"STET Model"
A Framework For Realistic Surveillance Setup Simulation

S D Suresh
Electronics & Radar Development Establishment,
Bangalore, India.

Dr. Smita D Naik
Institute of Armament Technology,
Pune, India.

Abstract *- 'STET model' is a framework for realistic surveillance setup in which multi-target multi-sensor scenario can be modeled for surveillance applications. The components of STET model framework are Sensor (S), Targets (T), Environment (E) and Terrain (T). The set of characters relevant to surveillance operation of the sensor is captured in Sensor modeling. In target modeling, the characteristics of the target, which can be seen by sensor and the movement of it are modeled. Environment model considers the factors that affect the sensor and surveillance. The elevation profile of the terrain is considered for modeling the terrain, which influence not only the detection characteristics of the sensor but also the movement of surface target on it. STET model framework suggests the modeling of each of its component that affects the surveillance scenario independently. It then considers the system as a whole while allowing for the simulation of whole scenario.*

Keywords: Surveillance, Sensor modeling, Target modeling, Terrain modeling, Data fusion.

1.0 Introduction

Surveillance using single sensor / single type of sensor has become history. Everywhere, network of heterogeneous sensors are used for surveillance. Data fusion is the process of combining data from multiple sensors and related information from associated databases with the aim of maximizing the useful information content, improving reliability and accuracy, which could not be achieved by a single sensor alone [1]. In recent years, multi-sensor data fusion has received significant attention for both military and civil applications. The focus on this area has dramatically increased due to the availability of excellent communication bandwidth & higher computational capacity.

Modeling and Simulation of heterogeneous sensor netting will greatly help to understand the problems in such an environment. One need to consider *Sensors*, which are responsible for sensing the data, *targets*, which are to be sensed, the *environment*, which affects the detection / visibility characteristics of the sensors and the *terrain*, which dictates the line of sight of sensors and the motion characteristics of surface targets for realistic simulation of a surveillance setup. We present "STET model" in this paper, which provides a framework for modeling of all the four components for realistic surveillance setup in which multi-sensor scenario for surveillance applications and target motions can be simulated. Though the Communication & Computation Capability(C) of the complete setup needs to be considered carefully while incorporating such a model into practice (C-STET model), we restrict to STET for this paper.

2.0 Framework

The STET model framework requires a global co-ordinate system in which the spatial parameters of the model are represented. It requires a common time frame in order to work on proper temporal order. This global co-ordinate system and common timeframe is needed so that all the models can be viewed with the same frame of reference using such spatial and temporal setup. This makes integration of the framework very efficient.

In this framework, we can independently model sensor, target, environment and terrain, which are the vital components in a surveillance scenario. As the models are independent of each other, they each can be simulated independently to create / modify / update the model data. Any modification of one model will not affect any other model. Also, each model follows specific formats. So, while simulation of the model, a number of files can be created to represent specific situation in each model. The simulation process can take one such created data file from each model as input for surveillance setup simulation and results of such scenario can be seen. This framework facilitates simulation of any sensor – target – environment - terrain configuration by means of seamless integration.

3.0 Sensor Modeling

Sensors can be broadly classified into active and passive sensors. An active sensor is a detection device that requires input energy from a source other than that which is being sensed. Passive sensors use energy from observed source for sensing. Each sensor has its own strength and operational restrictions. The surveillance setup should be designed in such a way to exploit the maximum potential of a sensor's capability.

The set of characters relevant to surveillance operation of the sensor needs to be captured in Sensor modeling. Concentration is on the modeling of the sensor by capturing details about observation characteristics of the sensor, its coverage levels, details of its measurement inaccuracies, its possible limitations and the output data format of the sensor. The operational effectiveness under various conditions such as whether the sensor require line of sight for observation, light source, and the effect of rain, cloud, fog are also captured. The operational requirements of each sensor like on which power source it operates, restrictions on continuous operations are also modeled. If the sensor is mounted on a platform which is moving, then the motion of the platform is also captured [2].

