29

Efforts in Agent-based Simulation of Human Panic Behaviour: Reference Model, Potential, Prospects

Bernhard Schneider
University of the German Armed Forces Munich, Computer Science Department
Germany

1. Introduction: Challenges in Modelling Human Behaviour

Human behaviour and its modelling is one of the major challenges in state of the art modelling and simulation for a wide range of application areas, no matter if dealing with question sets in social, economic or even in a security or military context. Two major questions arise: what is the task of the modelling expert and what methods are suitable to tackle these tasks?
To represent human behaviour in simulation models in an adequate fashion, the human being has to be perceived a psychosomatic unit with cognitive capabilities that is embedded in a social environment. Physiological and psychological factors together define the internal state of human being that unfortunately is not directly measurable or observable. Accordingly, the modelling expert has to address on determining and modelling relevant somatic characteristics and intangibles in the form of cognitive, emotional and social determinants of human behaviour, their dynamics, correlation, and impact on the concrete shape of human behaviour in specific situations.
In brief, a complex system has to be created, where the output at a certain point of time by means of observable domain dependent patterns of behaviour depends on the entirety of sensory inputs at that time and the current internal state. A system theoretical view on the modelling task seems to be appropriate to describe transitions of the system's state and interconnect the single factors.
In order to provide the capability to consider even highly realistic human behaviour and to obtain valid simulations, it is necessary to keep the conceptual model of a human being, strictly speaking the subset of relevant aspects of human behaviour to be simulated, as close as possible to reality. This can be achieved by theory driven modelling based upon the latest theories and findings in psychology and sociology.
On the technical side, agent-based methods proofed to be suitable for constructing simulation models including human factors. The paradigm of agent-based modelling proclaims the representation of human beings by autonomously deciding and acting software agents. The design process is supported by established agent architectures and reference models.
An application area where all of the mentioned aspects on modelling and technical side are of importance can be found in the modelling of human behaviour in large event security

scenarios where even the danger of a panic breakout during evacuation processes in public places like a station concourse or even in closed rooms, pedestrian tunnels or airplanes has to be taken into account. To analyze, assess and optimize the quality of security concepts and the system of systems approach, computer simulations can be a very helpful instrument, helping to increase quality and reduce risks in the design cycle and overall costs.
This chapter gives an overview about current research work related to modelling and simulation of human behaviour in panic situations and presents the new reference model SimPan as an innovation in this area. The research work is interdisciplinary in its nature and touches on research areas in computer science, especially modelling and simulation, systems theory and artificial intelligence as well as psychology with the main areas social psychology and cognitive psychology.

2. State-of-the-art in simulation of evacuation situations

Two different approaches to describe human behaviour in evacuation situations have been established in the last decade. Behaviour models on the one hand are theories about human behaviour in panic situations that are based upon empirical data and socio-psychological findings. Movement models on the other hand concentrate on detailed description of the dynamics of pedestrian movement. Dependent on the chosen degree of resolution, movement models can be subdivided into macroscopic, microscopic and mesoscopic models.
Macroscopic models as presented by Daamen (Daamen, 2002) and Helbing (Helbing et al., 2002) assume an analogy with the motion of pedestrians and the motion of gases and fluids and do not focus upon individual differences between human beings in a moving crowd. In microscopic models by contrast, human beings are represented as single simulation entities with individual features. Typical exponents of that approach are cellular automata as described by Kirchner (Kirchner & Schadschneider, 2002) and Muramatsu (Muramatsu et al., 1999) as well as agent-based models as developed by Becker and Schmidt (Becker & Schmidt, 2005), Banarjee (Banarjee et al., 2005) or Gipps and Marksjö (Gipps & Marksjö, 1985). Mesoscopic models as described by Vassalos (Vassalos et al., 2002) combine aspects of both approaches by situational conditioned employment of interconnected macroscopic and microscopic simulation parts.

3. SimPan as an innovation in the scope of modelling panic behaviour

In common to all of the mentioned approaches is the fact that psychological determinants of individual behaviour in evacuation situations are, if at all, just of marginal interest. In contrast to related modelling approaches, the SimPan reference model integrates established psychological theories and findings to model and simulate observable patterns of human behaviour in the course of panic situations. It contains modelling approaches for common environmental phenomena in context of panic, describes their impact on an individual's internal state and comprises corresponding patterns of human behaviour. The reference model SimPan serves as a conceptual basis for the construction of agent- based models to simulate human behaviour in panic situations but equally leaves space for individual adaptation to specific requirements defined by particular fields of application.

4. System-theoretical modelling principles

The human being can be seen as a complex system. A system in terms of system theory is characterised by a set of state variables. These state variables can change their value on the basis of their own dynamics or on the basis of a sensory input. Besides the state variables, dependent variables can be introduced and calculated by means of the state variables. The modified internal system state consisting of the new values for state variables and the new dependent variables will then lead to an output that can, in some cases, take on the form of an observable action executed by an agent.
The transfer function F describes how the system state variable z(tn) turns into the subsequent state z(tn+1), in the time-discrete case:

$$z(tn+1) = F(tn, z(tn), w(tn), x(t)) \quad (1)$$

The following equation describes the state transfer in the time-continuous case:

$$z'(t) = F(t, z(t), w(t), x(t)) \quad (2)$$

The algebraic function H describes the relation between the state variable z(tn+1) and the dependent variable w(tn+1):

$$w(tn+1) = H(tn+1, z(tn+1)) \quad (3)$$

The output function G determines the manner in which the new internal state, which came about as a result of the input, shows itself as output y(tn+1) to the outside:

$$y(tn+1) = G(tn+1, z(tn+1), w(tn+1), x(tn+1)) \quad (4)$$

The interplay between these functions to model the human information processing system is depicted in figure 1.

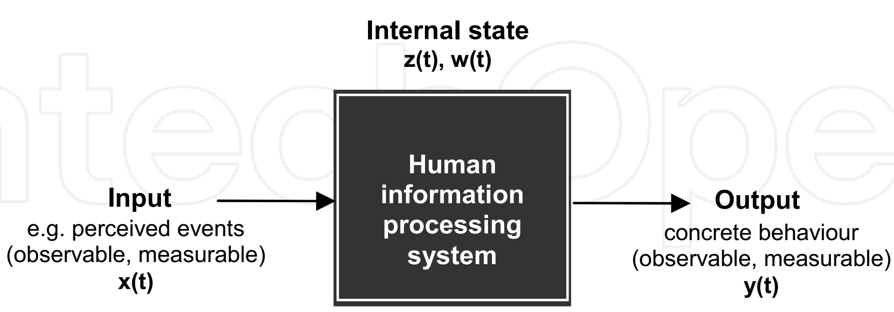


Fig. 1. System-theoretical modelling approach for a complex system

An example could be a state variable FearS representing the emotion fear. The value for that FearS can change by itself or through mental processing of inputs from the outside, e.g. the cognitive evaluation of a perceived event in the environment. Such a sudden frightening experience as input can lead to a sudden increase of the state variables value. By contrast, if

nothing happens in the environment, the value of FearS decreases continuously over time until it reaches a minimum value. It is the function F that describes both of these changes in time.
The dependent variable FearM is closely correlated to the state variable FearS. FearM is the corresponding strength of the motive to reduce that fear, e.g. by introducing a flight reaction. The stronger the fear state FearS, the higher the value for the motive strength FearM. The algebraic function H determines the dependency of FearM on FearS.

5. Reference Models

A reference model is a domain independent methodology-founded scheme of construction as proposed in (Klinger 1999) that describes a standard solution for modelling problems and serves as a blueprint for a class of real systems sharing a common deep structure. Major aim in using reference models is to reduce the complexity of design tasks and thereby reduce the effort in time and work concerning the development of simulation models. A reference models capacity depends on the size of its set of solvable problems.
In the modelling and simulation context, two different kinds of reference models can be distinguished. The first sort of reference models proposes a structure for simulation models similar to the addressed real system and addresses implementation issues. Hence, the proposed structure is defined by a set of abstract model components and different types of semantic connections between them: causal dependencies and discrete information flows. As an example the PECS reference model developed by Urban (Urban, 2007) can be named.
The inner life of abstract model components has to be specified by a second sort of reference models that contains comprehensive modelling approaches for domain dependent cause-effect relationships detached from structural or implementation issues. The second kind of reference models fills a given structure with concrete content. The reference model SimPan to be presented in this chapter belongs to the second class of reference models. It provides a comprehensive modelling approach for a specific problem area: human behaviour in evacuation situations. SimPan is inherently structured but does not give any recommendations on the structure of a SimPan- based simulation model. For this reason, SimPan can be supplemented by PECS.

