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

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Summary

Current situation

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

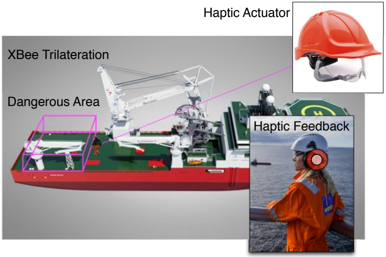
- The Offshore Safety Case regulations holds operators responsible for identifying the major hazards and to reduce risks to As Low As is Reasonably Practicable (ALARP)[1].
- The regulations specifically state that Quantitative Risk Assessments (QRA) must be used when preparing the Safety Case.
- However, 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.

[1] J Wang. "Offshore safety case approach and formal safety assessment of ships". In: *Journal of Safety Research* 33.1 (2002), pp. 81–115.

An XBee-based positioning system with embedded haptic feedback



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™

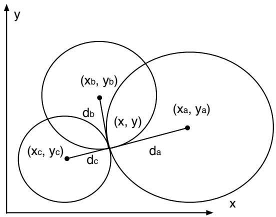
The XBee radio communications modules allow for building a low-power, low-maintenance, and self-organising network:

- 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):

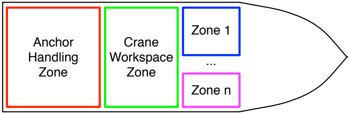
- The received RSSI is a function of the distance between the transmitter and the receiver.
- Tracking of moving objects can be achieved if both moving objects and some reference objects are using Radio frequency (RF) signals to communicate.



- 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.

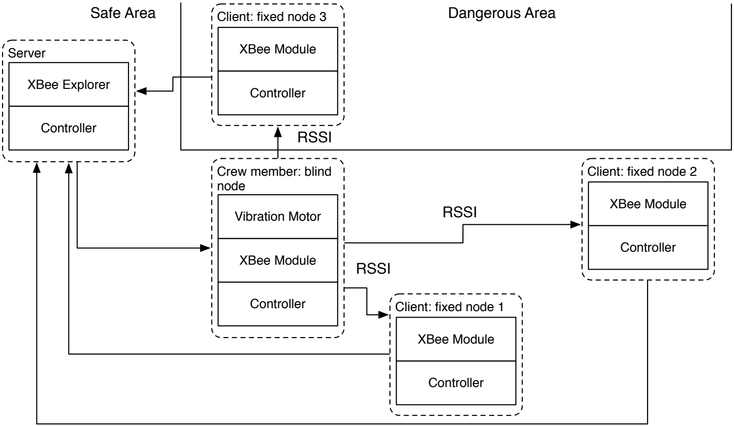
[2] Shaifull Nizam Othman. "Node positioning in zigbee network using trilateration method based on the received signal strength indicator (RSSI)". In: *European Journal of Scientific Research* 46.1 (2010), pp. 048–061.

Modular organisation

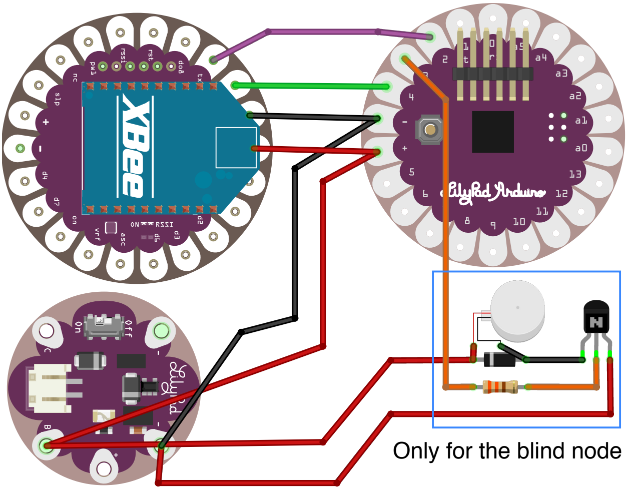


- Different zones to be actively monitored can be dynamically identified according to different operation scenarios.
- These zones can be easily configured and dimensioned according to different operational scenarios.

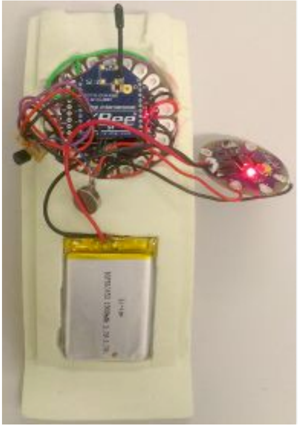
System architecture



Blind node and clients wiring schematics



Real circuit embedded in the operator's helmet



Logic of the framework

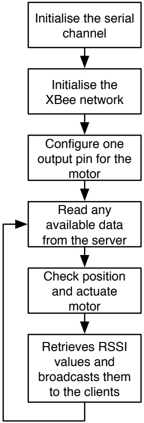


Figure 1: Blind node

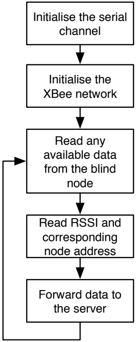


Figure 2: Clients

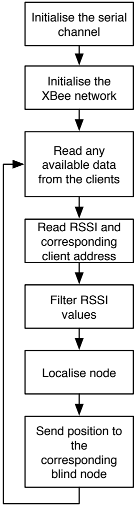


Figure 3: Server

Experimental results

As given in[3], in order to acquire a distance, the server uses the following equation:

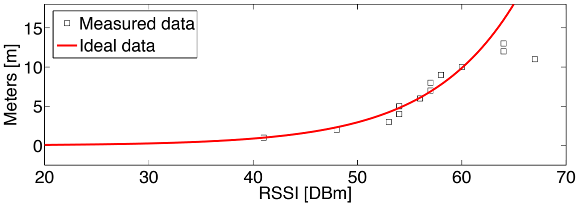
$$RSSI = -(10n \log_{10} d + A), \tag{1}$$

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:

$$d = 10^{\left(\frac{RSSI - A}{10n}\right)}. \tag{2}$$

[3] Wan-Young Chung et al. "Enhanced RSSI-based real-time user location tracking system for indoor and outdoor environments". In: *Proc. of the IEEE International Conference on Convergence Information Technology*. 2007, pp. 1213–1218.

Experimental results



- 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.

Conclusion and future work

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].

[4] Filippo Sanfilippo and Kristin Ytterstad Pettersen. "A wearable health-monitoring system for offshore operators". In: *submitted to the Proc. of the 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS), Milan, Italy*. 2015.

Thank you for your attention

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