Ultra Wideband for Shipyard 5.0 Indoor Gantry Crane High-Precision Positioning

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Abstract: The shipyard of the future, called Shipyard 5.0, is a highly technological environment where real-time monitoring of products, by-products and transport vehicles is crucial. Among the technologies able to locate such elements indoors, Ultra Wideband (UWB) is a good option for providing accurate positioning. However, the use of UWB in shipyards faces challenges due to interference from metallic objects, which impacts its accuracy. To validate the use of UWB in a shipyard, this paper presents tests that were carried out in workshops that Navantia owns in Ferrol's estuary, where UWB tags were placed on a gantry crane hook. The presented results show the performance of the system when locating the hook in 3D and the impact of attaching multiple tags to the hook to harness signal diversity. Specifically, a relatively low error is obtained when estimating only the height of the gantry crane hook (approximately 1 m), while the three-dimensional positioning error reached an error of between 2 and 3 m for the z-axis.

1 Introduction

Industry 5.0 is the natural evolution of Industry 4.0. While Industry 4.0 is primarily concerned with the automation and digitization of industrial processes, Industry 5.0 seeks greater integration of human and technological capabilities (Directorate-General for Research and Innovation, 2021). Furthermore, Industry 5.0 emphasizes sustainability and social responsibility, attempting to balance technological progress with human well-being.

Between 2015 and 2021, Navantia, Spain's largest shipbuilding company, dedicated itself to researching the application of various technologies to shipyards and ships through the so-called Joint Research Unit (JRU) "The Shipyard of the Future". One of the research lines of the JRU concentrated on the automatic identification and traceability of shipbuilding components, tools, and products throughout their life cycle. Throughout the life of this line, numerous studies on auto-identification technologies (Auto-ID) were conducted (P. Fraga-Lamas et al., 2016, 2017). In line with these developments, the goal of the work presented in this paper was to assess the performance of Ultra-WideBand (UWB) technology for 3D object localization in Navantia's workshops when using a gantry crane to move them.

2 Design, implementation and evaluation of the system

2.1 Used hardware and software

To validate the use of UWB in crane hook positioning, two independent systems were designed and built. Then, their performance was compared when determining the height of the crane.

The first system consisted of the following components:

- A single DWM1001 module (Qorvo, 2023) attached to the crane hook. Such a module acted as a tag (i.e., as a mobile node).
- Several DWM1001 modules were deployed along the workshop. Such modules acted as anchors (i.e., as fixed nodes).

Every DWM1001 module embeds a Nordic nRF52832 System-on-Chip (SoC), which provides Bluetooth connectivity and that allows the tag position to be transmitted to a remote smartphone (i.e., to an Android application). Moreover, each DWM1001 module includes a Decawave DW1000 UWB transceiver, which handles bidirectional range exchanges between tags and anchors. The manufacturer provides a default firmware for the DWM1001 modules (Decawave, 2017) that makes it simple to implement a basic RTLS (Real-Time Location System).

The second developed system is made up of only two DWM1001 modules: One module serves Initiator, while the other one acts as Responder. The Initiator sends a frame, waits for a response from the Responder, and then calculates the distance based on the TOF (Time of Flight). The output is sent via the provided UART port, to which a Raspberry Pi Zero is connected to process and to save the position data.

Although the first and second system employ a one-way TWR (Two Way Ranging) scheme (SS-TWR), they are different on the fact that the RTLS created by the first system requires at least three anchors to calculate their location based on beacon message anchor positions.

2.2 Experimental setup

The experiments presented in this paper were carried out in a workshop at Navantia's shipyard of Fene (Galicia, Spain), where seven anchors of varying heights were installed. To ensure a wide coverage area, three anchors were placed on one side of the workshop, and three more on the other side, with each side anchors separated by 15 m. The positioning of the anchors in the workshop is shown in Figures 1 and 2.

During the tests, two tags were used simultaneously to verify the use of UWB for 3D gantry crane hook positioning, as shown in Figure 16.3(a). Such tags were placed on top of the crane hook as it is shown in Figure 16.3(b). While the anchors located throughout the workshop helped one tag determine its 3D position, the other tag was only responsible for measuring the crane height. This was achieved by placing another tag on top of the crane (as shown in Figure 4), using a Raspberry Pi Zero powered by a battery to store the collected data. Moreover, the Raspberry Pi Zero can be used to transmit the information opportunistically to a remote smartphone or computer.

2.3 Results

Initial tests

Some measurements were taken during the initial placement of the modules in the crane to determine the initial error for the two tested systems. Figure 16.3(b) shows the initial moment when the modules were placed and the first measurement was taken; the hook was at a height of 1 m. At that moment the system that only measured the height yielded a result of 0.8 m while the 3D positioning system was unable to maintain a constant result because in this first position, due to obstacles in the environment, it only received information from three or less anchors.

Figure 1: Test scenario (right side of the workshop) with the anchors (inside yellow squares).

Figure 2: Test scenario (left side of the workshop) with the anchors (inside yellow squares).

Tests at a height of 7.5 meters

In the first actual set of tests, the crane hook was placed at a height of 7 m. In such a position the height positioning system gave a result of 7.2 m (i.e., a 0.3 m error was obtained), which remained constant throughout the movement of the crane (i.e., a constant offset was observed).