5.1. PECS: A reference model for the structure domain in agent based models

With the PECS reference model as described in (Urban, 2000), a component-oriented hierarchical architecture for the agent-based simulation is proposed that applies to a wide range of systems where human behaviour plays a part. The principal architecture as depicted in figure 2 claims to be applicable for more than just special ad hoc cases.
In PECS the complex real system to observe is decomposed into a set of interacting components, where each component consists of a set of state variables and rules or equations, which describe the state transitions and output of that component. The overall structure of the PECS- world is shown in figure 1. Besides the PECS- agents, there are two global components, Environment and Connector, which represent and administrate the modelled environment and realise interaction between agents.

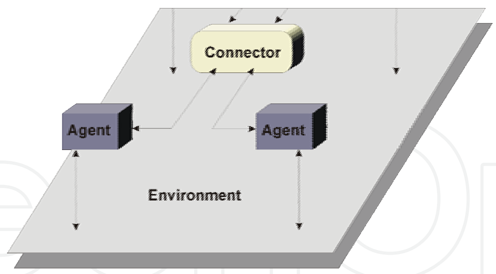


Fig. 2. The PECS- world

The internal structure of a PECS agent is based on a system-theoretic approach and on the usual architecture in robotics. PECS provides a network of abstract model components, organized in three layers: an input layer, an intermediate layer and an output layer. The input layer comprises components Sensor and Perception. The component Sensor is intended to encapsulate functionality for the reception of sensory input data from the environment of the agent. Sensory information is pre-processed in the component Perception, where information-filtering mechanisms or perception processes may be realised.

The intermediate layer describes the internal state of an agent and consists of components Social Characteristics, Cognition, Emotion and Physis. These components describe the internal state of the agent and contain the state variables and the associated state transition functions. The component Cognition, in particular, provides space to model a knowledge base as well as high level functionalities as a basis for realization of deliberative and reflective agent behaviour.

Finally, the components Behaviour and Actor belong to the output layer and describe the observable behaviour of an agent. The component Behaviour contains a set of condition-action rules to model the reactive behaviour of the agent and to co-ordinate the interaction of reactive, deliberative and reflective behaviour by means of determining the execution order of actions that derive from a specific behaviour. Execution orders are passed on to the Actor component that contains a repertoire of actions that the agent is capable of. These actions can be divided into external and internal actions. External actions may have an impact on the environment. Internal actions can have a direct effect on the agent's internal state. Figure 3 illustrates the overall structure of a PECS agent.

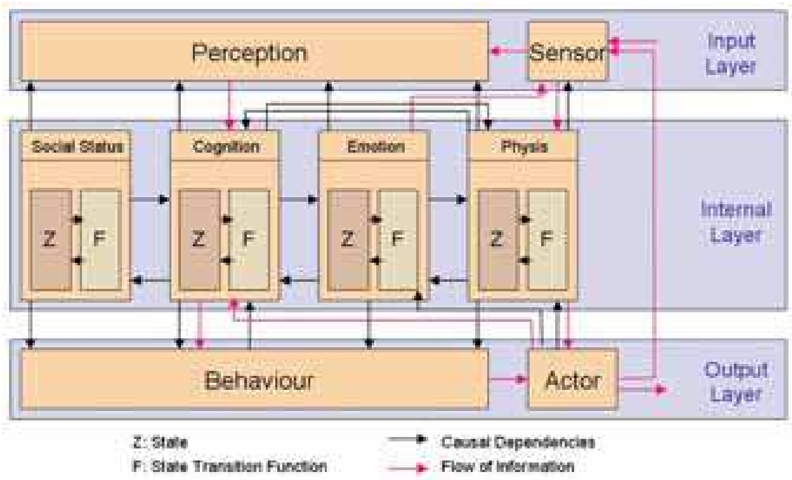


Fig. 3. The internal structure of a PECS Agent

5.2 PECS Component Cognition

As the PECS reference model is based on the component-oriented, hierarchical modelling principle, complex components can be functionally decomposed into a set of specialised, interconnected sub-components. Following this maxim, the component Cognition of the PECS reference model is subdivided into five components: SelfModel, EnvironmentModel, ProtocolMemory, Planning and Reflection. Each of these sub-components contains its own state variables and its own state transition function.

The component SelfModel contains the agent's knowledge about its own internal state and related operations. The component EnvironmentModel is construed for storing a mental representation of the agent's environment and mental processes designed to manipulate and extend this representation such as learning or reasoning. The idea for providing a component ProtocolMemory originally was inspired by the approach taken by Dörner (Dörner, 1999). ProtocolMemory is intended to gather information about executed action sequences, formerly pursued action plans and methods used to analyse them. Within the component Planning, planning process can be modelled. A planning process is responsible for the generation of action plans to reach the agent's intended goals, whereas a plan is considered a sequence of actions to be performed one after the other. To construct a plan, the component Planning can retrieve information from the components SelfModel, EnvironmentModel and ProtocolMemory. The basic idea of having a component Reflection was taken from Sloman, who proposed a three-layered architecture for human-like agents including a Meta-Management-Layer (Sloman, 2000). The function of the component Reflection is to monitor, evaluate and improve internal processes. In order to perform this task, reflective processes can exchange information with the components SelfModel, EnvironmentModel, ProtocolMemory and Planning. The component Reflection acts as a supervisor or manager within cognition. It is necessary if the agent should possess reflective capabilities. The internal structure of the component Cognition is shown in figure 4. A complete description of the PECS reference model is provided in (Urban, 2007).

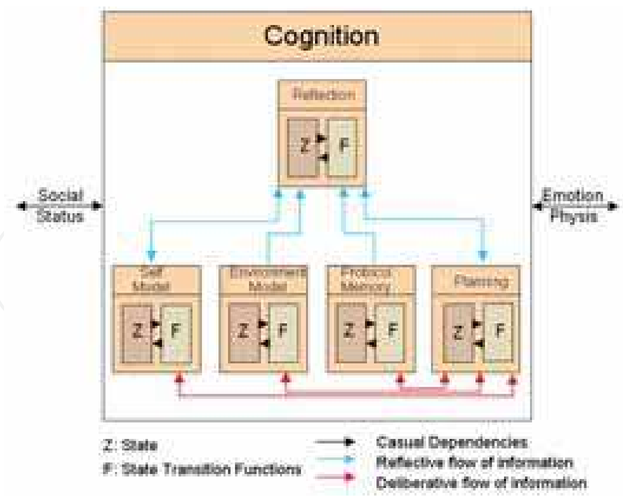


Fig. 4. The interior of component cognition

As PECS describes a structure and makes proposals how to distribute model parameters and functions in the structure, the challenge by employing the reference model is to fill its abstract components with life. Adopting the general reference model to individual peculiarities of a real system is possible by filling in the empty spaces provided by the architecture. This means, for example, that the number and the type of state variables, the dependent variables as well as the structure of the transfer function F, the algebraic function H and the output function G can be modified without difficulty. Similarly, the agent can be endowed with a diverse repertoire of actions that indicate the internal and external actions that the agent is capable of. As a result, very diverse agents and communities of agents can be described with the same reference model.

5.3 Agents as representatives for human beings

The application area for human-like agents is very wide. It comprises - among others - figures in games, robots which interact with humans, software agents meant to provide information to their clients as well as human beings in simulation models with social psychological background. Agents as model-representatives for humans are constructed using the filtering mechanisms of abstraction and idealisation. The application of these filtering processes is a necessary step in modelling but equally prevents the creation of a direct replica of real facts. Accordingly, the resulting model can only be a reduced version of its original and does not contain all the qualities which distinguish human beings as human beings. Nevertheless, agents can still have a purpose in science, technology and theory. The application area for agents in the research work to be presented is the modelling of human behaviour in evacuation situations.

6. The reference model SimPan

In this paragraph the basic theories and concepts to model scenarios in the context of security operations are presented.

6.1 Different conceptions of panic

In the context of security research regarding evacuation situations, it is important to have a clear understanding of the term panic, its emergence and dynamics. According to (Foreman, 1953), there are two basic conceptions of panic in the area of social psychological research. The first one comes from the area of economy and defines panic as a mass response to a real or imaginary collapse of the market. This mass response arises from the collective attempt to escape from a period of inflation and exhausting trade. Besides this economical conception for panic, the second one is based on a sociological point of view. This definition concentrates on individual emotional states and the resulting individual behaviour of a human being as reaction to a real or imaginary imminent threat to his own life. Panic is regarded as internal state, which is determined by demoralisation, confusion and fear or anxiety. This state may – besides other reactions – result in precipitous flight reactions.