For example, consider an active sensor RADAR (RAdio Detection And Ranging), with co-located transmitter and receiver for surveillance [3]. Radar is a *line of sight* (LOS) device, in which objects are detected by the reflections made by them from radiated energy, which cannot pass through any blockage in line of passage of radiation. The parameters, which need to be considered for modeling here include the maximum range, azimuthal coverage, scan speed, beam details, accuracy, degradation due to rain, snowfall, if any and data format for various messages such as scan message, mode of operation message, target report, etc.

The range and coverage decides the territory of surveillance for the radar. Scan speed is used to decide at what rate, the radar sees each point in coverage. The beam details such as azimuth and elevation beam width are used to create beam pattern. The beam is extended till the maximum coverage point or till there is a blockage in line of sight due to terrain. The accuracy of radar is needed for stochastic simulation in error, which is introduced in target measurement during detection report formation. In this way, all the components captured during modeling are used during realistic simulation of the surveillance setup.

As to make the model realistic for simulation purposes, the on-line changes in the operational parameters of the sensor needs to be captured. So, facility to capture any change in any of the operating parameters, which are internal to the sensor is provided in the model. Each state of the sensor can be captured as a separate segment and the complete state changes of the sensor over the period of operation can be captured as a sequence of time ordered segments.

4.0 Target Modeling

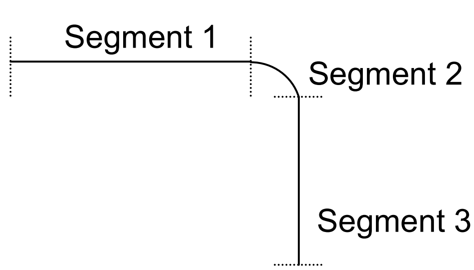
The object that needs to be observed during surveillance is modeled in target modeling. Here, not only the characteristics of the target which can be captured by sensor but also the movement of targets need to be modeled. The targets need to be classified into various categories, such as surface / aerial / underwater / combination. The types of motion of target to be considered include stationary, level, turn, acceleration, climb and allowable combination of them. The target motion can be split into various logical segments whenever there is a change in the state of motion [2].

The motion in each segment is decided by the initial target position, its speed, heading, elevation angle and motion type. For algorithmic purposes, calculation of motion within the segments for targets can be done with the help of motion type for a particular segment and its relevant parameters, which are shown below. The end parameter of each segment becomes the start / initial condition for the next segment.

Level motion	:	duration/distance
Acceleration	:	acceleration rate, duration/distance
Climb	:	climb angle, duration
Turn	:	turn rate, turn angle

The following figure shows how the motion of a target is represented using various segments, based on the change in state.

Segment 1 : Level
Segment 2 : Turn
Segment 3 : Acceleration



Probability of detection (Pd) need to be associated with each segment so that its detection probability, when performing simulation can be modeled based on the segment type. A few general characteristics of each target such as size, dimension, visibility under various environments and limits are considered in this model in order to simulate proper detection characteristics.

5.0 Environment model

The environment affects performance of surveillance in a great way. Some sensors require light for detection. Some sensor’s performance can be adversely affected by climatic conditions such as rain, fog, snowfall, etc.

The factors that affect the surveillance such as the light available at any point of time at any available location and the natural factors that create unwanted detections such as sea clutter are modeled here. The clutter can be modeled by defining the position, statistical distribution of the disturbance with volume and density. Any change in environment over a period of time can be stored as a time ordered sequence of segments, with each segment containing the change in the parameters.

6.0 Terrain modeling

Most of the active sensors require line of sight. In order to incorporate the effect of terrain in which the complete surveillance is planned, we need to model the details of terrain in such a way that we can check for the line of sight from any given point to any other point. The elevation detail at each point for the whole volume of surveillance plays a key role for this. The digital elevation model (DEM) can be used for this purpose [4].

Digital terrain modeling refers to the process of representing any characteristics of a terrain in a discrete form or in the form of any equation of a surface [5]. When the characteristics chosen is elevation, the process is termed as digital elevation modeling. A digital elevation model can be stored as an ASCII or binary file that contains only spatial elevation data in regular grided pattern in raster format.

