Distributed Sensor Systems

THALES

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Systems used for distributed measurements and wireless communication are becoming increasingly important and are used in a growing number of applications at different scales. One can think for example of security systems on the streets which include TV cameras, or guarding large industrial areas using infrared sensors. The possibly large number of sensors raises all sorts of issues such as (i) how should sensors be distributed, (ii) how many are needed, and (iii) do we need to read all the sensors all the time?

The development of wireless tools has lead to so-called Micro-Electro-Mechanical devices (MEMs). The possibility to produce sensors, batteries and radio's on increasingly smaller scales enables such units to become more efficient in their use of energy which increases their operating times. Moreover, these units have become cheaper to produce and easier to purchase.

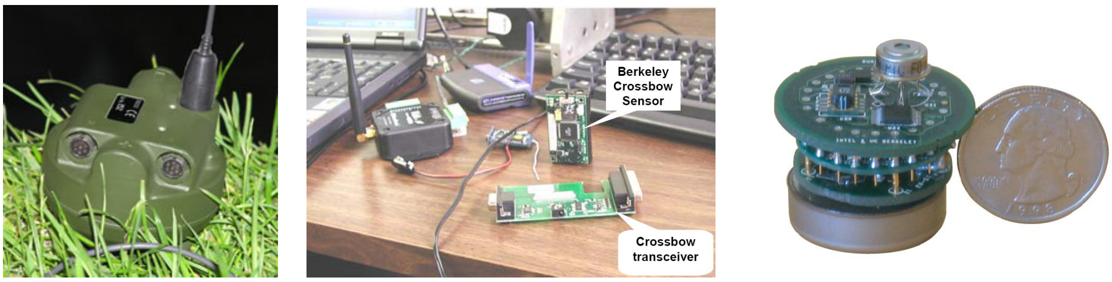

Figure 1: Berkeley/Crossbow nodes and THALES UK mini intrusion sensor

On a slightly larger scale, simple radar devices can be combined in a network to make it possible to observe larger areas in a distributed sense. The goal of such systems can be, for example, the detection and tracking of objects. Examples include the detection of intruders in industrial areas, but also applications in health care such as an alarm system which detects that an (elderly) person has fallen down. In biology, such systems can be used to study animal behavior.

Problem formulation. Below is indicated how an object or building (the black rectangle) can be guarded using distributed passive infrared sensors. A sensor (indicated using a little blue cross) raises an alarm (small red circles) if something is detected within its domain (large yellow circles). A sensor may give a false alarm if it raises the alarm incorrectly. A sensor may also fail to raise an alarm if an object is indeed present in its domain, which is called a misdetection. The probability that something will be correctly detected is called the detection probability while one minus this probability is called the failure probability. In the network shown below two objects are present (indicated using black circles).

Sensor Networks. It is clear that in a sensor network as the one indicated here, the quality of the estimate of the object's position will improve if the sensor density is increased. However, a higher sensor density also means increased costs. Moreover, it may not be possible (or too expensive) to receive information from all sensors at the same time, so one may choose to read only a limited number of sensors every second.

There may also be a priori information available, such as information concerning the places where objects can enter the guarded area.

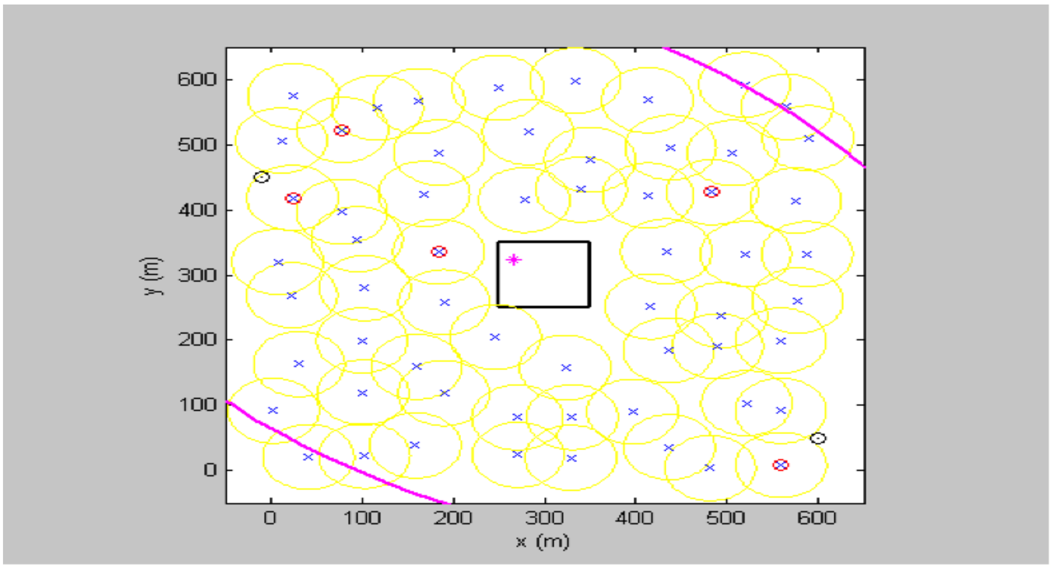

Figure 2: A sensor network

A standard implicit assumption in this application which is often made, states that misdetections and false alarms are independent over time. However in situation in which sensors have broken down, this assumption is no longer valid, and a good model should be able to incorporate this fact.

Questions.

1. When a certain sensor density is prescribed and both the dynamics of objects that should be tracked and places where objects may enter the area have been given, what is the best distribution of sensors in space to get the best possible estimate of the objects position?
2. Is there a difference when sensors are distributed according to a deterministic or some stochastic procedure (for example, using a uniform distribution)?
3. Are other characteristics of the object important (such as the speed of the object)?
4. If we only want to read off a limited number of sensors per time step, which ones should we choose, if we want to detect objects as well as possible? Trying every possible combination is impossible in practice: choosing 10 sensors out of 200 will give us more than 5.6×10^{18} combinations!