According to Dombrowski and Pajonk (Dombrowski & Pajonk, 2005) there are also two different empirical approaches to explain panic behaviour. The first one bases on the classical crowd psychology, which emerged at the end of the nineteenth century and was mainly influenced by Gustave LeBon (LeBon, 1973). The main axiom of crowd psychology states, that in a crowd, the individual is subjected to the influence of the community (Heinz & Schöber, 1972). The term crowd is described by Kruse (Kruse, 1986) as the affiliation of individuals to a common spirit, which evens out the differences between individuals and enervates the intellectual abilities of the individuals. This state transition manifests itself in the loss of sense of responsibility (Reicher, 2001) and a tendency to impulsive, deviant and irrational behaviour (Mummendy & Otten, 2002).

The second empirical approach emanates from human science and was mainly influenced by Enrico Quarantelli (Quarantelli, 2001) in the mid of the twentieth century. The approach emphasizes mental processes of the individual. This socio- psychological approach tries to get insights into human behaviour during situations of crisis by analysing empirical material through comparative data analysis. Two motivationally determined distinctions in collective behaviour concerning panic can be made: the flight from a certain undesirable situation and the resolute trial to achieve something desirable. In each of these two modes of collective behaviour there exists a kind of competition, which cannot be controlled by social or cultural constraints any longer. Due to these theories, there are quite different suppositions for the development of panic: they reach from irrational behaviour, induced by fear and social influences to rational evaluation of effort and benefit as well as the emergence of normative support of self-serving behaviour.

6.2 Definition of the term panic

As a basis for the modelling work, the sociological conception of panic is referenced. Within the scope of SimPan development, panic is defined as an internal state of a human being, marked by the presence of the dominant emotional motive fear. Strong fear prevents an individual from showing highly-developed kinds of behaviour like conscious and planned behaviour, and reduces the range of available behavioural patterns to thoughtless flight reactions, instinct-guided behaviour and rigidity. This definition combines theories suggested by Quarantelli (Quarantelli, 1954) and Janis in (Schulz, 1964).

6.3 States, motives and motive selection

Motives can be seen as the mainsprings for human behaviour. According to Schmidt and Schneider (Schmidt & Schneider, 2004), motive is a psychological force deriving from an internal state of a human being. There is a close connection between states and the corresponding motives: motives are consciously experienced states. Motives like drives or emotions, and not physiological states, institute acting and direct it towards a certain target.
All motives appear with certain intensity and compete against each other. The motive with the highest motive-intensity at a certain point of time determines – possibly influenced by additional factors – the behaviour of the agent, in the sense that it gets action-leading (Dörner, 1999). Dependent on other internal influences like the current degree of self-control or availability of information about possible flight destinations, the action-leading motive determines the current behaviour and thus the performed action of an individual at that time. As the intensity of motives changes with time, different motives may be action-leading at different points in time. Hence, the agent may behave in a completely different way due to the changed action-leading motive. The interaction between states, motives and behaviour is depicted in figure 5.

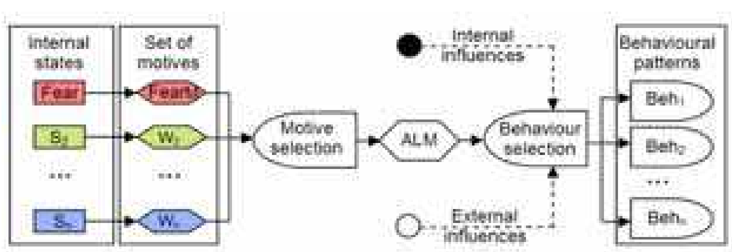


Fig. 5. Motives and motive selection

6.4 The state variable fear

Following the suggested conception of panic, the relevant motive to model is the emotion fear. The theory of cognitive appraisal for emotions as described by Cañamero (Cañamero, 1997), serves as a theoretical basis for modelling emergence and temporary course of individually experienced fear. Accordingly, individuals evaluate constantly perceptions concerning events taking place in the environment. Detection or assumption of a possible threat is considered to be responsible for arise of emotion in the sense of a sudden discrete increase of fear.
According to Schmidt (Schmidt, 2000), a single emotional state like fear can be modelled following the system- theoretical approach by a single state variable that does not depend on other internal states. The dynamics of the state variable FearS is supposed to have a continuous and a discrete part. The continuous part describes a permanent decay (eq. 7) and increase (eq. 6) of the state intensity over the time and is described by differential equations:

$$FearS' = FearInc - FearDec \tag{5}$$
$$FearInc = PC\_FearInc * FearS * SenP * Crow\_i * SForce\_i \tag{6}$$
$$FearDec = PC\_FearDec * FearS * Crow\_i * SForce\_i \tag{7}$$

The constant factors PC_Fear{Inc,Dec} determine the individual propensity to get anxious (eq. 6) and to return to a relaxed internal state (eq. 7). The dependent variables Crow_i and

SForce_i represent the individually weighted impact on the internal state of an agent ascribed by crowding and social forces. The parameter SenP reflects the individual sensation of physical pressure in the environment, while Sc is a constant factor acting as a scaling parameter.
Discrete decay of fear (eq. 8, 9) is modelled by simulation events. A decay of fear occurs if an agent realises calming stimuli emanating from direction signs (e.g. showing the way to an exit) or from loudspeakers (e.g. providing information about possible escape routes and appropriate behaviour in evacuation situations) reflected by the dependent variable FearInf (eq. 8, 10) or from other agents expressed by the dependent variable FearRefA (eq. 9, 11).

$$\text{FearS\^{}} = \text{MAX}(\text{C\_FearMin}, (\text{FearS} - \text{FearInf} * \text{MAX}(0,(1-\text{SenP}*\text{Sc} + \text{Crow\_i}*\text{Sc} - *\text{SForce\_i}*\text{Sc})))) \tag{8}$$

$$\text{FearS\^{}} = \text{MAX}(\text{C\_FearMin}, (\text{FearS} - \text{FearRefA} * \text{MAX}(0,(1-\text{SenP}*\text{Sc} + \text{Crow\_i}*\text{Sc} - *\text{SForce\_i}*\text{Sc})))) \tag{9}$$

$$\text{FearInf} = \text{PC\_CalmingInf} * \text{EffCalmingInf} \tag{10}$$

$$\text{FearRefA} = \text{PC\_CalmingRefA} * \text{EffCalmingRefA} \tag{11}$$

The dependent variables EffCalming{Inf,RefA} in equations (eq. 10, 11) represent the actual efficiency of calming attempts influencing an agent. It is suggested that the first attempt is the most successful one, later attempts have a smaller impact on the individual fear. This is expressed by equations (eq. 12, 13) where the constants C_Calming{Inf,RefA}Max represent the maximum efficiency achievable by calming stimuli. The corresponding graph is depicted in figure 6.

$$\text{EffCalmingInf} = \text{C\_CalmingInfMax}*(1/\text{NumAttemptsInf}+1) \tag{12}$$

$$\text{EffCalmingRefA} = \text{C\_CalmingRefAMax}*(1/\text{NumAttemptsRefA}+1) \tag{13}$$

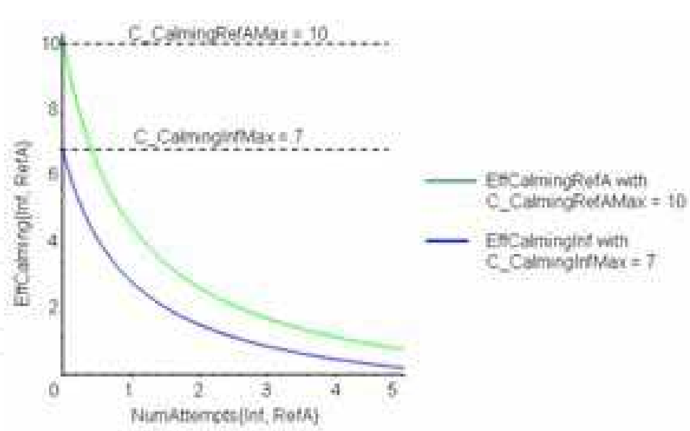


Fig. 6. Motives and motive selection

A discrete increase of the state variable FearS as expressed by equation (14) is triggered by the perception of a fear-inducing event.

$$\text{FearS\^{}} = \text{MIN}(\text{C\_FearMax}, (\text{Fear}+\text{Threat}*(1+\text{SenP}+\text{Crow\_i}+\text{SForce\_i}))) \tag{14}$$

The variable Threat expresses the individually evaluated perception of a threat. Threat is a numerical value that depends on the type of perception modelled by the parameter Perception_type, which can hold the integral values 0 to 3, where the value 0 indicates no perception of the event at all, the value 1 describes a perception of the effects of the event with a certain delay in time, the value 2 stands for an immediate perception of the effects of the event and the value 3 defines a direct perception of the event itself, where the agent is located near the origin of the threat. These values can be used to evaluate the threat emanating from the perceived situation. The higher the value of Perception_type, the more dangerous the current situation is to be evaluated. This can be implemented using a tabular function as shown in table 1, which maps the value of Perception_type to a concrete value of the variable Threat. As the evaluation of a situation concerning threat depends on an agent's individual predisposition for fear and his experiences with critical situations in the past, this has to be expressed by the tabular function.
Table 1 shows a tabular function that correlates the type of perception with the Threat value. The third row insinuates a low predisposition for fear, the fourth one a high predisposition. Figure 7 elucidates these dependencies.

