XBeep Positioning System with Embedded Haptic Feedback for Dangerous Offshore Operations: a Preliminary Study

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Summary

1. Introduction

2. Trilateration method and system architecture

3. Experimental results, conclusion and future work
Safety of offshore installations is a crucial issue:

- Increasingly demanding marine operations are at the heart of the maritime industrial cluster.
- These advanced operations are associated with a high level of uncertainty on board of an offshore installation because such an installation usually operates in a dynamic environment in which technical, human and organisational malfunctions may cause accidents.
Motivation factors

The Offshore Safety Case regulations hold operators responsible for identifying the major hazards and to reduce risks to As Low As is Reasonably Practicable (ALARP)[1].

The regulations specifically state that Quantitative Risk Assessments (QRA) must be used when preparing the Safety Case.

However, this formal risk estimation does not necessarily correspond with an individual’s perception of risk.

Improving the user’s risk perception plays a crucial role in effective risk reduction:

There is an urgent need to develop faster methods and tools that enhance an individual’s perception and assessment of dangerous situations on board a vessel so that accidents can be avoided.

Underlying idea:

- Identify and isolate dangerous areas by adopting a node positioning algorithm based on an XBee network.
- Several on board areas and zones can be dynamically identified according to different operational scenarios.
- Different access permissions can be set individually for all the crew members in accordance with their specific duties.
- An intuitive haptic feedback is provided to the operator by means of a vibration motor embedded in the helmet.
Design choices

- Low-cost: the system is built with low-cost off-the-shelf components.
- Modularity and flexibility.
- Reliability: the system is easy to maintain, modify and expand by adding new features.
- Non-invasive approach: the system requires minimal changes to the environment to be monitored.

**XBee™**

The XBee radio communications modules allow for building a low-power, low-maintenance, and self-organising network:

- XBee modules are bi-directional.
- Unique addressing. Each XBee unit has a unique serial number. This means that two (or more) units can be set up to communicate exclusively with each other, ignoring all signals from other modules.
- XBee modules have a built-in data-packet building and error-checking to ensure reliable data transmission.
- The XBee protocol allows for a number of radio channels. By setting different units on different radio channels, additional interference can be avoided.
Trilateration method

Received Signal Strength Indicator (RSSI):

- The received RSSI is a function of the distance between the transmitter and the receiver.
- Tracking of moving objects can be achieved if both moving objects and some reference objects are using Radio frequency (RF) signals to communicate.

- Using the RSSI value, the distance to a node can be estimated and a trilateration calculation can be performed against other nodes with known positions.
- Trilateration is a method of determining the relative position of objects using the geometry of triangles in a similar fashion as triangulation.
- The adopted method was introduced in[2] and it is based on the calculation of the intersection of three spheres of which the radius is obtained from the distance estimated from the RSSI value.
- In order to work this model requires that the blind node must be inside the intersection of three reference nodes.

Different zones to be actively monitored can be dynamically identified according to different operation scenarios.

These zones can be easily configured and dimensioned according to different operational scenarios.
System architecture

Client: fixed node 1

Server
XBee Explorer
Controller

Crew member: blind node
Vibration Motor
XBee Module
Controller

Dangerous Area

Client: fixed node 2

Client: fixed node 3

Safe Area

Server
XBee Explorer
Controller

Client: fixed node 2

XBe Module
Controller

XBe Module
Controller

RSSI

RSSI

RSSI

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Blind node and clients wiring schematics

Only for the blind node
Real circuit embedded in the operator’s helmet
Logic of the framework

**Figure 1:** Blind node

- Initialise the serial channel
- Initialise the XBee network
- Configure one output pin for the motor
- Read any available data from the server
- Check position and actuate motor
- Retrieves RSSI values and broadcasts them to the clients

**Figure 2:** Clients

- Initialise the serial channel
- Initialise the XBee network
- Read any available data from the server
- Read RSSI and corresponding node address
- Forward data to the server
- Read RSSI and corresponding client address
- Filter RSSI values
- Localise node
- Send position to the corresponding blind node

**Figure 3:** Server

- Initialise the serial channel
- Initialise the XBee network
- Read any available data from the server
- Read RSSI and corresponding client address
- Filter RSSI values
- Localise node
- Send position to the corresponding blind node
As given in [3], in order to acquire a distance, the server uses the following equation:

\[ RSSI = -(10n \log_{10} d + A), \]  

(1)

where \( n \) is a signal propagation constant or exponent, \( d \) is the distance from the blind node to the reference node and \( A \) is the received signal strength at 1 meter distance. In particular, the distance \( d \) is calculated as follows:

\[ d = 10^{\left(\frac{RSSI - A}{10n}\right)}. \]  

(2)

The fit is quite promising for small distances. However, for larger distances, the RSSI based distance estimation is not so good, and therefore should be used with caution.

There are several factors that degrade and impact the RSSI values in a real application scenario including reflections on metallic objects, superposition of electro-magnetic fields, diffraction at edges, refraction by media with different propagation velocity, polarisation of electro-magnetic fields and unadapted MAC protocols. Consequently, the results are often affected by measuring errors.
A preliminary study of an XBee-based positioning system for offshore operations:

- The system allows for dynamically monitoring several on board zones according to different operational scenarios.
- A modular admission to the dangerous areas can be achieved by individually setting different access permissions for all the crew members in accordance with their specific duties.
- The user’s risk perception is significantly improved by using a vibration motor embedded in the operator’s helmet, which provides the user with an intuitive haptic feedback.

Future work:

- Different localisation algorithms can be implemented for an extensive comparison.
- To improve the proposed system a multi-sensor fusion approach with the integration of different sensors may be adopted.
- The integration of the proposed framework with a wearable integrated health sensor monitoring system for offshore operations that we recently developed[^4].

Thank you for your attention

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