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Intelligent Scenario Development for Computer Assisted eXercises

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ABSTRACT: Scenario development for Computer Assisted eXercises (CAX) is a very ambitious area in the Crisis management field. Generally, the reason for this is that CAX allows real world crises and objects translation in the more flexible digital world. The greatest challenge here is the consideration of terrorist attacks representation, modelling and simulation, where the information uncertainty is too high. This paper presents an ad hoc created methodology and tool for scenario development, based on the application of brainstorming, Intuitionistic Fuzzy Sets and random numbers, implementation in a real CAX system.

KEY WORDS: Scenario development, CAX, crisis management, intuitionistic fuzzy sets, modelling, simulations

Introduction

Scenario Development for CAX is a very important and complex topic of the Crisis Management (CM) area [1], [2], [3].

Here it should be noted that as far as Scenario Development is a part of the modelling and simulation process of CAX, a lot of techniques for this are already known [4], [5].

The model creation, in the wide-spread sense of this notion, is considered to be one of the basic mechanism of human thinking process, which is accomplished in logic, mathematics and philosophy [6]. The very application of the notion "model", however assumes representation of a certain set of characteristics of the object of interest. This disadvantage, allows representation of different aspects of the modelled objects.

With the emerging appearance of computers [7], the model utilization becomes a foundation of the computer simulation [8], which, on the other hand, allows an empirical test of a certain hypothesis or assertion, and also becomes a motive for emerging of the Operations Research area.

Finally, a single and unique definition of the notion "model" from the modern scientific point of view is significant only in the context of a certain problem, because the simulation could also be considered as a model of action.

So, in general the notion “model” could be considered as a virtual concept that gives a clear idea for the targets that should be reached in the process of modelling real objects and simultaneously provides abilities for objects properties modification in the sense of “model”.

The application of a certain model is closely related to the ability for changes in its present, past and future parameters during and/or after a certain simulation process and is the sine qua non of model connectivity of the real (object) and virtual (model) environment through an experimental framework, known in Cybernetics as a “feed-back principle” [9].

Here it should be noted that in accordance with the model’s generic logic the simulation process is also model dependant.

This short discussion about modelling and simulation is graphically generalized on Figure 1:

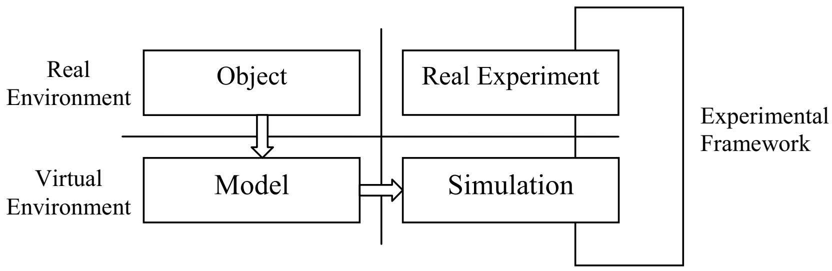

Figure 1. A graphical generalization of the modelling and simulation concepts

So, as it is clear from the above discussion and Figure1, the scenario development could also be considered as a kind of modelling and simulation by means of a certain situation representation in the context of CAX.

1. Methodology

The approach that has been chosen in this paper is based on the utilization of the well-known Systems Theory [10], [11], because the object of interest is a complex system with complicated behaviour.

As far as scenario development for CAX could be considered as a multi-aspect problem, and especially in Crisis management [3], the very scenario could be reckoned to be a complex dynamic system with a lot of objects and time-dependant relations.

Additionally, the real situation interpretation is always under discussion. So, here as a first step a brain-storming [5] approach was chosen.

This approach allows implementation of experts' knowledge in the described complex system, which to some extent, could be easily transformed into the machine world (virtual environment) in a certain scenario context.

The second, more technical step is choosing formalism for the above-mentioned knowledge machine interpretation. Finding solution of this problem is also a very controversial, so here a more general approach that considers knowledge representation on a meta-level was chosen.