Attribute	Concrete value			
Perception_type	0	1	2	3
$Threat_1$	0	7	28	65
$Threat_2$	0	40	78	100

Table 1. Relation between type of perception, realized threat and predisposition for fear

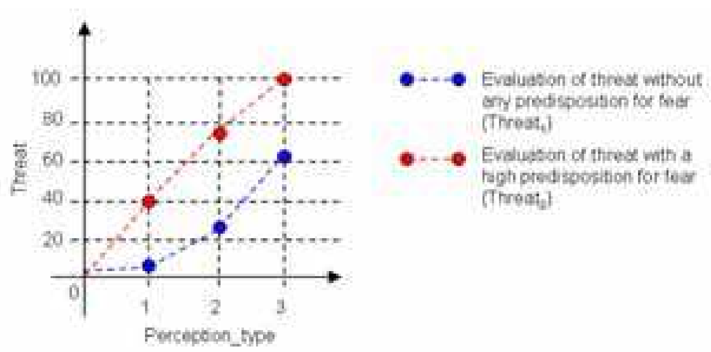


Fig. 7. Evaluation of threat

The course of the state variable FearS according to the equations (1, 8, 9, 14) is depicted in figure 8.

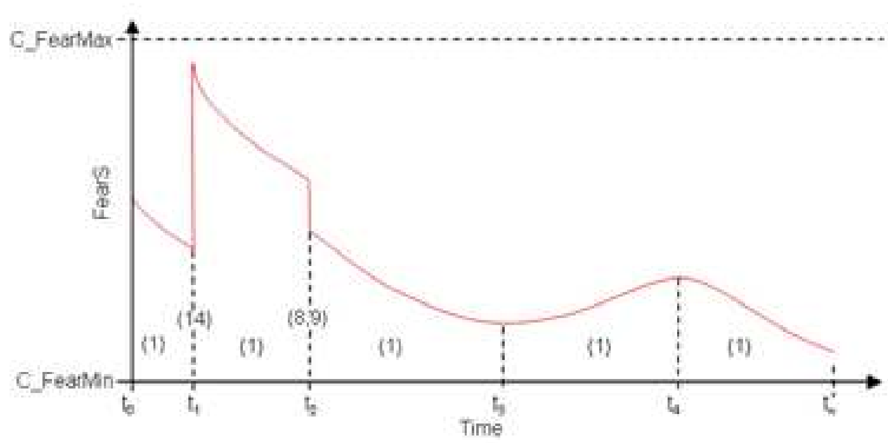


Fig. 8. Dynamics of the state variable FearS

6.5 Sensation of physical pressure

In panic situations, there is a physical factor that influences a human beings internal state: pressure. Pressure is caused by aggressive human behaviour that appears during competition for resources like space or flight opportunity. Pressure has the potential to attack infrastructure, to claim lives and also to cause panic situations. The sensation of physical pressure is supposed to increase fear. Further on, there is a relation between the objective amount of physical pressure affecting an agent and the individual experienced pressure. The later one is determined with the help of a set of individual thresholds as depicted on the left hand side in figure 9.

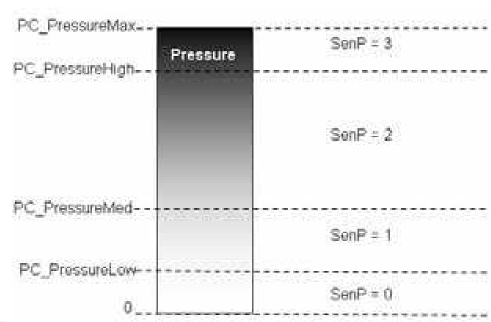


Fig. 9. Individual sensation of pressure

In addition to purely psychological processes, SimPan takes into account implications of physical pressure on the physical constitution of a human being in the sense of agents being crushed to death.

6.6 Crowding

Besides physical pressure, some less obvious quantities are supposed to influence the temporary course of individual fear. One among them is known as crowding. Stokols defines it as an "[…] experiential state in which the restrictive aspects of limited space are perceived by the individuals exposed to them." (Stokols et al. 1977). According to Langer (Langer & Saegert, 1977), crowding intensifies emotional responses to situations. As a decisive factor to express the individual feeling of being crowded, the dependent variable AgentDen to express the available space per agent and the individual suggestibility concerning crowding as constant value PC_Crow are getting introduced (eq. 15). Figure 10 shows different courses of the variable Crow_i dependent on the concrete value of the individual suggestibility.

$$\text{Crow\_i} = \text{C\_CrowMin} + \left(\frac{\text{C\_CrowMax}}{1 + e^{-\text{PC\_Crow}*(\text{AgentDen} - \text{C\_CrowIncMax})}} \right) \quad (15)$$

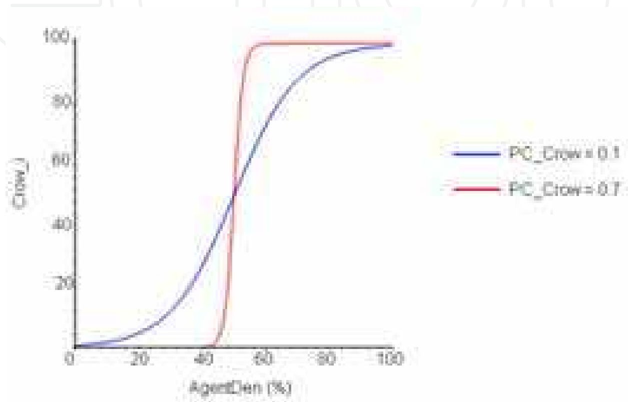


Fig. 10. Relation between crowding and available space per agent

6.7. Social forces

According to Latané (Latané, 1981), an individual's emotional state can be influenced by the mood of other human beings around. Latané suggests the intensity I of the influencing source, its proximity in time and space N and the number of influencing sources A as relevant parameters to describe the power of social influence.

This can particularly be applied to a crowd of human beings in panic which can confer the own fear on others. If strong social forces are acting on an agent, he can be infected by the predominant emotion in the crowd, dependent on his individual predisposition for social influences.

As fear is the only emotional state represented, social influence on fear is modelled by means of the dependent variable SForce_i. It represents the individually experienced degree of emotional charge in the environment. The modelling approach contains following interpretations of the parameters defined by Latané: A means the number of agents, I the average intensity of the motive FearM of all agents and N holds the size of the environment.

$$\text{SForce\_i} = \text{C\_SForceMin} + \frac{\text{C\_SForceMax} * (\frac{A}{N})}{1 + e^{-\text{PC\_SForce}*(I - \text{C\_SForceIncMax})}} \quad (16)$$

The course of the dependent variable SForce_i is depicted in figure 11. The value of the personality constant PC_SForce determines the gradient of the curve, the relation between number of agents and available space per agent determines the maximum strength of the suggestibility concerning social influence.

