2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

A VIRTUAL ENVIRONMENT FOR SIMULATION OF RADIOLOGICAL ACCIDENTS

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ABSTRACT

A virtual environment is a computer environment, representative of a subset of the real world, and where models of the real world entities, process and events are included in a virtual (three-dimensional) space. Virtual environments are ideal tools for simulation of certain critical processes, such as radiological accidents, where human beings or properties can suffer irreversible or long term damages. Radiological accidents are characterized by the significant exposure to radiation of specialized workers and general public. The early detection of a radiological accident and the determination of its possible extension are essential factors for the planning of prompt answers and emergency actions. This paper proposes the integration of georeferenced representation of the three-dimensional space and agent-based models, with the objective to construct virtual environments that have the capacity to simulate radiological accidents. The three-dimensional georeferenced representations of space candidates are: i) the spatial representation of traditional geographical information systems (GIS), ii) the representation adopted by Google Maps*TM*. Adding agents to these spatial representations allow us to simulate radiological accidents, quantify the doses received by members of the public, obtain a possible spatial distribution of people contaminated, estimate the number of contaminated individuals, estimate the impact on the health-network, estimate environmental impacts, generate exclusion zones, build alternative scenarios and train staff to deal with radiological accidents.

1. INTRODUCTION

Radiological accidents are characterized by the significant exposure to radiation of workers and the members of the public. These accidents usually occur as a result of human activity involving radioactive substances in various sectors: industries, hospitals and power generation [6].

The hard effects of radiological accidents, such as injuries and environmental contamination, lead the national government to establish mechanisms for national and international inspection on nuclear or radioactive applications. In September 1987, Brazil population suffered a great impact with the radiological accident in Goiania. In this event, a radioactive source of Caesium-137, used in radiotherapy equipment, was accidentally dispersed among the population and the environment. The source activity was 50.9 TBq and the chemical form was highly soluble caesium chloride salt. This fact had, in addition to the contamination of urban areas, contaminated 249 persons with high doses radiation, injured 20 persons with hematological disorders and led 4 persons to death. Shares and defensive measures involving 575 professionals were extended for 6 months, 41 houses were evacuated and 3,500 tons of residues were generated and surveyed [1].

The early detection of a radiological accident and determination of its possible extension are essential factors for the planning of immediate actions and following emergency procedures. The effects of radiological accidents on humans can be minimized if some actions can be taken to avoid contamination or exposure of individuals, such as, appropriate medical treatment and fast establishing of exclusion zones.

When a radiological accident occurs and members of the public, that do not use personal dosimeters, are involved other methods for the assessment of their doses must be done. These methods may be [5]: modelling of exposure, physical reconstruction of exposure or biological dosimetry.

The modelling uses up basically of equations, such as:

- the rate of dose:

$$\dot{X} = \Gamma .\, A/d^2 \qquad (1)$$

  where:
  - $\dot{X}$ = rate of dose, in mSv / h (Siviert / hour);
  - A= The source of activity, in Bq (Bequerel);
  - d = distance between the source and measuring point, in meters;
  - Γ = constant characteristic of any radioactive source (range factor), in $(mSv.m^2) / (h.Bq)$.

- the absorbed dose:

$$D = \dot{X}.t \qquad (2)$$

  where:
  - D = absorbed dose, in Gray (Gy);
  - t = time of exposure, in hours (h).

The traditional model of calculation based on mathematical formulas can provide a first estimate of the doses received. This very simple calculation does not taking into account the possible barriers between the source and the target. On the other hand, these information generally are very difficult to obtain [5].

The physical reconstruction of an accident involves some factors, such as, the knowledge of realistic environmental conditions in which the accident occurred; the use of phantoms to simulate the individuals involved; the use of radioactive sources and personal dosimeters; etc. Other important aspects are the reconstruction of the real scenario and the costs involved. All these aspects must be considered to the physical accident reconstruction and can be a great limitation.

