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# THE APPROACH FOR RANDOM OBJECTS CREATION WITHIN THE FRAMEWORK OF PRIMARY RADAR SENSOR MODELLING

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***Abstract:*** *The paper contains a description of the factors that affect the process of radar sensor modelling. The radar sensor is not modelled in terms of its technical implementation, but the attention is concentrated on the nature of the output information, which is provided by a realistic primary radar sensor. In the paper there is presented a topic related to the creation of false targets (random targets) in the process of the primary radar sensor modelling. The topic primary radar sensor modelling was solved within the dissertation thesis at Air Defence Systems Department at University of Defence in Brno. The aim of this work was to create universal models of 2D and 3D primary sensor radars which are in use of Czech forces with the subsequent use in the simulation environment for creating of plots or tracks radar datas. The model will be used as the part of the simulator for Czech air force staff training.*

***Keywords:*** *radar sensor, modelling, simulation, modelling approach, probability of false alarm, Swerling target model.*

## 1. INTRODUCTION

The use of simulation technologies for training occurs at most levels of NATO armies. Simulation technologies are no longer regarded only as a supplement to real training, but they are also used in full preparation, training and evaluation of operating personnel. Within Czech forces was solved the defence research project called SIMOS - *Use of simulation technology within the framework of the Air Force operational centres*. One part of this project is oriented to radar sensor modelling. The construction of a surveillance radar sensor model may be realized in a very simple way or in a complex way. It depends all the time on our demands, but we have to focus our attention to the function of real radar system.

At the department of Air Defence (AD) systems a simulation tool MÄK, a powerful toolkit for simulating of air and ground forces, is successfully in use. This simulation tool is in use for the combat situation simulation of ground and air forces. It is possible to make either real situation simulation, or hypothetical situation simulation. It is possible to program 3D objects, put them into 3D terrain environment, to simulate their movement, fire and much more.

This simulation tool is able to work in a network, thus it is very convenient for the tactical situation simulation. It is a modular system, for which there exist a lot of enhancements and upgrades. The most used part of this simulation tool is *VR-Forces* subprogram, which is a powerful and flexible simulation toolkit for generating and executing battlefield scenarios. It has all the necessary simulation features for use as a tactical leadership trainer, threat generator, behaviour model test bed, or Computer Generated Forces (CGF) application.

One of the marginal problems of AD warfare simulation is the modelling of AD surveillance, which should be approaching a real environment on the one hand and on the other hand should be simple and as fast as possible. In spite of contemporary computers being fast and their computing power constantly increasing, the simplicity of AD surveillance simulation process is a basic requirement for all warfare simulation models, because it is a prerequisite for simulations running in real time.

## 2. MODELLING OF AD SURVEILLANCE SENSOR

**2.1 AD surveillance sensor model.** The main type of AD surveillance sensor is a radar sensor. The radar sensor model will be in our case an element working with the simulation environment - with the MÄK simulation tool. The source of flight paths is a simulation tool MÄK, which generates conditions of tactical situation according to the predefined start point, waypoints and destination.

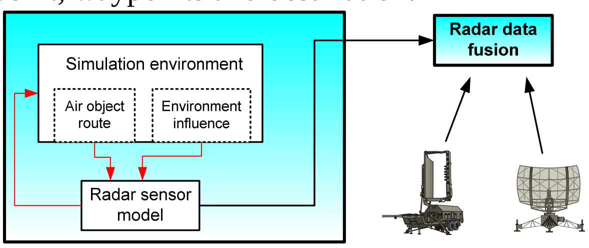


Figure 1.: Radar sensor model placement as the part of the simulation environment

The model of radar sensor makes a function of the information filter, which separates incoming information, what are a *position* and a *type* of all air objects (they differ in the size and in Swerling 1,2 or Swerling 3,4 fluctuating nature), which will be in the antenna detection area. According to the decision-making process the radar sensor model adjudicates, which objects are currently visible and which objects are in the range of the radar sensor model. Afterwards, their positions are sent to the succeeding processing encoded into the protocol ASTERIX (All Purpose Structured Eurocontrol Surveillance Information Exchange). Under the technical term “succeeding processing” it is possible to understand e.g. a radar data fusion or a system of the fire control as the part of the rocket system.