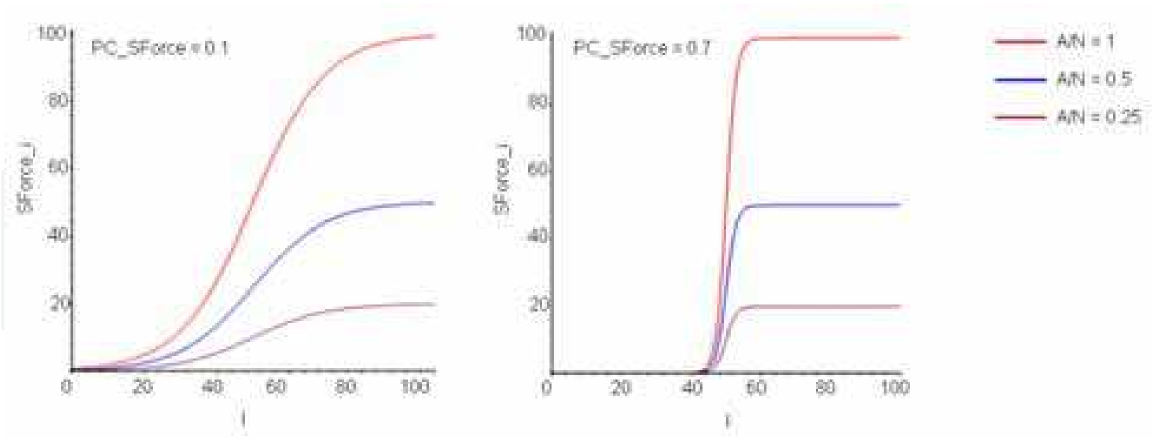


Fig. 11. The modelling of social force

6.8 Emotional Intelligence

To enable SimPan-agents to counteract against behavioural limitations caused by their own fear, they are provided with capabilities going along with emotional intelligence. The psychological concept of "Emotional Intelligence" introduced in 1990 by Mayer and Salovey serves as a modelling basis. Mayer and Salovey defined emotional intelligence as "the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use this information to guide one's thinking and action" (Mayer & Salovey, 1997). Of special interest are the capabilities to observe and to monitor actual emotions and the act of will to replace emotion-induced actions by others, more suitable and sensitive ones.

The modelling of emotional intelligence is described in detail in (Schmidt & Schneider, 2004). Basic model elements are an agent's arousal, the emotional intelligence quotient EQ and the motive FearControlM. A high value for the motive FearControlM indicates the need to control the own emotional state. In the special case of simulating short time panic situations, the parameter EQ can be supposed not have any dynamic behaviour and thus is modelled as a constant parameter. Arousal is defined as sum of all motive intensities.

If, and only if, an agent's arousal is lower than an individual threshold ThresArousal that is influenced by the agent's EQ and the motive FearControlM is action-leading, the agent is given the chance to enter a reflective phase temporarily and thereby realise that it is the own fear that motivates the agent to execute inappropriate actions. A reflective phase is characterized by a modified computation of the state variable FearS. The related equation considers the agent's EQ in the following way: the higher the EQ the faster the fear state of the agent, and as a direct consequence, the intensity of the motive FearM decreases.

In the suggested modelling approach, the conscious control of emotion is not reserved to reflective agents, but the lower the motive intensity of FearM (and therefore the higher the degree of behaviour control), the more likely the motive FearControlM becomes action guiding. Therefore it is most likely that an emotional intelligent acting agent is a reflective or at least a deliberative one.

7. The motive FearM

The emotional state FearS is connected to the corresponding motive FearM (eq. 17).

$$\text{FearM} = \text{C\_FearMMin} + \frac{\text{C\_FearMMax}}{1 + e^{-\text{C\_FearMInc} * (\text{FearS} - \text{C\_FearMIncMax})}} \tag{17}$$

Figure 12 shows the relation between the motive FearM and the state FearS. The modelling of motives, based upon states, is described in detail in (Schmidt, 2001).

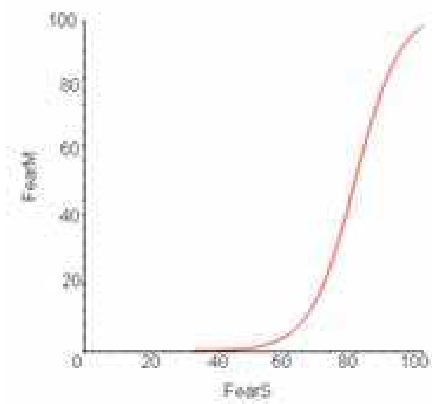


Fig. 12. Relation between FearM (motive) and FearS (state)

8. Gradual reduction and impairment of human behavioural control

The emotional motive FearM is supposed to exert a strong influence on human behaviour in panic situations. The modelling approach addresses this by introducing a fear-based reduction of an individual's ability to control the own behaviour, accompanied by a restriction of the spectrum of available behavioural patterns. Strong fear may prevent an individual from showing phylogenetically highly-developed kinds of behaviour like conscious and planned behaviour. Marked by strong fear, human behaviour is most likely guided by instinct, often expressed by thoughtless flight reactions of panic participants. The reference model encounters these aspects by classifying human behaviour into reactive, deliberative and reflective patterns and by suggesting a gradual reduction of the human behavioural potential in dependence of the intensity of the motive FearM and individual thresholds as depicted in figure 13 on the left hand side.

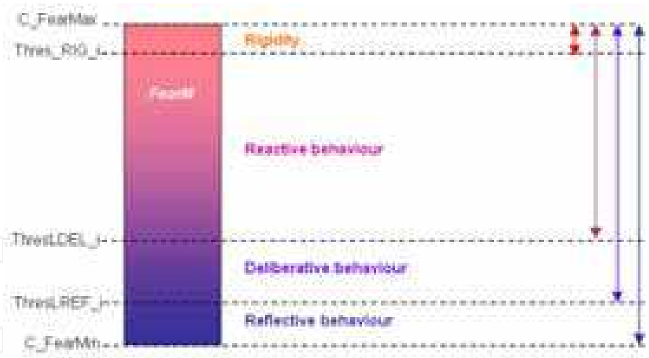


Fig. 13. Impairment of behavioural control

At a low value for the motive FearM (that means FearM ϵ [C_FearMin, ThresLREF_i[), the whole spectrum of behavioural patterns is available. An increase of the motive intensity goes along with a gradual reduction of the set of potential available behaviours from reflective to deliberative and finally reactive behaviour. Very strong fear causes an agent to fall into rigidity. The concrete shaping of behaviour is determined by an agent's personality, individual attitudes, experience, and quality of information about the exact situation as well as familiarity with the place.

The developed concept provides the opportunity to model a behavioural spectrum comprising rigidity, panic-stricken flight response coined by self- preservation, herding as well as cautious flight reactions and altruistic behaviour shown by less fearful or trained human beings such as enforcement officers.

9. Reactive behaviour

Reactive behaviour is to be characterised as instinct-driven or trained. People acting in the reactive spectrum of behaviour are expected to not being able to process complex information and to determine independent flight destinations. Therefore they are reliant on simple information for example visual stimuli like signs or the observation of a fleeing crowd. In the reactive range, SimPan offers modelling solutions for rigidity, wandering around and participating in a mass stampede.

9.1 Rigidity

If a human being suddenly gets very frightened or shocked due to the perception of a threat, it is possible that the ability to move and act is suspended temporarily. Such a state is referred to as rigidity. Accordingly, the modelling approach defines two preconditions (a, b) for rigidity, which must be satisfied by an agent: the intensity of the motive FearM must exceed the individual threshold ThresRIG_i (a) and a fear-inducing event was perceived by the agent recently (b). If both preconditions are satisfied, rigidity is activated. It is implemented as time-consuming internal action, which disables cognitive processes and the execution of external actions and lasts as long as FearM falls below the threshold ThresRIG_i. This can for example be due to the continuous decrease of fear or calming attempts by other agents or technical sources of information.

9.2 Wandering around

In panic situations it can be observed that people start moving in a certain direction without objectively identifiable destination, suddenly stop for a while to apparently realign and subsequently start moving in another direction. It is supposed that these people either have no information about possible flight destinations at all or are not able to process complex information like verbal directions to exits far away due to temporary non-availability of planning processes. To enable an agent to show a similar behaviour, SimPan defines two preconditions (c, d) to be satisfied: the intensity of motive FearM must be in [ThresDEL_i, ThresRIG_i[(c) and the agent possesses no information about a possible flight destination (d). If both preconditions are satisfied, the agent stays at his current position for an individual period of time. Afterwards it determines a preferred direction to move in this direction for a random span of time. The current cycle of movement ends, if the selected span of time is expired or the agent abuts upon an obstacle in the environment. In these cases the next cycle is started. The behaviour of wandering around is repeated as long as the motive FearM leaves the indicated range or an exit gets into the view of the agent. The consequent behaviour of the agent may then be modified in two ways. First, if the agent's fear decreased so that FearM < ThresDEL_i is now able to select a behaviour pattern out of the deliberative spectrum. Second, if the agent's fear increased so that FearM ≥ ThresRIG_i, and it perceived a fear-inducing event, rigidity is enforced.