The biological dosimetry method is based on use of biological samples, from individuals who were subjected to exposure / contamination of radioactive material, as a means to evaluate the doses received. For example, the analysis of urine is used to evaluate the absorption of Tritium, while the cytogenetic analysis is generally used to estimate the effective dose from external radiation [5]. The main limitation of this method is related to the collection of biological samples, since not always have access to individuals who suffered an exposure and / or contamination.

2. A VIRTUAL ENVIRONMENT FOR SIMULATION

At this work, the environment means:

- i) the set of circumstances, objects or conditions involving a particular entity;
- ii) the complex of physical, chemical and biotic factors (such as climate, soil, living beings) that act on a body or a community ecological and ultimately determine its form and survival.

A virtual environment would then be a computational environment that represents the real environment with virtual entities, also representative of real entities (Figure 1). Usually the real environment is a three-dimensional space with real entities, objects, people or animals that interact with each other and with the environment. The virtual entities are virtual computational abstractions of real entities. In general, users can interact with the virtual environment and simulate phenomena or processes that would be impossible to reproduce in the real world, due to security issues or excessive cost. For these reasons the virtual environments are ideal tools for the simulation of certain critical processes, such as radiological accidents. [3], [4]

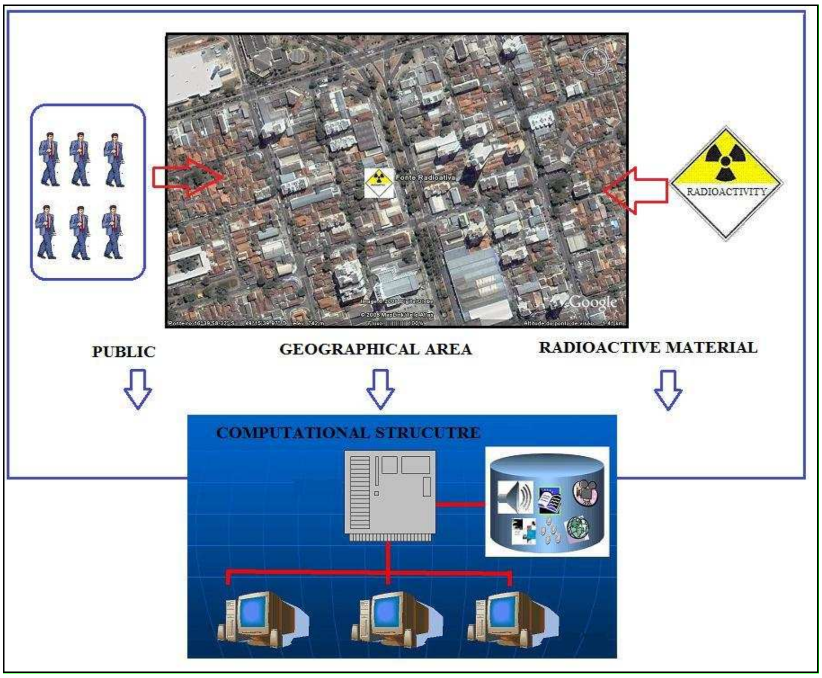

Figure 1: Simulation model

This project proposes to integrate georeferenced representations of three-dimensional space and models based on intelligent agents, with the goal of building virtual environments that have the ability to simulate radiological accidents. The three-dimensional representations of space georeferenced candidates are: i) the spatial representation of geographical information systems, ii) the representation adopted by Google Maps*TM*.

The representation of the area selected (e.g. shape file or Google Maps*TM*) will be the virtual environment that will be inserted into the virtual entities representing objects in the real world. They are virtual computer abstractions, called software agents, which represent different types of actors of the real world - from animated beings with a high degree of intelligence, to beings with basic behavior. The agents can interact with each other and are scheduled to be pro-active entities, autonomous, endowed with behavior with greater or lesser degree of intelligence and able to understand the environment in which they are immersed. [2] [3]

A greater degree of realism in simulations and models based on agents can be achieved integrating it the technologies of agents, geographical information systems and data acquisition via satellite. In other words, the virtual environments in which the agents will act will be a two-dimensional description (digital maps) or three-dimensional (digital elevation models) very close to reality as those displayed on tools like Google Maps*TM* . It is possible to achieve, therefore, a model space (environment) very accurate, upon which the agents, with their attributes and behaviors, are positioned initially and, during a simulation time, interact with each other and the environment, simulating the dynamic processes or phenomena.