On the other hand, the 3D positioning system gave a more variable result. It determined a

(a) One of the test moments in which the crane was used.

(b) Placement of the modules.

Figure 3: The crane hook with the modules attached.

height between 5 and 7 m, depending on the distance to the surrounding anchors. This variation in the results of several meters is due to the movement of the crane when traveling through the workshop.

The results of this first test are shown in Figure 5 between iterations 0 and 400. This substantial inaccuracy in the calculation of the 3D positioning might be attributed to the fact that the tag height was higher than the anchors, which were all between 3 and 4 m high, so the tag did not have a direct reference at that height.

Tests at a height of 3.5 meters

In a second set of tests the gantry crane hook was raised to a height similar to the one of the surround anchors (4 m). In such a scenario it was observed how the height positioning system determined a 3.3 m height, with a constant error of 0.2 m. The 3D system, on the other hand, began marking between 4 and 5 m, which represents an error of less than 0.5 m, but as the crane moved from one side of the workshop to the other, the error increased, reaching 1.5 m. The results of such tests are reflected in Figure 5 between iterations 400 and 1000.

Tests at a height of 5 meters

Finally, in a third set of tests, the gantry crane hook was lowered to a height of 5 m. The obtained results are shown in Figure 5 between iterations 1000 and 1200. It can be observed how the height positioning system marks constantly 5 m (i.e., there was no error), while the 3D positioning system determined a height of around 3 m, with an error of 2 m.

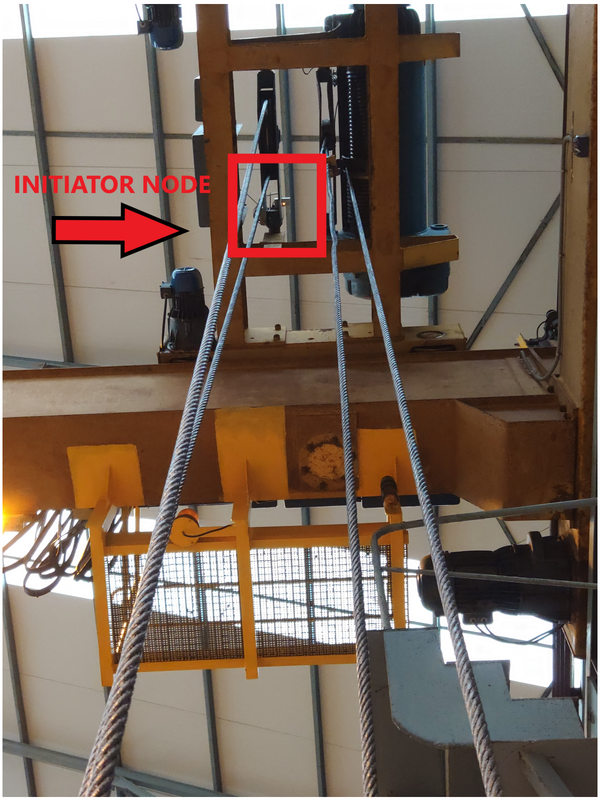

Figure 4: Placement of the Initiator node at the top of the crane.

3 Conclusions

This paper described an empirical evaluation of the precision of UWB tag positioning in a real-world environment (a workshop of Navantia in Fene's shipyard) and when locating the hook of a gantry crane. The differences in position accuracy have been shown for two independent systems: one that just determined the crane hook height and a second one that obtained the position in three dimensions. The results show that the height positioning system always manages to achieve a low error that remains constant and that can be easily corrected. The 3D positioning system, on the other hand, produces a larger error that varies as the crane moves through the workshop, sometimes producing errors of more than 2 m that would need to be corrected by modifying the system (e.g., by increasing the number of anchors or by placing such anchors in selected positions). In any case, the obtained results demonstrate the feasibility of using UWB technology to locate the crane hook in difficult industrial workplaces such as the one chosen, where numerous metallic objects are present.

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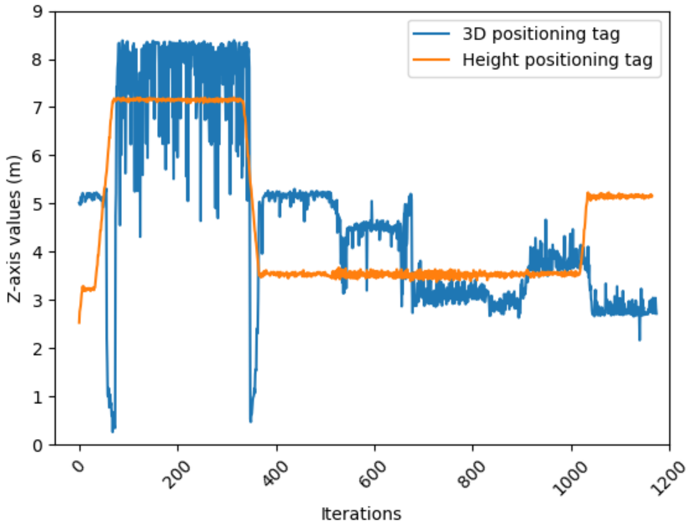

Figure 5: Height results obtained.

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