CHAPTER 3

SIMULATION MODELS

To measure the performance of the estimation algorithms, simulation has been carried out. This chapter explains the boundary representation, the dynamic boundary and how a contour point is measured on the boundary by the sensor. The models used in this work are discussed. The contour model is presented in the next section.

3.1 CONTOUR MODEL

The real-time monitoring applications which detect leakage of hazardous material, track forest fires and oil spill deal with the boundary which is an open contour. At time instance \( t \), the dynamic contour is assumed to be static. The open contour is shown in Figure 3.1. The work of Duttagupta et al. (2011) is based on the assumption that the boundary is an open contour. The contour considered in this work is not a continuous function with respect to time but approximated by number of points as shown in Figure 3.2. For example, a contour may be represented by a set of 2000 points. In Figure 3.2, contour represented in red is approximated by a set of points in blue. The y-axis movements of these points i.e., blue points is referred to as the dynamics of the contour. This work also assumes that the boundary is an open contour. The next section explains the sensor model.

3.2 SENSOR MODEL

The contour of interest is assumed to be located in a two-dimensional
plane with the sensors also on the same plane. Each sensor is assumed to know its position accurately in a reference frame using the GPS (Global Positioning System) capability and the localization algorithms.

![Figure 3.1 A contour on the plane.](image)

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![Figure 3.2 Approximation of boundary (red) by a set of points (blue) on the plane.](image)

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Sensors are either passive or active sensors. Passive sensors detect and measure magnetic, thermal, or acoustic signature of a target (Arora et al. 2004). The presence, velocity, range or direction of travel of a target is measured by ultrasonic sensors and radar which are active sensors.

Nowak and Mitra (2003) and Ding et al. (2005) used static sensors for boundary estimation where as Srinivasan et al. (2008) used mobile sensors. Duttagupta et al. (2011) used range sensors for dynamic contour estimation. The use of radar sensor, based on range, is a better option for real time tracking or disaster monitoring.
The sensors measure the location of the boundary or the front of interest with the help of a suitable method. One such sensor is radar sensor which detects motion over a 60 feet radius. Since the sensor knows its position and the orientation of the ranging, it can estimate the coordinates of the boundary of interest. Thus, each sensor is assumed to provide ranging measurement in one direction to obtain the position of the contour or the front in that direction. Assumptions made in this thesis is very similar to the model used by Duttagupta et al. (2011).

![Figure 3.3 Illustration of the sensor observation.](image)

It is assumed that the sensors know their locations; let \((\tilde{x}_i, \tilde{y}_i)\) be the location of sensor \(i\). Each sensor samples the edge of the contour in the \(y\)-direction and obtains the signed value of the range \(r_i\) to the boundary. From this range measurement and knowledge of its own position, each sensor can provide the location of a point on the contour as given by Equation (3.1)

\[
(x_i, y_i) = (\tilde{x}_i, \tilde{y}_i + r_i)
\]  
(3.1)
The measurement made by the sensor $S_i$ at time $t$ will be $(x_i, y_i(x_i, t))$; here $y_i(x_i, t)$ is the contour location obtained from an accurate measurement by sensor $S_i$ by ranging in the $y$-direction at time $t$. The scenario considered is illustrated in the Figure 3.3. Range sensors are arbitrarily distributed in the area of interest and they can obtain a sample location of the contour in the direction of ranging. In the Figure 3.3, the sensors range parallel to the $y$-axis and measure the distance to the contour.

This work is based on the assumption, that given a contour represented by discrete points, a sensor reading is only a single point on the contour. The theory and the methods are developed based on this scenario. However, much of what is developed as part of this work, can be significantly extended and is more generally applicable for tracking dynamic data in a variety of other situations.

Exploitation of temporal correlation to minimize the number of queries made by the sink tracking the dynamic boundaries in a centralized system is presented in the next chapter.