Hybridization of WSPRlive Real-Time Beacons Dataset, Friis Propagation Model and Numerical Solution for Localization

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Abstract

Accurate Localization in Radio Frequency (RF) environments is a critical focus across various navigation applications. To address this challenge, a variety of localization algorithms have been proposed, with particular attention given to Received Signal Strength (RSS)-based approaches. This study focuses on developing a localization algorithm leveraging the real-time WSPRlive dataset and the free space Friis propagation model. The localization process is divided into two stages. Initially, using continuous transmitting beacons data, ideal received powers are computed using the Friis propagation model, resulting in a dataset encompassing about 65.5 thousand location grids. To ensure reliability, WSPRlive, a hardware implementation of Weak Signal Propagation Reports (WSPR)-based beacons, operational 24/7, is utilized globally. This implementation, facilitated by the IntlWSPR project covering 40 spots, features beacons transmitting at 23 dBm, with maximum gains varying according to antenna types: 7 dBi for Skyloop 80-10, 5 dBi for DX Commander ABV, and 2 dBi for Q-Tek Penetrator antennas. With the ideal dataset established as a reference, location estimation becomes feasible by identifying the best beacon identities per received power for the query receiver. Using the initial stage as a reference table, RSS-based localization algorithm is developed to estimate the location along with localization error assessment. Future efforts, including Artificial Neural Networks (ANNs) aim to integrate this enhanced approach into the real-time application, with a focus on estimating the WSPR channel propagation model using additional real data provided by the WSPRnet spot database. Although the WSPRnet spot database offers non-contiguous timed datasets, it serves as a cornerstone for training regression Machine Learning models, facilitating further refinement of the localization process.

Introduction

Leveraging of datasets has shown inevitability for real-time systems. Our goal is to achieve location estimation using the open-source transmission architecture along with reliable numerical solution methodology with accepted localization tolerance. To achieve a reliable performance assessment, a real-time dataset is provided by the IntlWSPR project covering 40 spots of which the first beacon was setup at a satellite ground station near Milano, Italy by the team IU2PJI as shown in Fig. 1. Utilizing the power of datasets achieved in [6], our previous project successfully contributed to expanding data grids aimed at predicting the vertical total electron content (vTEC) for the ionosphere. Leveraging Ham Radio Networks in conjunction with data broadcasted from the International Space Station (ISS), and integrating them into the Galileo-based NeQuickG mathematical model, we developed a web-based application tailored to this purpose.

Fig. 1: IntlWSPR's first beacon at the satellite ground station, Milano, Italy.

To get the best use of the in-field dataset, antenna profiles have been investigated to meet the set assumptions. For instance, the Skyloop 2.0 antenna, shown in Fig. 2, has a near omni-directional Radiation Pattern (RP) when sweeping over different elevation angles as shown in Fig. 3.
Moreover, the Vertical/Inverted L antenna, whose setup shown in Fig. 4, has an almost omni-directional profile for the azimuth plane as shown in Fig. 5.a. However, it experiences a relative directivity at a low elevation angle as in Fig. 5.b. Accordingly, there is some optimization in the antenna tilting to approach the ideal omni-directional pattern, a crucial point for localization.

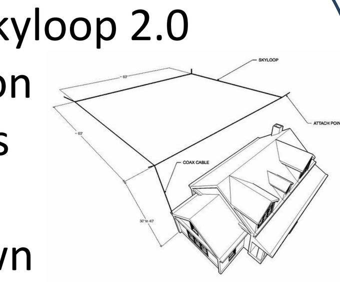


Fig.2: Chameleon Skyloop 2.0. *Source: pileupdx*

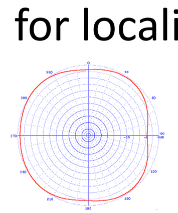


Fig. 5.a: Inverted L Az. RP

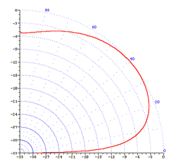


Fig. 5.b: IL Elev RP

Fig. 4: End fed half wave antenna 40/30/20m Vertical/Inverted L. *Source: egloff.eu*

