Low Cost Localization Techniques in Structural Damage Detection

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Summary

Structural Damage Detection sometimes requires full information of the damage location. If a wireless sensor network is used for damage detection, localization techniques of the wireless sensor network have to be adopted. To locate the sensors in the network, there are mainly two types of methods: range free and range based. The range free method is good at scaling on the network, but such method is not a god solution for low cost design. While the range-based localization methods uses time of arrival (TOA), angle of arrival (AOA), time difference of arrival (TDOA), also received signal strength intensity (RSSI). Among these techniques, the RSSI seems to be an energy efficiency solution for low cost sensor localization. This paper gives the analysis on the RSSI based localization and its accuracy.

Keywords: TOA, AOA, TDOA, RSSI, Localization, Wireless Sensor Networks, Structural Healthy Monitoring.

1. Introduction

Structural Healthy Monitoring needs to involve a large number of sensors; in some situations such sensors are implemented with wireless transmissions. For structural damage detection, it is necessary that the damage report comes together with its location. The information collected from the sensors should have information of the senor node location. Such issue of the wireless sensor localization has emerged as a topic also in structural damage detection.

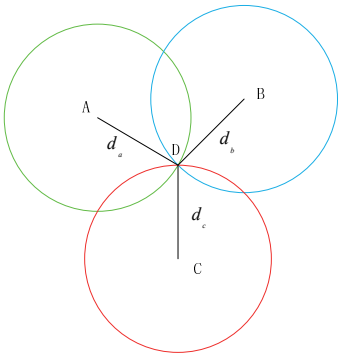

Fig. 1: Localization a sensor node

Unlike the conventional wireless sensor network, the sensor network used in structural health monitoring has more complicated wireless channel environment. Due to the widely implementation on reinforced concrete in structures, the wireless radio signal can be easily influenced by the surrounding objects, such as shadowing, reflection, scatter and shielding. So the localization method in such environment should be capable of overcoming these barriers; meanwhile, the sensors network should also be designed as simple as possible in

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terms of energy efficiency concern.

There are two main categories of localization methods, the range free and range based.

In the range-free localization methods, there are also algorithms which need a large number of beacon nodes, where each sensor will hear several beacon signals at the same time. Also there are algorithm methods based on flooding a network.

The range based localization includes Time of Arrival (TOA); Angle of Arrival (AOA); Time Difference of Arrival (TDOA), also Received Signal Strength Intensity (RSSI). Assuming the sensor node is simply designed for the low cost and energy efficiency constrains, it is necessary that the location information can be in a simple way, such as directly calculate the distance from the wireless radio signal. Compared with other methods, the Receiving Signal Strength Indicator gives the simplest way to get the location. The distance from the sensor to the beacon can be calculated directly from the received signal strength, and the sensor node needs no transmission signal back to the beacon, by just listening to the broadcasting message of the beacon, the node can get its location. So the RSSI is adopted as the low cost localization method.

At the same time, the RSSI method can be easily influenced by the channel distortion. Especially in the structural health monitoring, where the wireless channel is more complicated than Line of Sight (LOS) channel, the multipath, scatter, and reflection on the structure can heavily influence the accuracy of localization. So the challenge in this localization is the accuracy. Besides, the received signal have self-errors which will also influence the accuracy, such as the battery level of the transmitting beacon and the battery level of the receiving node, the antenna working environment of the beacon and the receiving node, etc. such distortion can also influence the localization accuracy in this methods. Hence the RSSI based localization is analysed and its accuracy due to the influence is also presented.

The Received Signal Strength Indicator (RSSI) uses low complexity hardware for localization, which measures the signal strength of the beacon and converts the signal strength to the distance from the training period in the beginning (to get the channel condition relation with distance.).

Assuming the beacon nodes A,B,C have their know position $(x_a\ y_a)$,$(x_b\ y_b)$,$(x_c\ y_c)$, and assuming there's no interference between each beacon nodes (e.g, they broadcast messages at different time slots or using different frequencies.) the node D with unknown position $(x\ y)$, then, the position of node D is given by the known position information from A,B,C.

The channel path loss model is used in the localization; the signal loss has two main factors, carrier frequency and distance; usually for a fixed network the carrier frequency is fixed. The path loss is mainly because of the distance. The sequence then become to identify the received signal strength, calibrate it with predefined value, the unknowns node can calculate the distance to the anchor. By knowing distances to 3 different beacon nodes, the location of the unknown node is calculated.

However, in the real working conditions, especially in reinforced concrete structures, where the signal suffers from multipath, scatter and shielding effects, the RSSI methods is not accurate due to the errors in the received signal or the signal strength is not accurate to reality, based on a error propagation assumption, an accuracy to error simulation is given in the paper. From the simulation it can be seen that when 50% of the receiving signal is wrong, then cause a significant accuracy problem. H however at lower signal error level, by adopting a certain correction parameter, the accuracy can be improved.