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ACCES: Offline Accuracy Estimation for Fingerprint-based Localization

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Abstract—In this demonstration we present ACCES, a novel framework that enables quality assessment of arbitrary fingerprint maps and offline accuracy estimation for the task of fingerprint-based indoor localization. Our framework considers collected fingerprints disregarding the physical origin of the data. First, it applies a widely used statistical instrument, namely Gaussian Process Regression (GPR), for interpolation of the fingerprints. Then, to estimate the best possibly achievable localization accuracy at any location, it utilizes the Cramer-Rao Lower Bound (CRLB) with interpolated data as an input. Our demonstration entails a standalone version of the popular and open-source Anyplace Internet-based indoor navigation service in which the software modules of ACCES are integrated. At the conference, we will present the utility of our method in two modes: (i) Collection Mode, where attendees will be able to use our service directly to collect signal measurements over the venue using an Android smartphone; and (ii) Reflection Mode, where attendees will be able to observe the collected measurements and the respective ACCES accuracy estimations in the form of an overlay heatmap.

I. INTRODUCTION

Fingerprint-based indoor localization systems can achieve very high accuracy (i.e., 1-2 meters), as it has been shown extensively in [1]. The particular techniques store signals from wireless, light or magnetic signals in a database at a high density, coined a Fingerprint Map (FM). A user can then compare, using known localization algorithms, its currently observed signal fingerprint against the FM in order to find the best match. For example, our in-house Anyplace Internet-based Indoor Navigation Service [2] takes an advantage of crowdsourcing-based fingerprint collection and achieves superb accuracy.

Even though the accuracy of localization can be estimated coarsely after the location request (i.e., the online mode), from a design perspective, it is very important to know the positioning quality of FM at a fine granularity in different areas of a building in offline mode, i.e., shortly after the data for the measurement map is collected, prior to any location request. A system operator who is aware that low accuracy is expected in some part of a building could take action to extend the positioning infrastructure (e.g., install additional beacons) and/or offer incentives to crowdsourcers to contribute more data in that area.

The problem of offline accuracy estimation for fingerprint-based localization was not thoroughly tackled so far. Existing approaches are either empirically-driven [3], thus, not being theoretically solid, or require some knowledge of the data model (e.g., radio-signal propagation) [4], hence, are not suitable for complex data (e.g., ambient magnetic field).

In this demo, we present ACCES [5], which is a novel framework for offline positioning accuracy assessment at arbitrary locations given the FM and disregarding the data origin. Our approach is constructed in three steps: First, we apply a black-box technique for fingerprints interpolation based on a widely used statistical instrument called Gaussian Processes. This tool allows to: (i) predict sensor readings at chosen locations given the initial input data (FM); and (ii) estimate the uncertainty of such predictions in the form of the variance of a Gaussian distribution. Then, given such predictive distribution, we derive a theoretically solid lower bound for the uncertainty in the location estimation, i.e., the localization error, in the form of a Cramer-Rao Lower Bound (CRLB). The CRLB construct is used in estimation theory to derive lower bounds on the variance of an estimator of deterministic parameters. We utilize the derived CRLB as the ACCES navigability score (FM), evaluate it at the fine grid of locations over the venue and show the results in the form of a heatmap.

II. OVERVIEW OF ACCES PROTOTYPE

We have implemented a prototype of ACCES in the popular and open-source Indoor localization architecture coined Anyplace [2]. In this section we summarize our developments by providing further details on the internal operation of our developments. Our demo consist of the three components.

The first component comprises the GPR interpolation algorithm. Given a FM as an input, GPR outputs a predictor, which can be used for estimation of the measurements at arbitrary venue locations. Even though such interpolation may appear to be computationally expensive, as long as the FM is not changed, the predictor is not subject to recalculations. Moreover, if the complete venue is split into the smaller parts (e.g., rooms, corridors) and for each such part separate predictor is found, changes of the FM in one such part, do not affect predictors in other parts.

The second component consists of the CRLB computation algorithm. Given the predictor from the first component, it is used for evaluation of the accuracy estimate (ACCES score) at...
order to analyze obtained fingerprint data (without altering
server and client infrastructure) we deploy separate modified
Anyplace Architect module on a laptop, which serves several
purposes: (i) fetching fingerprint maps from the main Anyplace
server instance; (ii) computation of the accuracy estimates
using our solution; and (iii) their visualization with a heatmap.

B. Demo Plan

Collection mode: In this mode, conference attendees will
have an opportunity to collect Wi-Fi fingerprint data in crowd-
source manner across the conference venue and observe them
in real-time using the Logger application. Conference building
floor plans will be prepared and uploaded to Server in advance.
After installing the Navigator/Logger application, attendees
will be able to find the conference venue building in the list
of available buildings. Then, on the Logger screen in the
application they would be able to observe the locations of
the already collected fingerprints across the venue. Finally, by
enabling fingerprint recording in the Logger, attendees would
be able to walk along the conference venue and collect Wi-
Fi fingerprint data, which will be uploaded to Server and,
subsequently, displayed on the Logger screen.

Reflection mode: In this mode, conference attendees will
be able to observe the impact of fingerprint collection on the
accuracy estimate, visualized in the form of a heatmap on
top of the venue floor plan (see Fig. 1). As it is described in
subsection III-A, we will deploy separate server instance on a
laptop for demonstration of our solution. User interface is built
on top of the Architect component in way that it will allow
attendees to: (i) observe the collected fingerprints; (ii) request
accuracy estimates calculation from the actual fingerprints; (iii)
visualize accuracy estimates via an overlay heatmap with a
blue color representing smaller ACCES scores (better accuracy)
and red color representing larger ACCES scores (worse accu-
rracy); and (iv) switch between FMs collected during different
time periods to observe the ACCES scores.

III. Demonstration Scenario

During the demonstration, the attendees will be able to
appreciate the key components of the ACCES framework.

A. Demo Artifact

We have implemented our framework using Python pro-
gramming language with the use of GPR implementation
from the open-source scikit-learn library. Both interpolation
and accuracy estimation algorithms are implemented as stand-
onel script applications. For the purpose of data collection
and interaction with users we utilize our Anyplace Logger
application, which communicates with our central Anyplace
server and allows users to perform fingerprint mapping. In
order to analyze obtained fingerprint data (without altering

arbitrary locations. Key advantage is that it does not require
any knowledge of the underlying data sources. Additionally, if
the parameters of GPR (e.g., kernel) are unknown, predictor
can be used as a black-box with accuracy estimates evaluated
using numerical approximations, or else, analytical represen-
tation can be derived.

The third component is the Anyplace IIN service [2], which
allows to interact with users for creation of venues, uploading
floor plans, fingerprint mapping, FM analysis and localization.
The Anyplace software stack consists of five main modules,
including the Server, the Data Store, the Architect, the Viewer
and two client applications running on Android smartphones,
namely the Logger and the Navigator. The Server module
contains the complete backend application logic of the service,
including the modeling, crowdsourcing and API functionality.
The Anyplace Architect is a Web App that enables users
to design and upload building structures to Anyplace. The
Anyplace Viewer is a respective Web App that allows search
and navigation off- the-shelf, without installation or logistical
challenges. The combined Anyplace Navigator and Logger is a
native Android application, which allows users to: (i) observe
their current location on top of the floor plan using Wi-Fi
FM localization; and (ii) collect Wi-Fi fingerprint readings and
upload them to our Server.

Fig. 1: ACCES on top of Anyplace will enable architects to
assess in the form of heatmaps the quality of the collected
fingerprints before launching the service to users.

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