The basic structure of how the radar sensor model works can be found in the figure 2.

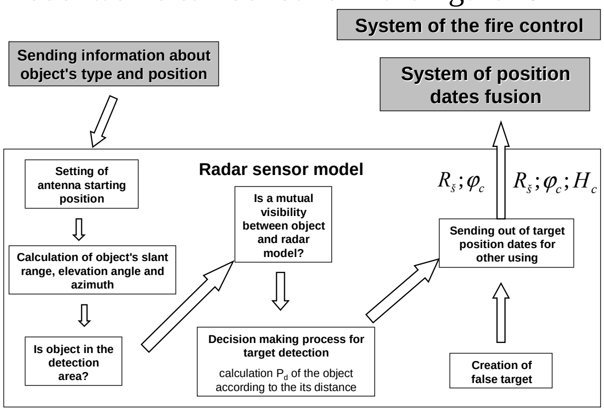


Figure 2.: Radar sensor model structure

In the simulation environment every moving object is sending its position and its type into the radar sensor model. Then, the radar sensor model solves according to some rules, if the position datas of the object will be send into the system for the other processing. Firstly, it is necessary to set up the random starting antenna position. Position of a moving object is given in Cartesian coordinates. Because of the fact that radar position data from the real radar are given in cylindrical coordinates, it is necessary to recalculate them. Then, the slant range, elevation angle and azimuth are obtained. Later, it is solved, if the object is currently in the detection area of the radar, this means if the object is in the range of the radar sensor model. If yes, it is solved, if the mutual visibility between object and radar is clear. In the other step, the value of the probability of detection is calculated according to the object distance, its size and the type of the object radar cross section fluctuation. Then, the decision making process is performed. Afterwards, the position data of the object are sent into the system of succeeding processing.

**2.2 The process of the random object generation.** In the output of the radar sensor model, at a certain time moment, will be generated the random object, the so called false target. During the process of radar sensor modelling, it is important to take into account the existence of the false target, because during the work of the real radar sensor, from time to time an object, which does not exist in reality, can be displayed on the screen of the radar. The probability, that this object will be displayed, is determined by the *probability of false detection (alarm)*. For current radar systems is used the value used is from $P_{fa} = 10^{-6}$ to $P_{fa} = 10^{-8}$.

When the radar antenna makes 1 turn, the space for the detection of the objects can be divided into a big number of elementary elements, which can represent a possible target. Regarding to 2D radar sensor, the number of these elements can be calculated according to:

$$P_{elem\_2D} = \frac{360°}{\Delta\varphi_c} \cdot \frac{d_R}{\Delta R_s} \quad \text{[elements]},$$

where:

$d_R$ – radar sensor instrumental range in the distance [m],

$\Delta\varphi_c$ – radar sensor resolution ability in the azimuth [°],

$\Delta R_s$ – radar sensor resolution ability in the slant range [m].

Regarding to 3D radar sensor, the equation will be:

$$P_{elem\_3D} = \frac{360°}{\Delta\varphi_c} \cdot \frac{d_R}{\Delta R_s} \cdot \frac{\varepsilon_{max}}{\Delta\varepsilon} \quad \text{[elements]},$$

where:

$\varepsilon_{max}$ – maximal value of the elevation angle [m],

$\Delta\varepsilon$ – radar sensor resolution ability in elevation angle [°].

Then, for the randomly selected 2D radar sensor can be calculated:

$$P_{elem\_2D} = \frac{360°}{1°} \cdot \frac{350000m}{500m} = 252000 \text{ el.},$$

and for the randomly selected 3D radar sensor can be calculated:

$$P_{elem\_3D} = \frac{360°}{1{,}5°} \cdot \frac{470000m}{120m} \cdot \frac{20°}{2{,}1°} = 8\,928480 \text{ el.}$$

An average value of the probability of the false target occurrence $M_{fc}$ will be defined according to the equation:

$$M_{ft} = P_{elem\_2D(3D)} \cdot P_{fa} \quad \text{[-]},$$

Now, the random target will be generated to be displayed during some number of antenna turns. The follow equation will be used:

$$G_{ft} = N_i + M_{ft} \quad \text{[-]},$$

where:

$N_i$ – a randomly generated number from the interval <0;1> [-],

$M_{ft}$ – an average value of the probability of the false target occurrence [-].

