EVALUATION OF RF-BASED INDOOR LOCALIZATION SOLUTIONS FOR THE FUTURE INTERNET[1]

D4.3b Report on the Cooperation with EvAAL and Microsoft/IPSN Initiatives

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Status/Version: FINAL
Delivery date: August 11, 2015
Confidentiality: PUBLIC
EVARILOS Identifier: EVA-D4.3b-TUB-V1.0

Keywords:
indoor localization, benchmarking, EvAAL, Microsoft/IPSN, EVARILOS Open Challenge

Abstract:
This document presents the process that precessed the Evaluation of RF-based Indoor Localization Solutions for the Future Internet (EVARILOS) Open Challenge. Specifically, the document overviews a cooperation of the EVARILOS Project consortium with the Evaluating AAL Systems Through Competitive Benchmarking (EvAAL) initiative, initiated with the idea of raising the visibility of the competition and to increase the potential impact of the EVARILOS Open Challenge. Established with the same goal of increasing the potential impact of the EVARILOS Open Challenge, the document focuses on the role of the EVARILOS Project in the Microsoft/Information Processing in Sensor Networks (IPSN) Indoor Localization competition.

[1]This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 317989.

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List of Acronyms

AAL Ambient Assisted Living

API Application Programming Interface

EvAAL Evaluating AAL Systems Through Competitive Benchmarking

EVARILOS Evaluation of RF-based Indoor Localization Solutions for the Future Internet

EOC EVARILOS Open Challenge

IPSN Information Processing in Sensor Networks

RF Radio Frequency

RFID Radio Frequency Identification

RMS Root-Mean Square

SUT System Under Test

1. Introduction

The EVARILOS Project consortium established cooperation with the EvAAL and the Microsoft/IPSN initiatives. EvAAL is an international contest in the field of Ambient Assisted Living (AAL), with strong track record in the recent years. Microsoft/IPSN indoor Localization competition gives different academic and industry groups the opportunity to test their indoor location technologies in a realistic, unfamiliar environment. This environment established a common baseline for assessing the relative accuracy and overhead of the different indoor location technologies. At the same time, it allows researchers working on the indoor location to meet and interact with each other, and closely observe the competing solutions in action. Both initiatives have been selected to increase the visibility of the EVARILOS project (and in particular of the EVARILOS Open Challenge described in the deliverable "D4.3 Report on the Results of the Open Challenge"), to increase its impact, and to attract a larger number of interested parties to potentially contribute to or from the EVARILOS Project.

The rest of this document is structured as follows. We firstly provide an overview of the cooperation of the EVARILOS Project with the EvAAL initiative. Secondly, we give an overview of the activities and main results of the cooperation with Microsoft/IPSN initiative. Finally, we conclude the document.

2. Role of the EVARILOS Project in the EvAAL Initiative

To raise the visibility of the EVARILOS project and to increase its potential impact, a decision has been made to establish cooperation with the EvAAL initiative, `http://evaal.aaloa.org/`), an international contest in the field of AAL, with strong track record. To this end, a series of online consultations, as well as a physical meeting during the EVARILOS project meeting in Madrid, have been conducted. The goal of the negotiations was to coordinate the organization and execution of the EVARILOS Open Challenge and the planned EvAAL 2014 contest.

As an outcome of this process, it was decided to join forces and to embed the EVARILOS Open Challenge in the EvAAL 2014 contest in the form of two special tracks targeting:

- complete localization solutions, where contestants have the opportunity to deploy custom hardware at one of the EVARILOS testing sites; and
- localization algorithms that can be implemented on top of the existing hardware available at the TU Berlin and iMinds EVARILOS testing sites.

Thus, the joint competition has been structured in three tracks, one coordinated by EvAAL and two coordinated by EVARILOS:

Track 1: Localization and activity recognition for AAL – Madrid, ES (EvAAL);

Track 2: Evaluation of RF-based indoor localization solutions in public spaces – Ghent, BE (EVARILOS);

Track 3: Evaluation of RF-based indoor localization algorithms – remote competition (EVARILOS).

With Track 3, EVARILOS offered an option for a completely remote deployment, execution and evaluation of competing localization algorithms.

Detailed technical annexes have been provided for all three tracks. The planned time-line and submission details were as follows.

- Submission of Extended Abstracts: **May 1, 2014**
- Notification of Acceptance: **May 12, 2014**
- Declaration of Winners: **July 11, 2014**
- Camera Ready Paper Deadline: **July 12, 2014**

Execution

Despite the good track record in the previous years, the EvAAL competition (Track 1) received too few submissions, and was therefore canceled by EvAAL. The EVARILOS consortium decided to continue with the organization of the Open Challenge (in the form of Track 2 and Track 3 - Track 3 later became the core of the EVARILOS Open Challenge). In the following we provide brief overview of the scope and the goals of these two EVARILOS tracks.