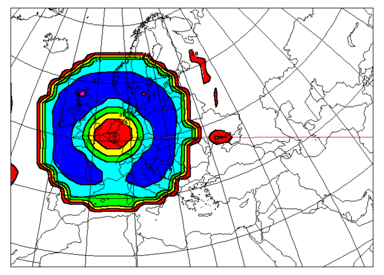


Fig. 5.c: IL Typical Coverage Map *Source: Broadcast Belgium/antenna.be*

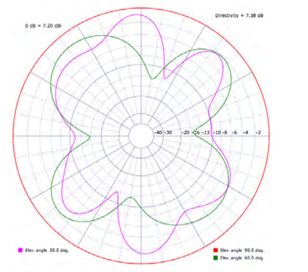
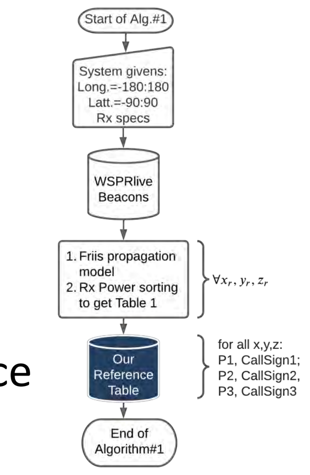


Fig.3: Radiation Pattern for a 635-feet perimeter Skyloop antenna at different elevation angles. *Source: RadioHobbysit*

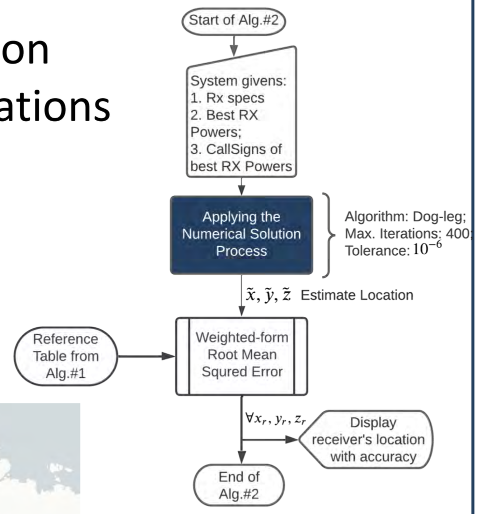
As reviewed in [1], many error estimations have been proposed to assess the localization performance among which is, adopted by this work, the weighted-form Root Mean Square Error (RMSE) along with the spatial RMSE.

Methodology

- ➢ The localization process leans on two stages:
1. Generating a reference table to be used later as performance assessment for the localization numerical solutions;
2. Sweeping over $\approx 65.5k$ grids with best three received powers and their respectful CallSigns.
- ➢ The first stage imports the real-time data provided by WSPRlive, as shown in Algorithm#1.
- ➢ Based on [5], the second stage develops the localization algorithm using Dog-leg algorithm with 400 max. iterations and tolerance of 10^{-6} as depicted in Algorithm#2.



Algorithm#1: Generating our reference table



Algorithm#2: Our proposed localization process

Data and Analysis

- WSPRlive Real-Time Transmitting Beacons, provided in [2], are installed in 40 spots as shown in Fig. 6.
- Table.1 and 2 show the beacons detailed dataset.
- The reference table, out of Algorithm#1, is shown in Table. 3.

Fig. 6: WSPRlive beacon spots

Table 1: Detailed Transmitting beacons dataset, [2]

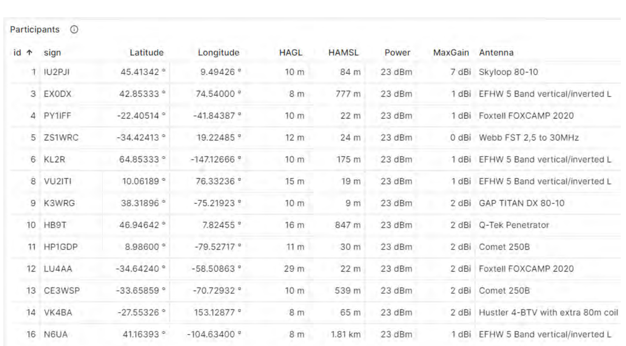


Table. 2: Beacons Uptime, [3]

