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# Ultra-Wideband based Smart Wheelchair Localization using Interval Analysis

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## Introduction

Autonomous navigation for Smart Wheelchairs (SW) [1] enables to enhance the user's autonomy, with, e.g. autonomous docking to a charging station after going to bed. This requires reliable indoor localization. We aim at providing a confidence domain of the pose of a SW, i.e. a box which is guaranteed to contain the true wheelchair position and orientation. The proposed indoor positioning system relies on Ultra-WideBand (UWB) radio modules, with ranging capabilities.

## Ultra-WideBand Sensors

A typical UWB-based indoor localization setup is a set of fixed UWB nodes in the room, or *anchors*, from which mobile UWB nodes installed on the robot, or *tags*, measure ranges. We installed such a setup with four anchors in the room and four tags on a SW (see Fig. 1).

Range measurement between an anchor and a tag is performed using two-way ranging, by measuring the time of flight of the UWB signal. The actual range between the two UWB nodes can be determined, assuming line-of-sight (LOS) propagation. In practice, UWB signals are also reflected or blocked by the environment (walls, furniture, people, wheelchair). This may lead to measuring non-line-of-sight

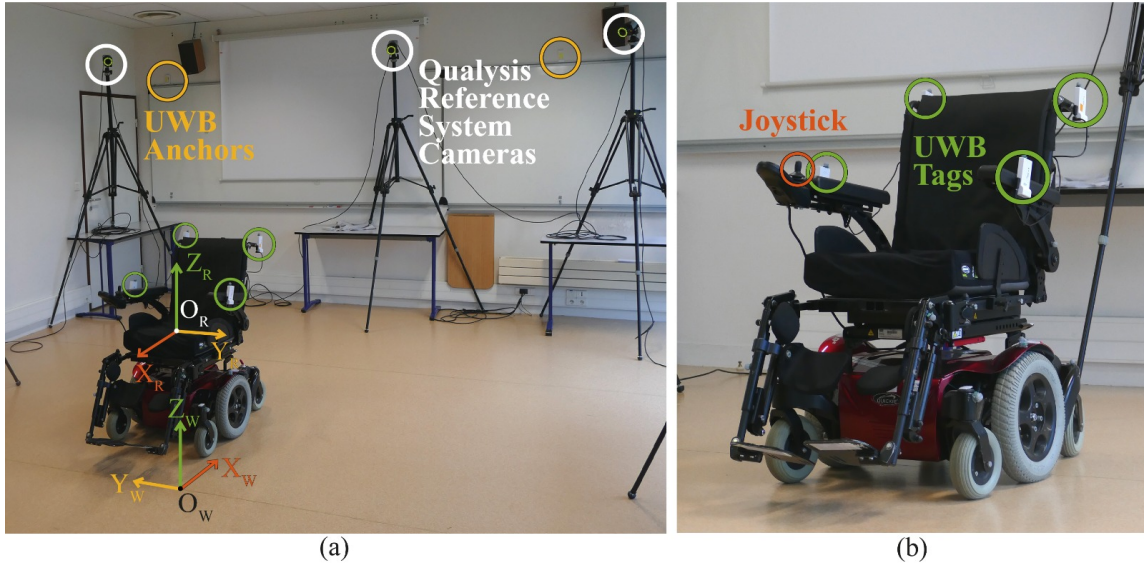


Figure 1: Experimental Setup.

(NLOS) propagation distances, which are longer than the actual distance between the two nodes.

Figure 2 shows the range error distribution of UWB data during trials in which a user was driving the wheelchair while performing daily-life tasks (ground truth comes from a motion capture system). One can distinguish two sources of uncertainties. In LOS conditions, uncertainties are coming from UWB sensors noise, easily handled by a bounded-error model. In NLOS conditions, uncertainties are coming mostly from multipath effects, providing range measurements greater than the actual one, leading to outliers.

## Wheelchair Pose Computation

We define the wheelchair pose domain computation as a CSP. Since outliers in range measurements are always positive, we can avoid using  $q$ -relaxed intersection [2] and GOMNE methods [3], as long as the wheelchair is inside the polygon defined by the anchors.