The phenomenon or process, that will determine whether to study the properties of the environment that should be spread or represented, as the inclusion of redundant properties, would increase the complexity of the system. Similarly, in the process of modeling of agents are selected the most appropriate behavior and properties to represent the actors found in the real world.

In the proposed virtual environment, both radioactive sources, as individuals subject to exposure, will be modeled by agents. For example, the modeling of the sources will be based on the formula of radioactive dispersal in the air $\dot{X} = \Gamma.\ A/d^2$, taking into account the radionuclides and their activity, the distance of people exposed to radioactive element, the time of exposure, as well as possible objects (shields) that offset the radiation received. An official representative of a radioactive source will have to state the following variables:

i) an identifier to the source;
ii) the position of the source, given by its coordinates;
iii) the former activity;
iv) the factor Γ for the specific source;
v) a factor of quality CF, used to measure the dose absorbed with regard to its alleged biological effectiveness.

A typical agent, representative of a person, possesses the following variables of state:

i) identification of the person;
ii) its position, given by its coordinates;
iii) time of exposure;
iv) the dose absorbed;
v) the effective dose.

One of the most interesting aspects of the virtual environment would be the ability to concentrate and see the information on a radiological accident in a graphical interface similar to that of Google Maps*TM*. Agents of various types (sources and individuals) could be positioned arbitrarily representation in this space. The radioactive sources, zones of exclusion and spatial distribution of people possible contaminated appear on a map for easy viewing and understanding.

2.1 – Methodology for the construction of a virtual environment

The methodology for building a virtual environment consists of the following steps [7]:

- Formulation of the problem: defining the problem to be studied, including the goal of the solution.
- Set goals and planning of the project: raising the questions that should be answered by simulation and the scenarios that will be investigated. The planning of the project will give the necessary time, resources, hardware, software and people involved, controls and outputs to be generated.
- Create conceptual model: hold an abstraction of the system of the real world that is being investigated on a mathematical model and relational logic.
- Collect data: identifying the data required for simulation.
- Building the model: build the model using a conceptual tool for simulation.
- Test whether it is true: verify that the implementation of this model being done correctly.
- Test is valid: verify that the model is a conceptual representation reasonably "accurate" system of the real world.
- Simulate scenarios: defining various scenarios and their parameters.

- Run and analyze the scenarios: estimate measures of performance for the scenarios that are being simulated.
- Generate documentation and report: provide information on the result of the executions carried out.
- Implement: based on the simulation performed to determine actions to be taken for the solution of the problem that is investigated.

3. THE AVSAR SYSTEM

The Virtual Environment for the Simulation of Nuclear and Radiological Accidents (AVSAR) proposed is very useful in the simulation and evaluation of real accidents [8]. The AVSAR will be based on a URL (website Home), accessible via a web browser (Figure 2).

Figure 2: AVSAR´s login

On the home page the user will enter the position of the radioactive source, defined by latitude and longitude of the same, according to the reference system WGS-1984. Then the user must supply the type and source activity. From equations (1) and (2) the AVSAR will calculate the exposure, absorbed dose, effective dose, possibly considering shielding effects. How effective dose (which is the quantity that really matters) depends on the exposure time, the AVSAR will draw concentric circles around the source indicating the effective doses received at a level that may affect health, indicating the exposure time required to achieve these doses. Both circles as the exposure time can be changed interactively by the user, resulting in different values of effective doses (Figure 3 and 4).