9.3 Approaching an exit within eyespot and pushing

Reactive agents are supposed not to be able to process most of the information offered by technical sources of information. SimPan suggests that the only information they can handle is the information emanating from an exit within their eyespot. If a reactive agent recognised an exit, it will try to approach it. This can be achieved without employing explicit processes of planning. To initiate this kind of behaviour the strength of the motive FearM must be in the range [ThresDEL_i, ThresRIG_i[and an exit must be within eyespot of the agent. To reach the exit, the agent tries to reduce the difference between the position of the exit and the own position in each step it takes. A simple approach to realise such a strategy is to segment a two- dimensional environment in quadratic cells of different types (e. g. accessible and not accessible), where each cell can be occupied by one agent at a certain point of time. The decision of an agent, which cell next to enter is made anew after each step according to a set of rules. If it is not possible for the agent to come closer to the exit in one step, for example due to obstacles or other agents blocking its way, it tries to exert pressure towards other agents being located on cells which are closer to the exit. If two agents try to enter the same cell using pushing mechanisms, the stronger one is successful. The weaker one has to stay on the current position. If an agent pushes into a cell, which is already occupied by an agent that cannot stand the pressure, the two agents swap their cells. Since pushing is regarded as aggressive, less considerate action, only reactive and deliberative agents use this mechanism in contrast to reflective agents.

9.4 Participation in a mass flight

Reactive agents, not explicitly possessing any information about a concrete flight destination, but being surrounded by other agents that form some kind of flight mass, are carried along with the crowd and orient their movements toward that of their fleeing neighbours. A mass stampede is headed by a reflective or deliberative agent moving consciously towards an exit (or at least towards the coordinates it supposes an exit to be). An agent must satisfy two preconditions to participate in a mass stampede in a non-leading role: the intensity of the motive FearM is in the range [ThresDEL_i, ThresRIG_i[and the agent observes a fleeing crowd. Note that the reactive agents do not know the destination of the mass stampede; they can only use information concerning the direction in which they have to move to follow the deliberative agent. An agent once participated in a mass stampede may also lose track of the crowd again if he gets out of sight and consequently wanders around again.

10. Deliberative behaviour

Deliberative behaviour is characterised by individual and cautious flight reactions directed towards a specific destination. In order to show deliberative behaviour, the value for the dependent variable FearM must be in the range [ThresREF_i, ThresDEL_i[. In this case, an agent is capable of determining a flight destination independently and of developing an appropriate action plan.

10.1 Planning

To choose an appropriate flight destination, deliberative agents are both able to use information already stored in memory and to process new information received from external sources of information such as loudspeakers. If the agent knows about more than one flight destination, it may choose one of them considering some quality factors like distance between its position and the possible flight destination. To reach the target location as quick and unharmed as possible, the employed planning process (e.g. an implementation of the A*- search algorithm) has to account for obstacles and other disturbing factors. By executing a plan, a deliberative agent may start to lead a mass flight. Leading in the case is a passive and "accidental" process, as deliberative agents simply follow their own goals and thereby provide a behaviour pattern which can be emulated by observing reactive agents around. The related modelling approach described below is geared to the principle of wandering ants, where a small number of heading ants provide a "spoor" of pheromones and the remaining population of the ants simply follow this spoor. The intensity of the spoor may decrease depending on the time passed by and atmospheric conditions. SimPan emulates this phenomenon by introducing the capability of deliberative and reflective agents to generate temporary information spheres.

10.2 Construction and update of information spheres

An agent's active potential information sphere (APIS) is a square in the model environment with side length of n cells, where the centre is defined by the cell currently occupied by the deliberative or reflective agent. The APIS satisfies two conditions: $n > 1$ and $(n \bmod 2) = 1$. In the APIS, an agent can spread different kinds of information (e.g. its current flight vector). Other agents entering a sphere can access the information. The active valid information sphere (AVIS) defines a subset of the APIS, excluding cells located in front of the agent (in direction of the agent's movement) and cells belonging to the blind spot of the agent. These are cells in the APIS from which the agent himself cannot be seen – for example due to obstacles like walls or columns. Figure 14 shows the APIS of a deliberative agent.

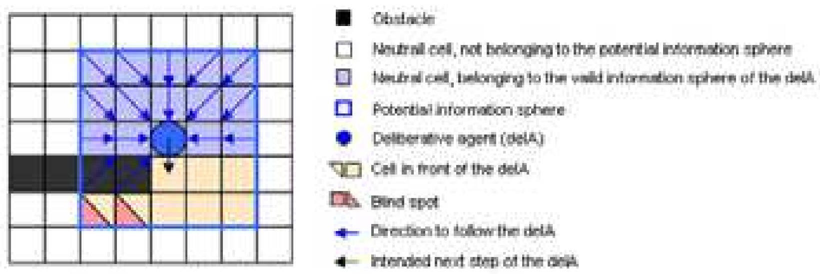


Fig. 14. The information sphere of a deliberative agent

Cells belonging to an agent's AVIS hold the information about which cell has to be entered next by a reactive agent to strictly follow the deliberative agent. By defining the AVIS it is ensured that reactive agents do not run towards the deliberative agent during a mass flight if located in front of it and are only able to join a mass stampede if they immediately observe agents already participating. A new AVIS is generated with each movement of the deliberative agent.

10.3 The Fading of former active information spheres

Just like the pheromone spoor of ants in nature, agent's former AVIS do not release their stored information immediately, but stay active for a period of time, which can be defined arbitrarily. As a consequence, there can be a set of AVIS at a certain point of time belonging to the same agent. If an AVIS expires, the related information stored in the cells is deleted.
Figure 15 shows the set of AVIS of a deliberative agent, where the transparency of the colour of the cells belonging to the AVIS indicates the time to its expiry. The more transparent a cell is, the nearer its time of expiration is.

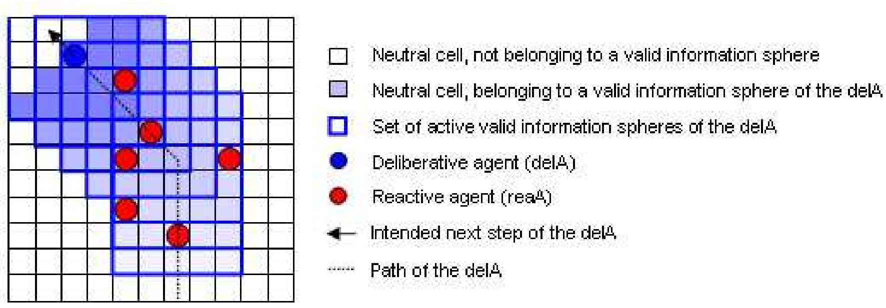


Fig. 15. Fading information sphere of a deliberative agent

10.4. Reflective behaviour

Reflective agents are capable of thoroughly controlling the own behaviour. Deliberative behaviour is therefore expanded by the ability to consciously leading, guiding and calming down reactive agents. An agent's reflective behaviour spectrum is enabled if motive intensity of FearM is in the range [C_FearMin, ThresREF_i[.
SimPan suggests introducing pacification spheres for reflective agents. The pacification sphere of a reflective agent equals the dimension as its information sphere and is not static but moves with the agent. As with the definition of an agent's active potential information sphere, an active potential (APPS) and a valid pacification sphere (AVPS) is defined. The

APPS is defined analogous to the VPIS, whereas just only cells in the blind spot of the agent are excluded in the AVPS. By excluding these cells it is ensured that a reflective agent cannot calm down agents, which are not in sight. A reflective agent does only possess one AVPS at a certain point of time. Figure 16 shows an exemplary pacification sphere of a reflective agent.

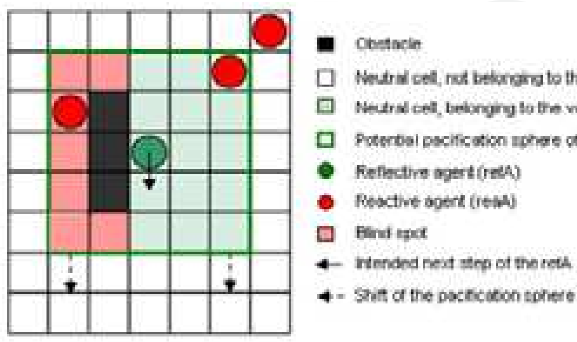


Fig. 16. Pacification sphere of a reflective agent

The fear state of a reactive agent that enters the pacification sphere of a reflective agent decreases discretely. The effect of a calming stimuli recognized by a certain reactive agent decreases with the number of attempts, as defined in equations (eq. 10-13).

