1, 1}$ is_intention_option(a, u)

Here c is a threshold value, for example 0.5. This is used to generate the options to be considered. To obtain only the intentions with highest utility, as a next phase, the selection process is modelled in two steps by:

LP31b If a1 and a2 are both intention options, but a2 has a higher utility, then a1 is ruled out as an intention option.
∀a1,a2:ACTION ∀u1,u2:REAL is_intention_option(a1,u1) ∧
is_intention_option(a2,u2) ∧ u1<u2 $\twoheadrightarrow_{0, 0, 1, 1}$
ruled_out_intention_option(a1, u1)

LP31c Eventually, an intention option that is not ruled out is selected as final intention.
∀a:ACTION ∀u:REAL is_intention_option(a, u) ∧
not ruled_out_intention_option(a, u) $\twoheadrightarrow_{0, 0, 1, 1}$ intention(a)

The complete utility-based decision model is depicted graphically in Figure 1. The circles denote state properties, and the arrows denote dynamic (LEADSTO) properties. Notice that the state properties of the type desire(...) are generated by the model described in the previous section.

Note that, in order to describe a specific decision making scenario with this model, the person described needs to have some expectancy about possible actions already at the start of the scenario. This expectancy may be triggered by observations (e.g., "I see a potential victim and no guardians, so I consider robbing this person"), or by other internal states (e.g., "I feel like seeking some thrill, so I consider robbing a bank this afternoon"). In the first case, the duration between the decision and the actual performance of the action is rather short, so that it is very likely that an opportunity for the considered action will indeed occur. In the second case, this duration will be longer, and it is possible that no opportunity will occur at all. The model can be used to describe both types of processes.

An Example Simulation Trace

Based on the model shown above, a number of simulation experiments have been performed to test (for some simple scenarios) whether it shows the expected behaviour. In this section, an example simulation trace is described in detail. The example scenario involves a street robber (indicated by criminal1) who observes some possible targets, and is deliberating about whether or not to perform an assault (and if so, which assault to perform). For simplicity, we assume that there are two possible assaults to choose from (indicated by assault1 and assault2, respectively). In case of assault1, he would steal an old lady's purse, without using extreme violence. In case of assault2, he would steal a young man's brand new laptop. However, since this man seems to be rather strong, he would probably have to use violence to achieve his goal. The characteristics of both assaults, as well as criminal1's individual preferences, are shown in Table 1.

Table 1: Characteristics of a criminal and possible assaults[2]

	weight factor (criminal1)	aspect utility (assault1)	aspect utility (assault2)
theory of mind	0.04	low, 0.7	low, 0.9
desire for aggressiveness	0.04	high, 0.3	high, 0.8
desire to act	0.17	high, 0.8	high, 0.8
desire to act safely	0.02	high, 0.1	high, 0.1
desire for actions with strong stimuli	0.17	high, 0.6	high, 0.8
desire for impulsiveness	0.12	medium, 0.5	medium, 0.5
positive emotional attitude towards others	0.02	low, 0.7	low, 0.8
negative emotional attitude towards others	0.04	low, 0.3	low, 0.3
desire for high gain	0.19	high, 0.5	high, 0.8
desire for low loss	0.19	high, 0.8	high, 0.5

In the first column of the table, the different weight factors assigned to criminal1 can be seen. These weight factors, which add up to 1, show the relative importance of each aspect for the criminal. The weight factor for desire to act safely, for example, is 0.02. This means that criminal1 has a low interest in the desire to act safely. The weight factor for desire for actions with strong stimuli is 0.17, which means that he has a high desire for actions with strong stimuli. In the columns to the right of the weight factor, the utility of the different aspects is mentioned (in the column in the middle for assault1 and in the column to the right for assault2). The values describe in how far the aspect is present in this particular assault. For example, has_aspect_utility(assault1, has_value(desire_for_aggressiveness, high), 0.3) shows that assault1 does not contribute much to the high desire for aggressiveness. On the other hand, has_aspect_utility(assault2, has_value(desire_for_aggressiveness, high), 0.8) shows that assault2 contributes much to the high desire for aggressiveness.

The results of applying the simulation model to this example situation are shown in Figure 2. Here, time points are on the horizontal axis, whereas the different state properties are on the vertical axis. A box on top of a line indicates that a state property is true at that time point. As shown by this figure, the criminal immediately has a certain desire, represented as d1. Note that this stands for a complex desire represented as:

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d(has_value(theory_of_min,low), has_value(desire_for_aggressiveness,high),
   has_value(desire_to_act,high), has_value(desire_to_act_safely,high),
   has_value(desire_for_actions_with_strong_stimuli,high),
   has_value(desire_for_impulsiveness,medium),
   has_value(positive_emotional_attitude_towards_others,low),
   has_value(negative_emotional_attitude_towards_others,low),
   has_value(desire_for_high_gain,high), has_value(desire_for_low_loss,high))
```

(which was not shown in the picture, for obvious reasons). This desire was generated by a complex process, involving a combination of biological and psychological factors. Due to space limitations, this part of the trace is not shown here either. However, more detailed simulation traces that include such processes are shown in Appendix A in (Bosse, Gerritsen and Treur, 2007b).

[2] This approach assumes that an individual's preferences (i.e., the weight factors), as well as the characteristics of certain actions (i.e., aspect utilities), can be expressed by real numbers. For the presented examples, the chosen numbers are not necessarily claimed to be realistic, and should rather be seen as rough estimations by the authors.

Based on the desire as described above, criminal1 then starts assessing the utilities of the two possible assaults (see the predicates belief(has_utility(…)) at time point 1), based on the aspect utilities and weight factors of these assaults. The action of stealing the young man's laptop (assault2) is assessed with value 0.678723, whereas the action of robbing the old lady's purse (assault1) has value 0.625532. Since both has_utility-values are higher than 0.5, both actions become possible intentions (see time point 2). Next, the criminal chooses the one with the highest utility, which leads to the intention to perform assault2 at time point 3. Later, when an opportunity for assault2 arises (time point 20), this assault is indeed performed (time point 21).

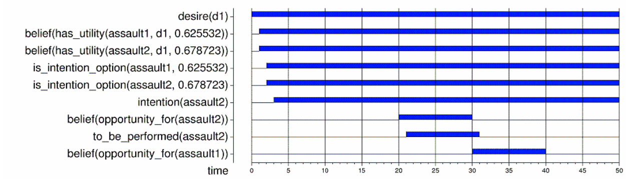

Figure 2: Example simulation trace

As illustrated by the trace in Figure 2 (and several similar traces that are not shown due to space limitations), the simulation experiments have indicated that the presented model successfully integrates personal biological and psychological aspects within the decision making process, which eventually leads to the selection of actions that correspond to the desires of the individual.

Discussion

The few papers on simulation of criminal behaviour found in the literature usually address a limited number of aspects. For example, Brantingham and Brantingham (2004) discuss the possible use of agent modelling approaches to criminal behaviour in general, but do not report a specific model or case study. Moreover, Baal (2004) puts emphasis on the social network and the perceived sanctions. However, this model leaves the psychological and biological aspects largely unaddressed.

In this paper, an agent-based model to analyse criminal decision making is presented. The model combines a BDI-agent model (as described for the case of a criminal with Intermittent Explosive Disorder in (Bosse, Gerritsen and Treur, 2007b)) with a model for multi-attribute decision making, and applies this to the case of street robbery. It enables a choice between different options for actions fulfilling a complex desire, according to the Rational Choice Theory. The resulting agent model combines qualitative, logical aspects of a BDI-model with quantitative, numerical aspects of utility theory.

The simulation model has been made with the aim to formalise, in an abstract and computationally useful manner, the decision making behaviour of certain types of criminals as described in literature from Criminology. Such a model can be used in a number of ways. In the first place, it can be used to simulate behaviour for given scenarios of circumstances occurring over time. This can be used to find out for such a given scenario of circumstances, whether a criminal of a certain type may show certain behaviour under these given circumstances. Second, the models can be used in the opposite direction, i.e., given a certain behaviour, to determine what kind of scenario of circumstances could have led to this behaviour. See (Bosse, Gerritsen, and Treur, 2007a) for details about how this can be done. Third, the models may be used to predict which behaviour certain types of criminals will show if circumstances are avoided or slightly changed (what-if reasoning). Using this approach, the behaviour of the subject can be modified by selecting or avoiding the appropriate circumstances, or by determining (cognitive) training programs for criminals. For all of these purposes, the model should be seen as a tool to support the user (e.g., the detective or the therapist) in its reasoning, by clarifying which scenarios are more plausible. It should however not be interpreted as a model of the absolute truth.

Validation of the model is a difficult issue. At least, the present paper has indicated that it is possible to integrate biological and psychological factors with rational factors within one model. Moreover, the model indeed shows the behaviour of different types of criminals as described in literature such as (Moir and Jessel, 1995; Raine, 1993; Delfos, 2004). In this sense the model has been validated positively. However, notice that this is a relative validation, only with respect to the literature that forms the basis of the model. In cases that the available knowledge about the behaviour and biological and psychological functioning of such criminal types is improving, the model can be improved accordingly. The modelling approach as put forward supports such an incremental development and improvement. The simulation model has been specified in a conceptual, not implementation-dependent manner, and is easy to maintain. In this sense the approach anticipates further development of the area of criminal behaviour.

In the cognitive literature, it is often claimed that cognition can be divided into two distinct systems: a low-level, emotional and unconscious system, and a high-level, evolutionary recent, conscious system, see, e.g., (Evans, 2003). At first sight, our proposed model seems to show significant similarities with this *dual process theory*. Our model to determine desires has characteristics of a low-level system, whereas the model for utility-based decision making resembles a high-level system. Future work will explore whether a more precise mapping can be made between the concepts introduced in our combined model and the concepts typically used in dual process theory. In addition, future work will explore how our model relates to models in which affective factors just ‘bypass’ decision making, such as in (Loewenstein, Weber, Hsee, and Welch, 2001).

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