Figure 3: AVSAR - location of the radioactive source

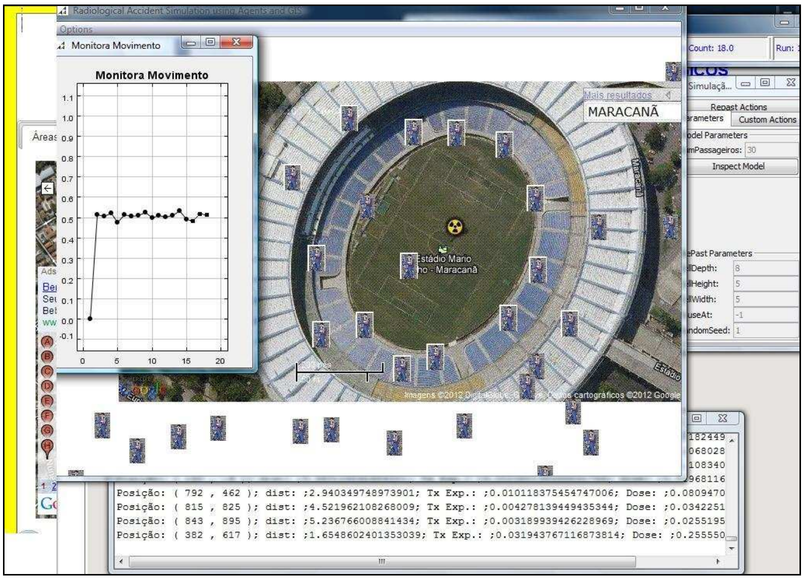

Figure 4: AVSAR – dose calculation in public

Finally, using the Google API's Maps^{TM} is possible to (Figure 5):

- Locate hospitals, schools and / or other institutions in a predetermined radius around the source;
- Draw polygons or circles to establish an exclusion zone around the source;
- Check alternate routes for the movement of vehicles and persons;
- Inform the public about the consequences of the accident by bands of distance from the source.

Figure 5: AVSAR - schools location, near the geographical area of radiological accident.

4. CONCLUSIONS

With the use of a virtual environment (AVSAR), focusing on simulation of radiological accidents, the final user can:

- Quantify the doses received by individuals;
- Have any partial distribution of people contaminated;
- Estimate the number of infected individuals;
- Estimate the impact on the network of health;
- Estimating environmental impacts;
- Generate zones of exclusion;
- Define emergency response and quick;
- Build alternative scenarios;
- Train technical staff to manage radiological accidents.

ACKNOWLEDGMENTS

We thank the Instituto de Radioproteção e Dosimetria (IRD) for the support in the development of this project.

REFERENCES

1. International Atomic Energy Agency, IAEA, The Radiological Accident in Goiânia, Vienna, Austria, 1988.
2. Wooldridge, M. J. An Introduction to MultiAgent Systems. John Wiley & Sons Ltd, April, 2002.

3. M. J. Wooldridge, and N. R. Jennings, “Agents theories, architectures, and languages: a survey.” In Proceedings of ECAI’94 Workshop on Agent Theories, Architectures and Languages, 1995, pp.1-22.
4. Silva, Tadeu Augusto de Almeida ; Farias, O. L. M. ; SANTOS, Neide dos . Simulating Radiological Accidents through Software Agents. In: International Conference on Intelligent Agents, Web Technologies & Internet Commerce – IAWTIC, 2006,Sydney.
5. International Atomic Energy Agency, IAEA, The Radiological Accident in Cochabamba, Vienna, Austria, 2004.
6. Tadeu Augusto de Almeida Silva and Oscar Luiz Monteiro de Farias (2012). Methodology for the Construction of a Virtual Environment for the Simulation of Critical Processes, Applications of Virtual Reality, Dr. Cecília Sík Lányi (Ed.), ISBN: 978-953-51-0583-1, InTech, DOI: 10.5772/35595. http://cdn.intechopen.com/pdfs/36542/InTech-Methodology_for_the_construction_of_a_virtual_environment_for_the_simulation_of_critical_processes.pdf (2012).
7. Banks Jerry , “Handbook of Simulation, , Principles, Methodology, Advances, Applications and Practice”, Emp Books, 1998.
8. Silva, Tadeu Augusto de Almeida. Uso de ambientes virtuais para a simulação de acidentes radiológicos . Tese (Doutorado) – Universidade do Estado do Rio de Janeiro. CDU 004.946. (2012).