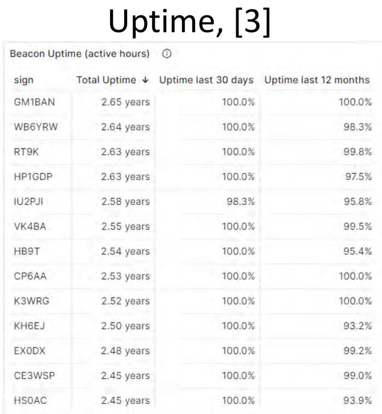
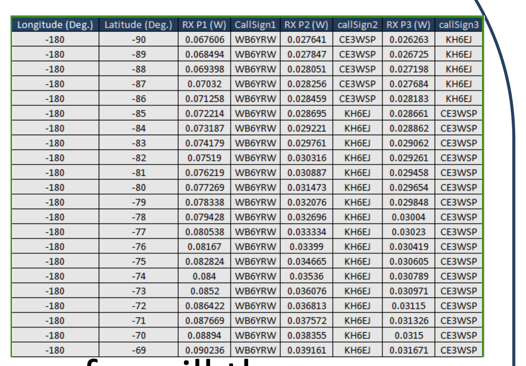


Table 3: Our reference table



- Utilization of the absolute error gives the sense of how far will the estimated grid be away from the true (reference) value. Moreover, weighted-form depicts the percentage of localization error.
- The 3D and 2D percentage localization errors are shown in Fig. 8.a and 8.b. respectively, having $RMSE \approx 4.9\%$.

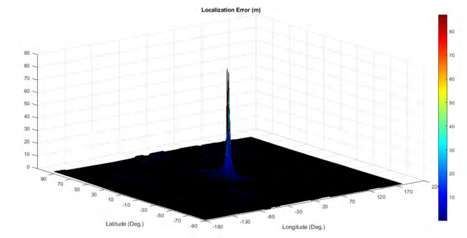


Fig. 7.a: 3D absolute localization error

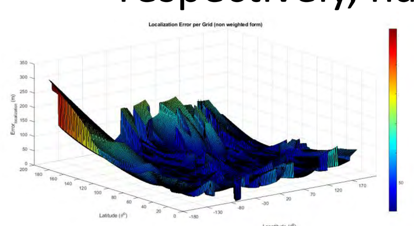


Fig. 10.a: 3D case study for the triangle method

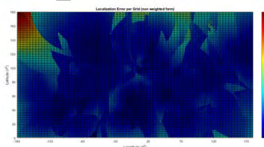


Fig. 10.b: 2D case study for the triangle method

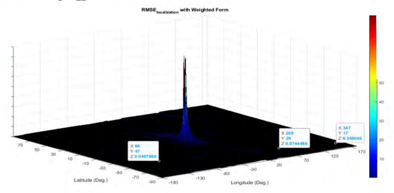


Fig. 8.a: RMSE Weighted form (3D)

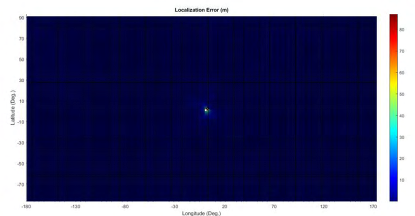


Fig. 7.b: 2D absolute RMSE

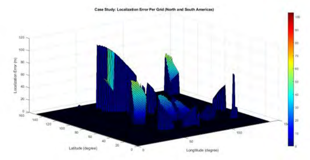


Fig. 9: 3D absolute RMSE in North and South America

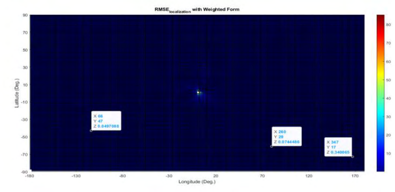


Fig. 8.b: Top view for the Weighted-form RMSE

Conclusion

- ➢ Our proposed hybridized algorithm achieved RMSE ≈ 4.9 %
- ➢ RX should be enclosed in a triangle of TX's (case study in Fig. 10)
- ➢ Future work: Artificial Neural Networks to be used in location prediction.

References

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Scan me!

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