- The wheelchair pose  $(x, y, \theta)$  defines the transformation between the world frame, and the body frame of the wheelchair (in which

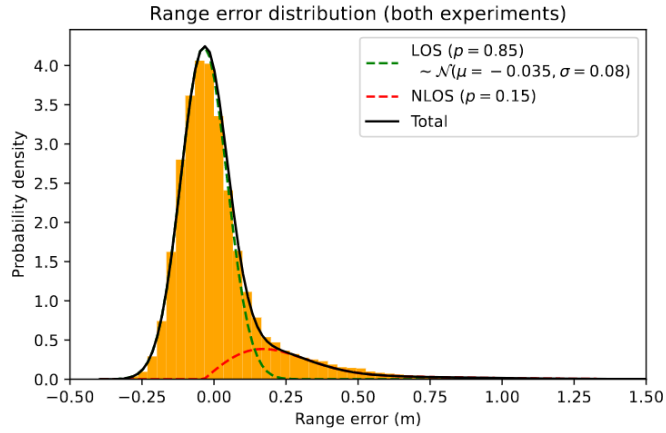


Figure 2: Histogram of the UWB range measurements error.

the tag positions are known).

- The measured UWB ranges  $d_{\text{meas}}$  provide constraints between the anchor positions  $\mathbf{x}_a$  and the tag positions  $\mathbf{x}_t$  in the world frame. To take NLOS propagation into account, we use only a single inequality constraint per measurement, assuming NLOS only yields longer measured ranges:  $\|\mathbf{x}_t - \mathbf{x}_a\| < d_{\text{meas}} + b_{\text{UWB}}$ , with  $b_{\text{UWB}}$  the UWB ranging error bound in LOS condition.

Solving the CSP with SIVIA and contractors, the set of all feasible wheelchair poses  $(x, y, \theta)$  compatible with UWB measurements is computed.

## Experimental Results

Experimental tests were conducted to record UWB data and validate our localization method. UWB range measurement error bounds were set to 24 cm. The midpoint of computed confidence domains is taken as an estimation of the SW pose. Experimental results are presented in Fig. 3, and demonstrate our method’s ability to deal with outliers using only our bounded-error model. The mean horizontal position error over all trials is 9.90 cm.

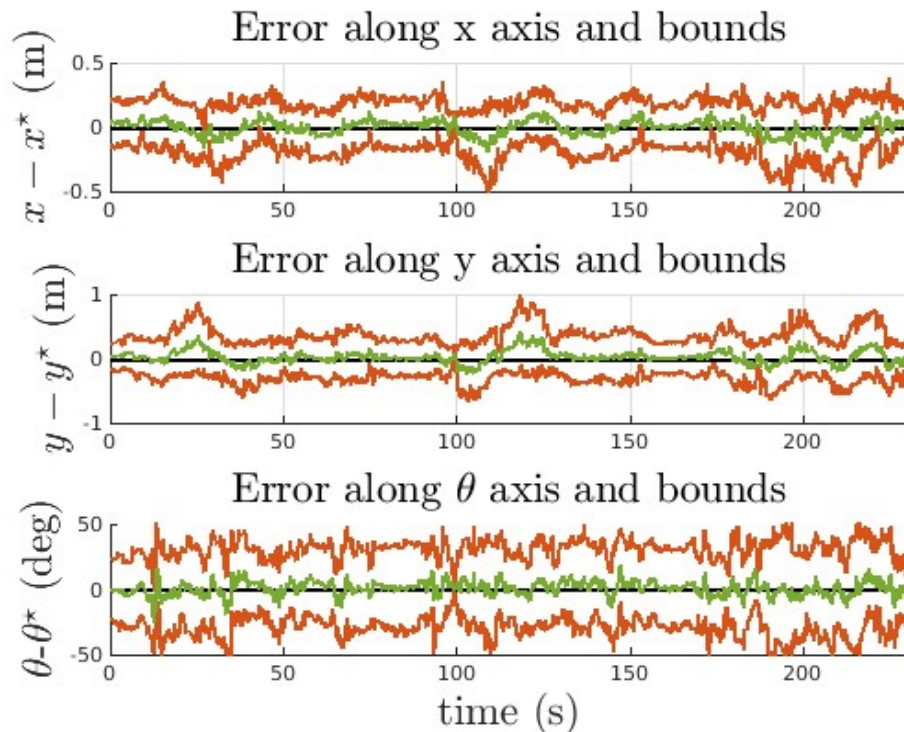


Figure 3: Set-membership position estimation error (green), and confidence lower and upper bounds (orange). The reference is at zero (black)

## References

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