With this step, a random number $G_{ft}$ will be obtained, in other steps this number is compared with the value of number „1“. Then, if $G_{fc} \geq 1 \Rightarrow$ the false target will be created and send to the succeeding processing; if $G_{fc} < 1 \Rightarrow$ the false target will not be created and send to the succeeding processing.

If the random target has to be generated, it is necessary to specify the position of this target. For this step, two generators of random position are used. This means that the random object can be displayed in the range of radar at least one time, but also, it does not have to be displayed.

With respect to the 2D radar sensor model, it is necessary to determine the concrete position of the random object in the range and azimuth. For the generation of random position in the range the modified generator $G_{distance}$ will be used:

$$G_{distance} = N_i(d_R)\cdot d_R \quad [-],$$

where:

$N_i$ $(d_R)$ – randomly generated number from the interval <0,01;1> [-],

$d_R$ – maximal radar sensor instrumental range of 2D radar sensor [km].

For the generation of random position in the azimuth the modified generator $G_{azimuth}$ will be used:

$$G_{azimuth} = N_i(\varphi)\cdot \varphi \quad [-],$$

where:

$N_i$ $(\varphi)$ – a randomly generated number from the interval <0,01;1> [-],

$\varphi$ – a maximal value of azimuth of 2D radar sensor (360°) [°].

The algorithm for the 2D random target generation could be presented as:

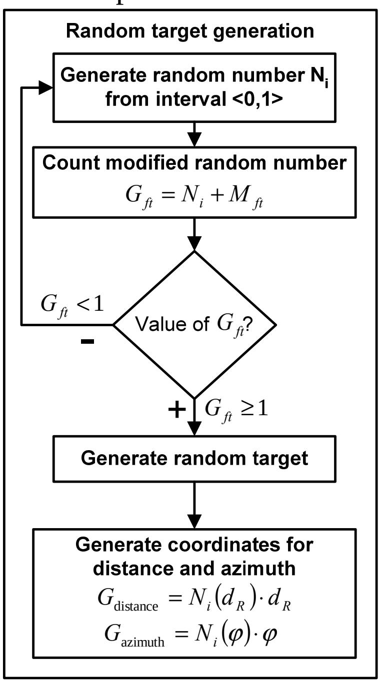


Figure 3.: Algorithm for the 2D random target generation

With respect to the 3D radar sensor model, it is necessary to determine also the concrete position of the random object in height. For this the modified generator $G_{height}$ will be used:

$$G_{height} = N_i(H_{max})\cdot H_{max} \quad [-],$$

where:

$N_i$ $(H_{max})$ – a randomly generated number from the interval <0,01;1> [-],

$H_{max}$ – a maximal value of the height of 3D radar sensor [m].

And for the 3D random target generation algorithm can be presented as:

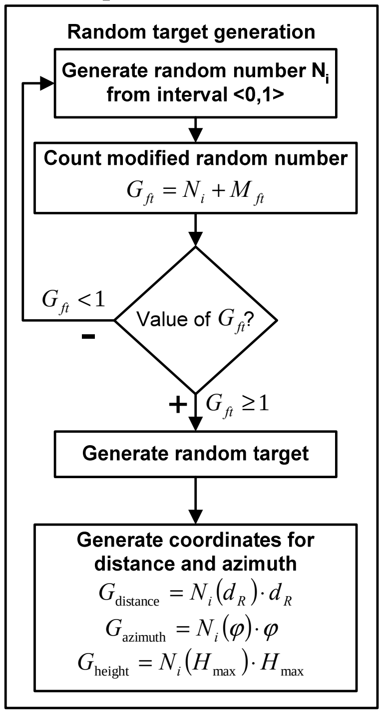


Figure 4.: Algorithm for the 3D random target generation

## 3. CONCLUSIONS & ACKNOWLEDGMENT

In this paper, the authors were trying to highlight the importance of the random objects generation within the framework of surveillance radar sensor model creation.

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