This approach is the famous Entity-Relationship (E-R) model for machine data/knowledge representation [12], which shows a nice closure to the reality.

On Figure 2 a graphical interpretation of the E-R model is given:

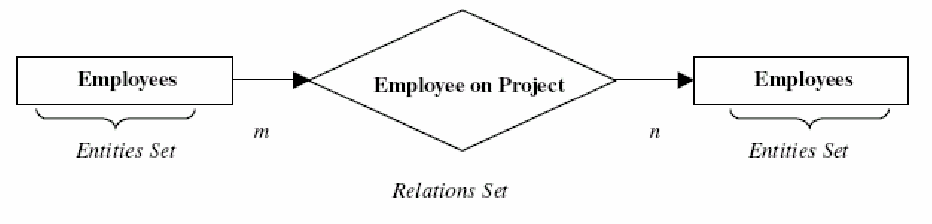

Figure 2. A graphical interpretation of the E-R model

As it is clear from Figure 2, the implementation of the E-R model allows working with sets of objects by means of real ones in two different aspects that utilize the cause-effect modus.

To be more realistic and close to the real world the next step was to add weight and time lag to the relations between different objects in the scenario.

At this third step, a very simple and intuitive approach was accepted again. The idea is to utilize relationship weighting and timing in a discrete value scale.

However, generally, the scale discretization puts a lot of questions about the accuracy that in combination with the information reliability can make this step very difficult and complex.

For partial solving of this, the fourth step is established. This step considers the information uncertainty of the relations' weights. It is known that the uncertainty problem has been considered from long ago [13], and though the Shannon's Information Theory achievements [14] and lots of other probabilistic approaches [15], [16] still has no universal solution, which has no a reasonable answer and is still an open problem from a long time [17].

Here a modification of the fuzzy sets [18] – intuitionistic fuzzy sets [19] is proposed because it removes the necessity of statistic analyses and directly offers abilities for uncertainty manipulation [20].

According to [19] IFS A^* in E is an object that has the following form:

(1) $$A^* = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in E\},$$

where: $\mu_A : E \to [0,1]$ and $\nu_A : E \to [0,1]$ are functions defined over an usual set A that defines the degrees of membership and non-membership of the element x from the fixed set E (called universe of disclosure) to A^*, shortly marked as A.

The sum of functions μ_A and ν_A values, is limited by the inequality:

(2) $$0 \leq \mu_A(x) + \nu_A(x) \leq 1$$

In accordance with the right constraint of (2), the function π_A that determines the degree of uncertainty, could be defined as follows:

(3) $$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x),$$

where: $\pi_A : E \to [0,1]$ is a function that determines the degree of uncertainty of x, $x \in E$.

Finally, one of the graphical interpretations of IFS is shown on Figure 3:

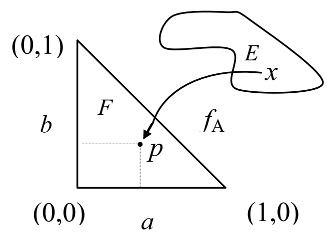

Figure 3. One of the graphical interpretations of IFS [19]

Here it should be noted that a and b refer to the values of the membership (μ_A) and non-membership (ν_A) functions limited in the interval [0, 1] of an IFS point p.

After defining (1) - (3), another useful definition of an operator for uncertainty modification will be given [19]:

(4) $\Box A(x) = \{\langle x, \mu_A(x), 1-\mu_A(x)\rangle \mid x \in E\}$;

(5) $\Diamond A(x) = \{\langle x, \nu_A(x), 1-\nu_A(x)\rangle \mid x \in E\}$;

(6) $F_{\alpha,\beta}(A) = \{\langle x, \mu_A(x) + \alpha.\pi_A(x), \nu_A(x) + \beta.\pi_A(x)\rangle \mid x \in E\}$,

(7) $\alpha + \beta \leq 1, \alpha, \beta \in [0, 1]$,

where: $\Box$ is "necessity", $\Diamond$ is "possibility" (known from modal logic [21]) and all other notations have the meaning discussed above (see IFS definition).