11. Content and structure: interplay between SimPan and PECS

To implement the reference model SimPan it is recommended to specify the agent's model structure following the guideline given by the architectural pattern PECS. The reference model SimPan can easily be projected onto the PECS structure to fill its components with content. Internal states and state transition functions defined by SimPan can be assigned to specific PECS model components. Like that, the dynamics calculation of the state variable FearS (5-14) and the motive FearM (17) can be encapsulated in the PECS component Emotion. Further on, the influence of physical pressure on the continuous increase of fear (8, 9, 14) can be realised by employment of a predefined casual dependency between PECS components Emotion and Physis.

12. Potential and Prospects

The reference model SimPan has already been put into practice by integrating the developed modelling concepts into a prototypical agent-based simulation model. The simulation model was developed using the Simplex3- Framework, described in (Schmidt, 2001)

12.1 Case studies

First case studies were done to verify the suitability of the presented modelling approach. Characteristic elements of real panic situations like arching and clogging around exits and casualties due to high pressure exerted by a jostling crowd were observable. Figure 17 shows a screenshot taken from a simulation run with the prototypical simulation model involving 360 agents in an environment composed of 41 x 45 cells, each with a side length of 0.5 meters.

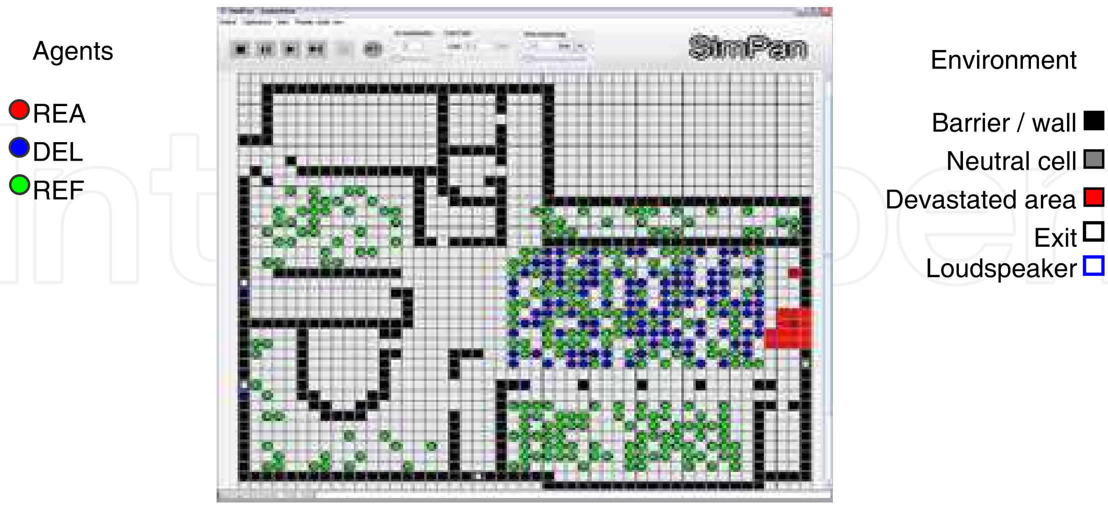


Fig. 17. Screenshot taken from a case study

The scenario is based on a real world panic event that took place on February 20, 2003 in the Station Nightclub in West Warwick, Rhode Island. A fire caused by pyrotechnics near the stage of the club triggered a panic flight towards the main entrance of the club. Egress from the night club was hampered by crowding at the main entrance. In the course of the panic event 96 people lost their lives, 87 were injured.

12.2 Propects

SimPan does explicitly not claim to replace established approaches in the context of evacuation simulations but to complement them and to open up new research areas in the given context. The development of a reference model for agent-based modelling of human behaviour in panic situation seems to be a reasonable step to address research questions that are not sufficiently manageable using existing models, for example where and when to initiate what kind of calming stimuli, how to proceed with panicking people in the crowd or how to detect emotional charge in the environment before it comes to a panic breakout.

The next steps to transfer SimPan from academia into practise are definition of a concrete real world use case (in the best case in cooperation with an external customer), adaptation of the reference model to the specific requirements of the use case, construction of a new SimPan- based simulation model using a high- performance simulation framework to be able to handle even large evacuations scenarios with thousands of people involved and finally calibration of the simulation model in respect of the use case scenario. The aim of calibrating the model is to reduce the set of assumptions to be made regarding initial values for model parameters (especially defining the internal state of a human being to be simulated).

It is important to mention that the success of calibration efforts, especially for simulation models including human factors, strongly depends on the availability of real world data. For this reason, plausibility considerations and face validations done by subject matter experts are often conducted to supplement calibration with “hard” comparison data. Additionally, “intelligent experimentation” by employing the Data Farming methodology can be used to support the calibration process. Data Farming circumscribes selective generation of simulation data by conducting thousands and, if necessary, millions of simulation runs on a high performance computer cluster. Certain Designs of Experiment are employed to determine model parameters to be varied (and thus to define scenarios to be simulated). Analysis of the generated data with the help of distribution plots or regression trees can be done in terms of a sensitivity analysis and can help the analyst to gain important insights into the model dynamics.

13. Summary

In the chapter, the reference model SimPan was presented. SimPan provides as a comprehensive approach for psychologically based modelling of human panic behaviour and follows a system theoretical perspective on modelling of complex systems such as the human being. The reference model itself serves as a conceptual framework for the construction of agent- based models in the given context and offers space for individual adaptation to specific requirements defined by particular fields of application.

Panic is defined as an internal state, marked by the strong emotional motive fear. A high level of fear may prevent an individual from showing certain kinds of behaviour, among them conscious and planned behaviour. More critical, strong fear can additionally lead to thoughtless flight reactions of panic participants. The modelling approach addresses this by introducing a fear-based reduction of an individual's ability to control the own behaviour, accompanied by a restriction of the spectrum of available behavioural patterns.

Additionally, SimPan addresses motivation and mechanisms of motive dynamics and motive selection in particular, social influence on the emergence of emotion, attitude and action and emotional intelligence and the ability of consciously controlling emotion and different kinds of human behaviour, categorised as reactive, deliberative and reflective.

As a basis for modelling the concepts of human panic behaviour, the architectural pattern PECS was considered. The PECS reference model provides capabilities for object- oriented model specification. Its application area is settled in the field of agent- based simulation. PECS offers a modular but comprehensive view of human behaviour modelling, where a human being is considered an autonomous creature with physical conditions, emotional states and cognitive capabilities, embedded in a social environment.

Experiments with a simulation prototype based on the reference model SimPan reproduced characteristic elements of real panic situations like arching and clogging around exits, propagation of pressure in the environment and an increased the emotional charge of individuals during an evacuation situation. In a next step, model parameters should, as good as possible, be calibrated. This sophisticated task mainly depends on the availability of real world data concerning human behaviour in panic situation.

The model is intended for employment in the field of analysing and testing kinds of behaviour and strategies to avoid panic. Simulating the complexity of panic situations in an adequate way also includes emergent phenomena and gives the analyst the possibility to identify specific dangerous situations that could be avoided by changing the procedure of an operation or some parts of the infrastructure. Possible fields of application are hereby mass meetings of political kind, sporting events, fires in closed rooms, acts of terrorism in public places or air accidents. The intersection of all mentioned scenarios is the need to develop strategies to evacuate people from danger zones in a systematic manner without triggering panic behaviour. Figure 18 gives an overview about relevant parameters of the reference model SimPan.

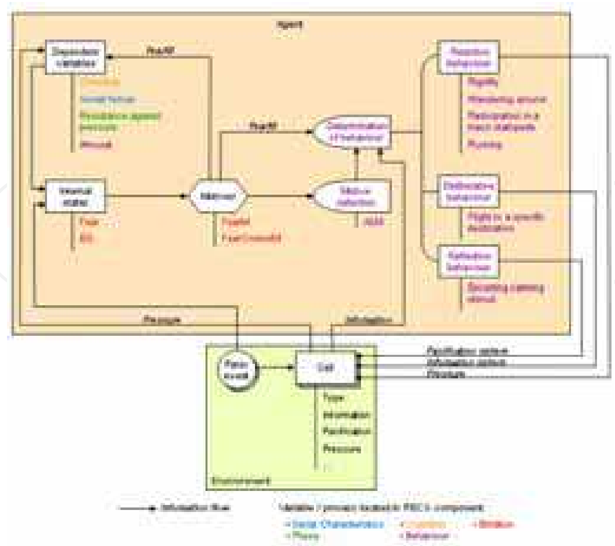


Fig. 18. Graphical representation of the reference model SimPan

14. References

Banarjee S., Grosnan C. & Abraham A. (2005). Modeling Crowd Behavior Using Emotional Ants. *Journal of Studia Universitatis Babes-Bolyai, Informatica*, Volume L, Number 1, 2005, pp. 37-48

Becker, C. & Schmidt, B. (2005)., Bewegung von Menschenmengen - Agentenbasiertes Simulationsmodell zur Untersuchung von Drängel- und Druckmechanismen. *Proceedings of the ASIM2005*, pp. 792-794, ISBN : 3-936150-41-9, Erlangen, September 2005, SCS Publishing House, Erlangen

Cañamero, D. (1997). Modeling Motivations and Emotions as a Basis for Intelligent Behaviour. *Proceedings of the First International Symposium on Autonomous Agents (Agents '97)*, pp. 148-155, Marina del Rey, February 1997, The ACM Press, New York

Daamen, W. (2002). SimPed: a Pedestrian Simulation Tool for Large Pedestrian Areas, *Proceedings of the European Simulation Interoperability Workshop 2002*, London, June 2002

Dörner, D. (1999). *Bauplan für eine Seele*, Rowohlt Verlag, ISBN : 3499611937, Reinbeck bei Hamburg.