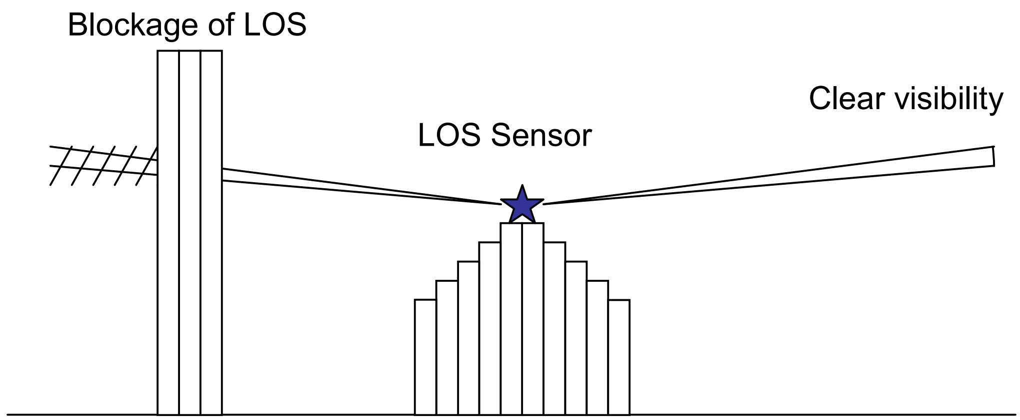
In this terrain model, volume of operation in which the surveillance is conducted can be divided into grids of X-Y axis with grid spacing as dx and dy in respective direction. The elevation data is to be stored at each such point. By this, we can store the complete height of the area.

. . .	. . .	…
ht	ht	…
ht	ht	…

Typical example:

Area of observation:10 km x 10 km; dx = dy = 100 m;
Each cell represents the average height (ht) at that 100 x 100 m cell.

The following figure shows how such a representation will help finding the coverage of a sensor.



Terrain with elevation at each point: One dimension (height) considered for the figure

As the above representation can easily find the visibility of any point from a particular location, optimal installation of sensors can be done to get maximum and best coverage with available sensors. It also helps to find out any possible blockages which need to be removed in order to increase the security of the place under surveillance.