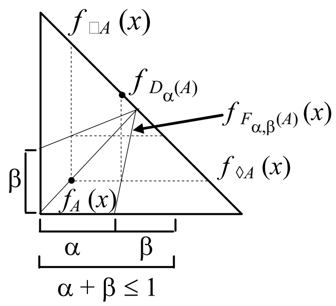

Figure 4. A graphical interpretation of the operator $F_{\alpha,\beta}$

As it is clear from IFS definition they directly treat the uncertainty problem in a very convenient manner if an assumption for a random number generator [22] for the values of α and β implementation is made and constraint (7) in (6) is taken into account.

Finally, the application of IFS tool for uncertainty manipulation provides ability to work in real environment by means of notions like: degree of truth, degree of falsity, degree of truth & falsity, which practically supports the scenario development, because usually the knowledge for the modelled situation is insufficient.

2. Software Implementation

In this section a software implementation of the methodology from section 1 will be revealed.

On Figure 5 and Figure 6 screen-shots from a software application - I-SCIP (Intelligent Scenario Computer Interface Program) of the methodology from section 1 are given.

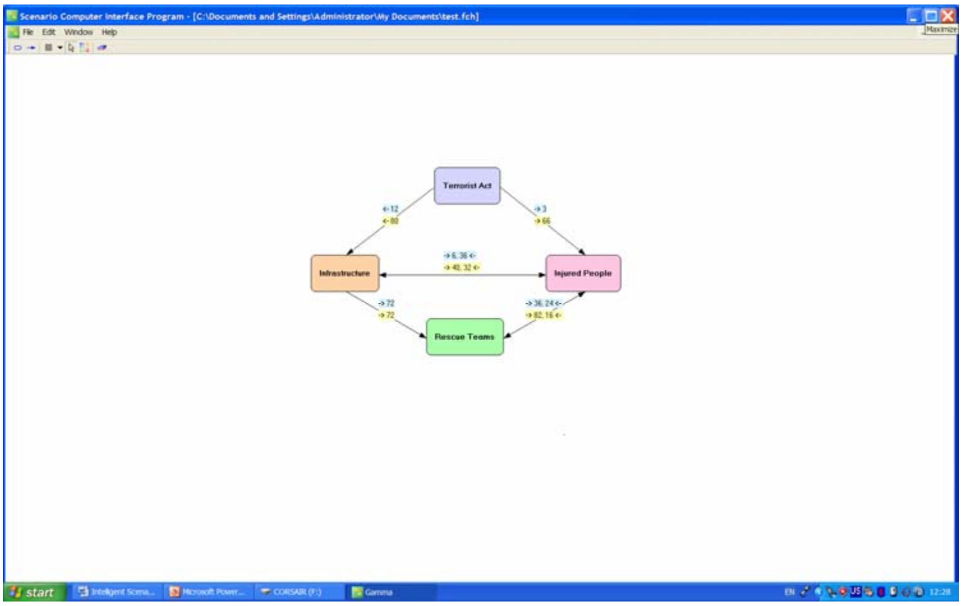

Figure5. A screen-shot of the I-SCIP software application

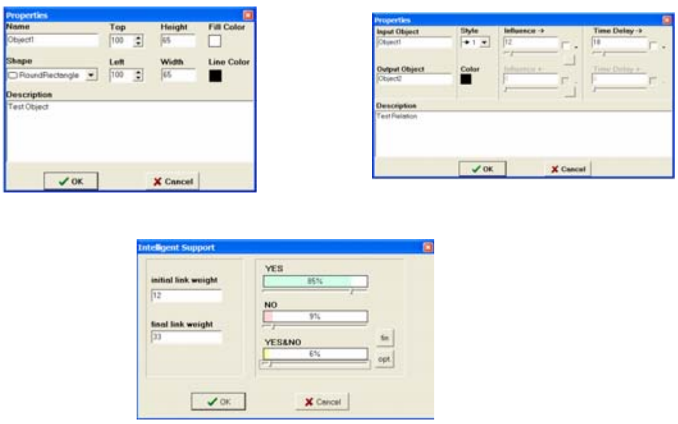

Figure 6. Screen-shots of the object/relations properties management

In the I-SCIP program, the discussed idea for uncertainty manipulation is directly embedded with the assumption for the degree of truth (μ_A) as a first step of the experts' evaluation of a certain relation weight. The program allows combination of floating point uncertainty calculations and discrete integer percentage based scale for the input data.