Dombrowski, W. R., Pajonk, F. - G. (2005). *Panik als Massenphänomen*. Der Anaesthesist, 54, 2005, pp. 245-253

Foreman, P. B. (1953). Panic Theory, *Sociological and Social Research*, 37, 1953, pp. 295–304

Gipps P. G. & Marksjö M. (1985). A microsimulation model for pedestrian flows, *Mathematics and Computers in Simulation,* 27, 1985, pp. 95-105

Heinz, W. R., Schöber, P. (1972). Kollektives Verhalten – Alte Fragen, neue Perspektiven, In : *Theorien kollektiven Verhaltens Band 1,* Heinz, W. R. & Schöber, P. (Eds.), Hermann Luchterhand, 9783472611189, Darmstadt

Helbing, D., Illés F. & Vicsek T. (2002). Crowd disasters and simulation of panic situations, In :*Science of Disaster: Climate Disruptions, Heart Attacks and Market Crashes*, Bunde, A., Kropp, J., Schellnhuber, H. J. (Eds.), pp. 193–216, Springer, 3540413243, Berlin Heidelberg.

Kirchner, A. & Schadschneider, A. (2002). Simulation of evacuation processes using a bionic-sinspired cellular automaton model for pedestrian dynamics. *Physica A*, 312, 2002, pp. 260-276

Klinger, A. (1999). *Referenzmodelle für die Abbildung von Personalsteuerung in der Simulation*, SCS, 156555129X, Erlangen.

Kruse, L. (1986). Conceptions of Crowds and Crowding, In : *Changing Conceptions of Crowd Mind and Behavior*, Graumann, C. F. & Moscovici, S. (Eds.), pp 117–142, Springer, 9780387961873, New York

Langer E. J. & Saegert S. (1977). Crowding and Cognitive Control. *Journal of Personality and Social Psychology*, 35, 3, 1977, pp. 175-182

Latané, B. (1981). The Psychology of Social Impact. *American Psychologist,* 36, 1981, pp. 343-356

LeBon, G. (1982). *Psychologie der Massen*. Kröner, 9783520099150, Stuttgart

Mann, L. (1999). *Sozialpsychologie*, Beltz Verlag, 9783407220424, Weinheim, Basel

Mayer, J. D. & Salovey, P. (1997). What is Emotional Intelligence? In : *Emotional development and emotional intelligence*, Salovey, P. & Sluyter D. (Eds.), pp. 3-32, BasicBooks, 0465095879, New York

Mummendy, A. & Otten, S. (2002). Aggressives Verhalten. In: *Sozialpsychologie. Eine Einführung*, Stroebe, W., Jonas, K. & Hewstone, M. (Eds.), Springer, 9783540420637, Berlin

Muramatsu, M., Irie, T. & Nagatani, T. (1999). Jamming transition in pedestrian counter flow. *Physica A*, 267, 1999, pp. 487- 498

Quarantelli, E. L. (2001). The Sociology of Panic. In*: International Encyclopedia of the Social and Behavioral Siences*, Smelser, N. J., Baltes, P. B. (Eds.), pp. 11020-11030 , Pergamon Press, 9780080430768, Elsevier

Quarantelli, E. L. (1954). The Nature and Conditions of Panic. *The American Journal of Sociology*, Vol. 60, No. 3, Nov. 1954, pp. 267-275

Reicher, S. (2001). The Psychology of Crowd Dynamics. In: *Blackwell Handbook of Social Psychology : Group Processes*, Hogg, M. A. & Tindale, S. R. (Eds.). pp. : 182-208, Blackwell, 9780631208655, Oxford

Schmidt, B. (2000). *The Modelling of Human Behaviour*, SCS-Europe BVBA, 1565552113, Ghent

Schmidt, B. (2001). *The Art of Modelling and Simulation - Introduction to the Simulation System Simplex3*. SCS- Europe BVBA, 1565552288, Ghent

Schmidt B. & Schneider, B. (2004). The Reflective Control of Cognition and Emotion, *Proceedings of the 2004 Operational Research Society Simulation Workshop*, Birmingham, May 2004

Schulz, D. (1964). *Panic Behavior. Discussion and Readings*. Random House, New York

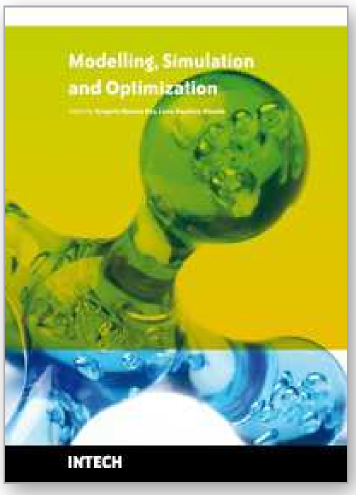
Sloman, A. (2000). Architectural requirements for human-like agents both natural and artificial. (What sorts of machines can love?), In: *Human Cognition and Social Agent Technology, Advances in Consciousness Research*, Dautenhahn, K. (Ed.), pp. 163-195, John Benjamins, 1556194358, Amsterdam

Stokols, D., Rall, M., Pinner, B. & Schopler, J. (1973). Physical, social and personal determinants of the perception of crowding. *Environment and Behaviour*, Volume 5, 1973, pp. 87-115

Urban, C. (2007). *Der Mensch im Simulationsmodell*, VDM Verlag Dr. Müller, 9783836420532, Saarbrücken

Urban, C. (2000). PECS: A Reference Model for the Simulation of Multi-Agent Systems, In : *Tools and Techniques for Social Science Simulation*, Ramzi S., Troitzsch, K. G. & Gilbert, N. (Eds.), pp. 83-114, Physica-Verlag, 379081265X, Heidelberg

Vassalos, D., Kim, H., Christiansen, G. & Majumder, J. (2002). A Mesoscopic Model for Passenger Evacuation in a Virtual Ship-Sea Environment and Performance-Based Evaluation, In : *Pedestrian and Evacuation Dynamics*, Schreckenberg, M. and Sharma, S. (Eds.), pp. 369-392, Springer, 3540426906, Berlin



Modelling Simulation and Optimization

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Computer-Aided Design and system analysis aim to find mathematical models that allow emulating the behaviour of components and facilities. The high competitiveness in industry, the little time available for product development and the high cost in terms of time and money of producing the initial prototypes means that the computer-aided design and analysis of products are taking on major importance. On the other hand, in most areas of engineering the components of a system are interconnected and belong to different domains of physics (mechanics, electrics, hydraulics, thermal...). When developing a complete multidisciplinary system, it needs to integrate a design procedure to ensure that it will be successfully achieved. Engineering systems require an analysis of their dynamic behaviour (evolution over time or path of their different variables). The purpose of modelling and simulating dynamic systems is to generate a set of algebraic and differential equations or a mathematical model. In order to perform rapid product optimisation iterations, the models must be formulated and evaluated in the most efficient way. Automated environments contribute to this. One of the pioneers of simulation technology in medicine defines simulation as a technique, not a technology, that replaces real experiences with guided experiences reproducing important aspects of the real world in a fully interactive fashion [iii]. In the following chapters the reader will be introduced to the world of simulation in topics of current interest such as medicine, military purposes and their use in industry for diverse applications that range from the use of networks to combining thermal, chemical or electrical aspects, among others. We hope that after reading the different sections of this book we will have succeeded in bringing across what the scientific community is doing in the field of simulation and that it will be to your interest and liking. Lastly, we would like to thank all the authors for their excellent contributions in the different areas of simulation.

Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821