# A Wireless Sensor Network (WSN) Model for Mapping of Remote Large Scale Environments using Extended Kalman Filter (EKF) and FastSLAM for Military and Defence Applications.

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# Abstract

*An implementation of a Simultaneous Localization And Mapping (SLAM) is carried out on Wireless Sensor Network of multiple autonomous rovers (clients) sending data to a specified server with algorithms based on the existing Extended Kalman Filter and FastSLAM to minimize the errors.*

**Keywords**: SLAM, WSN, EKF, FastSLAM, Mapping

## Introduction

### SLAM

SLAM is a process by which a mobile robot can build a map of an environment and at the same time use this map to deduce it’s location. In SLAM both the trajectory of the platform and the location of all landmarks are estimated on-line without the need for any prior knowledge of location.

At a time instant k, the following quantities are defined:

• xk: The state vector describing the location and orientation of the vehicle.

• uk: The control vector, applied at time k−1 to drive the vehicle to a state xk at time k.

• mi: A vector describing the location of the i-th landmark whose true location is assumed time invariant.

• zik: An observation taken from the vehicle of the location of the i-th landmark at time k. When there are multiple landmark observations at any one time or when the specific landmark is not relevant to the discussion, the observation will be written simply as zk

### Wireless Sensor Networks (WSN)

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSN measure environmental conditions like temperature, sound, pollution levels, humidity, wind, and so on.

These are similar to wireless ad-hoc networks in the sense that they rely on wireless connectivity and spontaneous formation of networks so that sensor data can be transported wirelessly. WSN are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a micro-controller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoe box down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth.

### Extended Kalman Filter (EKF)

In estimation theory, the extended Kalman filter (EKF) is the nonlinear version of the Kalman filter which linearizes about an estimate of the current mean and covariance. In the case of well defined transition models, the EKF has been considered the de-facto standard in the theory of nonlinear state estimation, navigation systems and GPS.

In the extended Kalman filter, the state transition and observation models don't need to be linear functions of the state but may instead be differentiable functions.

xk = f(xk-1, uk) + wk

zk = h(xk) + vk

Here wk and vk are the process and observation noises which are both assumed to be zero mean multivariate Gaussian noises with covariance Qk and Rk respectively. uk is the control vector.

The function f can be used to compute the predicted state from the previous estimate and similarly the function h can be used to compute the predicted measurement from the predicted state. However, f and h cannot be applied to the covariance directly. Instead a matrix of partial derivatives (the Jacobian) is computed.

At each time step, the Jacobian is evaluated with current predicted states. These matrices can be used in the Kalman filter equations. This process essentially linearizes the non-linear function around the current estimate.

Unlike its linear counterpart, the extended Kalman filter in general is not an optimal estimator (of course it is optimal if the measurement and the state transition model are both linear, as in that case the extended Kalman filter is identical to the regular one). In addition, if the initial estimate of the state is wrong, or if the process is modeled incorrectly, the filter may quickly diverge, owing to its linearization. Another problem with the extended Kalman filter is that the estimated covariance matrix tends to underestimate the true covariance matrix and therefore risks becoming inconsistent in the statistical sense without the addition of "stabilising noise".

Having stated this, the extended Kalman filter can give reasonable performance, and is arguably the de-facto standard in navigation systems and GPS.