Finally, the calculated weight of a certain relation could be interpreted either as a value of some of the degrees of truth, falsity or uncertainty, to which the expert is mostly trusted or as an average value of these three degrees.

In accordance with the relations' directions and their weights, a heuristic classification of the objects included in the scenario is made. This classification is similar to the one developed in [23], but concerns more peculiar problems for the certain scenario of interest. All the results of this classification are generalized in a sensitivity diagram (see Figure 7):

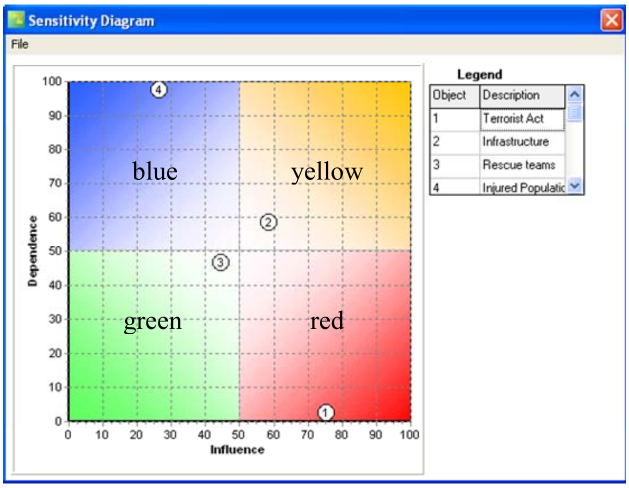

Figure 7. A screen-shot of the sensitivity diagram of I-SCIP

As it is clear from the sensitivity diagram screen-shot (Figure 7) the classification in I-SCIP allows distribution of the objects from a scenario into four basic sectors, edge gradient coloured in green, red, yellow and blue (inscribed internally on Figure 7).

The disposition in a certain region for a given object is accomplished on the basis of normalized weights sums (in 100/100 measurement scale) of the input and output relations with the assumption of influence (input arrows weights normalized sum) and dependence (output arrows weights normalized sum) classification.

Here it should be noted that in the green sector there are objects that in accordance with the experts' evaluation are not critical for a certain scenario (model) of interest – influence/dependence maximum ratio (IDMR) = 50/50. The red sector is filled up with critical objects, which however are not manageable for the scenario of interest (e.g. a terrorist attack), IDMR =100/50.

At the end in the blue and yellow sectors objects with IDMR = 100/50 (blue) and 100/100 (yellow) are positioned. These sectors represent balancing and subcritical objects, which are usually of the highest interest in CAX scenario for CM.

Finally, it should be mentioned that I-SCIP supports its own comma separated file format for the developed scenarios storing and MS Excel interoperability by means of relations weights and time lags matrix representation.

3. Conclusion

The revealed methodology for scenario development with application for CAX as a part of CM allows a very flexible and intuitive work on one hand and on the other gives an opportunity for implementation of Systems Theory, intelligent uncertainty manipulation by means of IFS application in combination with brainstorming and random numbers.

Further development of the I-SCIP is planned to be in the direction of time lags distribution diagram and implementation of the agent-based modelling and simulation approach.

The I-SCIP program has been already successfully experimented in a real CAX – EU TACOM SEE 2006 [24] as a part of the Joint Training Simulation & Analysis Center in Civil-Military Emergency Planning/Response (JTSAC – CMEP) - Analytical Center.

Additionally, this program is planned to be a part of the contribution of Center of Excellence in Operational Analyses (CoE-OA) in NATO RTO MSG-049 project [25].

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