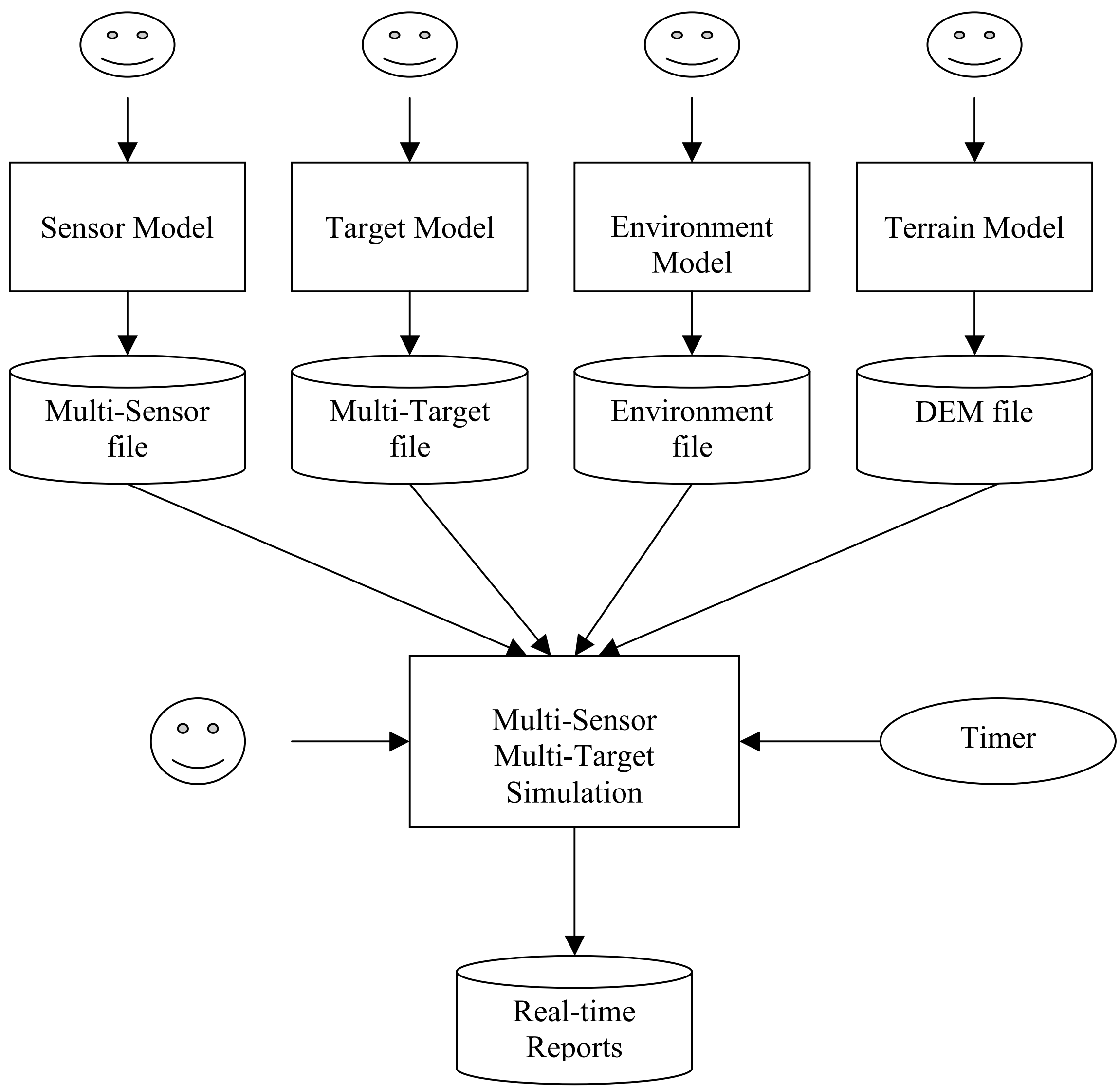
7.0 STET model usage

Using the STET model, Sensors, Target, Environment and Terrain can be independently modeled and converted into software programs. Each program can work on its own, and can create its own data file, i.e., the user can create specific instances of sensors, target, environment and terrain. The user can also modify those files independently. As the spatial and temporal system used in all the models are same, they can be interrelated for simulation of multi-sensor multi-target situation.

For example, a set of sensor files can be created to with various positioning of available sensors in a given coverage area. A set of target files can be created with various possible types of targets and its motion. A few environment files can be created, say, one for day-time and one for night-time with rain. Realistic representation of the surveillance area can be done for the place of observation with the help of terrain model.

A multi-target multi-sensor simulator can be developed, which takes all the four model files as input for surveillance simulation. It can simulate the actions of sensors and targets under the given environment and terrain constrains from the STET model. It can create reports of the scenario as seen by the various sensors for the given conditions. These reports can either be seen real-time to see the performance of surveillance setup or they can be stored in files and replayed to analyze the effects of various factors considered.

The following figure shows the context flow of the ‘STET model’ for simulation.



‘STET Model’ Simulation: Context Flow

8.0 Conclusion

In this paper, we have presented ‘STET Model’ in which a framework is proposed for realistic surveillance setup simulation; which includes modeling of sensors, targets, environment and terrain. The STET model framework can be used for creating various realistic surveillance setup.

Simulation of such scenario can be used for finding

a. Feasibility of such surveillance setup, if it is for a new setup
b. Shortcomings of the setup
c. Optimal deployment of the sensors
d. Terrain restrictions

This model can be applied for Campus surveillance such as industrial surveillance, airport surveillance, etc. It can be used to find possible improvements in existing setup due to terrain restrictions.

9.0 Reference

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