Track 2 - Evaluation of RF-based Indoor Localization Solutions

The Track 2 of the EVARILOS Open Challenge focused on evaluating full localization systems, including their hardware aspects. To this end, it issued an open challenge towards solution providers (both industrial and academia) that leverage dedicated hardware capable of producing accurate location estimates. Track 2 envisioned evaluation of multiple metrics using a wide range of scenarios, including scenarios with interference. Within the specified deadlines, the Track 2 received information requests from 7 participants, 5 of which ultimately submitted an abstract for participation. Unfortunately, in the end only one participant decided to continue with the participation. The reasons mentioned for these cancellations include the following:

- The EVARILOS Open Challenge was organized too soon after the Microsoft competition during IPSN 2014 (in which EVARILOS was active), thereby resulting in less abstract submissions.
- The travel costs to come over to Ghent to install the hardware proved prohibitive for several localization solution providers, since many of these companies are smaller start-ups.
- Similarly, many small start-ups have a very tight development deadlines, including tweaking localization solutions for specific customers, which came in the way of their participation.
- Finally, one participant had to cancel due to unexpected problems with defective hardware and had to order new hardware systems.

As a result, only one participant could be evaluated using the developed EVARILOS Benchmarking Suite. The solution of the participant was evaluated in 4 scenarios, including 3 interference scenarios, in less than 8 hours including setup time. Integration time was minimal, requiring only the creation of a simple web interface. As such, the feedback from the participant was overwhelmingly positive.

Due to the limited number of participants, no scoring between different participants could be done, and as such Track 2 was canceled.

Call for Continuous Evaluation

Motivated by the lessons learned during the organization of the EVARILOS Open Challenge and the goals of:

- further refinement of the EVARILOS benchmarking methodology and suite,
- expansion of the EVARILOS database of evaluated indoor localization systems, and
- better support to the indoor localization community;

the EVARILOS project has decided to issue an open-ended call announcing the continuous opportunity for evaluating RF-based indoor localization algorithms and solutions using the methodology and infrastructure developed in the scope of the project.

The call has been published on the project website (`http://www.evarilos.eu/evaluation`). As part of this call, the EVARILOS facilities are made open to anyone from academia and industry, potential users and contributors, until the end of the project.

The solutions can be evaluated in one or both of the following settings:

- **Track 1:** Turn-key Radio Frequency (RF)-based indoor localization solutions, tested on-site at iMinds, Ghent, Belgium
- **Track 2:** RF-based indoor localization algorithms, tested via remote access to test facilities at TU Berlin, Germany

Track 1 focuses on benchmarking of complete localization solutions. The participants will have the opportunity to install additional hardware and software at the iMinds test facility in Ghent, Belgium. Available contexts include an office environment and an enclosed open space. The candidate systems have to be either RF-based, or in case of multi-modal systems, they have to possess a strong RF-based component. Hybrid systems where other technologies are used such as infrared, ultrasound, Radio Frequency Identification (RFID), or other are also allowed.

Track 2 offers remote evaluation of RF-based indoor localization algorithms. No traveling is needed in case of pursuing this option. Evaluation opportunities under influence of different RF-interference scenarios are also supported. The participating localization algorithms have to be implemented on top of the existing hardware resources available at the EVARILOS experimental facilities at TU Berlin, including large number of IEEE 802.11g/n access points and IEEE 802.15.4 sensor nodes, deployed in a typical multi-floor office space context.

3. Role of the EVARILOS Project in the Microsoft/IPSN Competition

A close cooperation has been established with Microsoft Research to support the indoor localization competition organized by Microsoft that was collocated with IPSN 2014 (April 2014, `http://ipsn.acm.org/2014/`). EVARILOS participated in the planning and the execution of the competition. As part of a parallel evaluation of the competing artifacts, the EVARILOS project has also demonstrated the capabilities of the automatized benchmarking suite, achieving results that closely matched those obtained by laborious manual evaluation of the competing systems. The benchmarking system, the obtained evaluation results, as well as the upcoming EVARILOS Open Challenge were also presented at the associated indoor localization panel at the conference.

Even though the official evaluation in the Microsoft/IPSN competition was based on the manual process described in [1, 2], the organizers had the ability to leverage the EVARILOS benchmarking platform [3] to automatically evaluate the localization accuracy of the two wining solutions in the infrastructure-based and infrastructure-free categories.

The EVARILOS benchmarking platform is an integrated experimental infrastructure that fully automates the evaluation of indoor localization systems. It leverages the TWISTbot mobility platform comprised of a Kubuki mobility base, a Microsoft Kinect sensor and a Hokuyo URG-04L laser ranger, to enable accurate and repeatable positioning of the evaluated localization devices at different evaluation points (Figure 3.1). During the competition, the TWISTbot platform was able to automatically extract the floor plan of the evaluation area using its onboard sensors. Each team's device was mounted on top of the robot, and then the robot was given the true coordinates of each of the 20 evaluation points. In response, the robot autonomously navigated to the evaluation points and when there, it recorded the location of the System Under Test (SUT). Even though, the EVARILOS platform can interact with the evaluated localization system over a well-defined Application Programming Interface (API), locations were manually recorded and compared with the ground-truth information provided by the TWISTbot to reduce the integration overhead for the competitors.

The best two teams in the competition (Bestmann et al. [4], and Klepal et al. [5]), as determined by the

manual evaluation process, were invited to another evaluation round using the EVARILOS benchmarking platform. Figure 3.2 shows the average location error for both the robot and the manual evaluation process. Surprisingly, the approach by Bestmann et al. was able to achieve the exact same localization accuracy indicating the stability and reliability of the technology. The accuracy of the approach by Klepal et al. was only slightly increased by 0.15 m. Given that this is a pure WiFi-based approach, the overall accuracy and its stability is impressive.

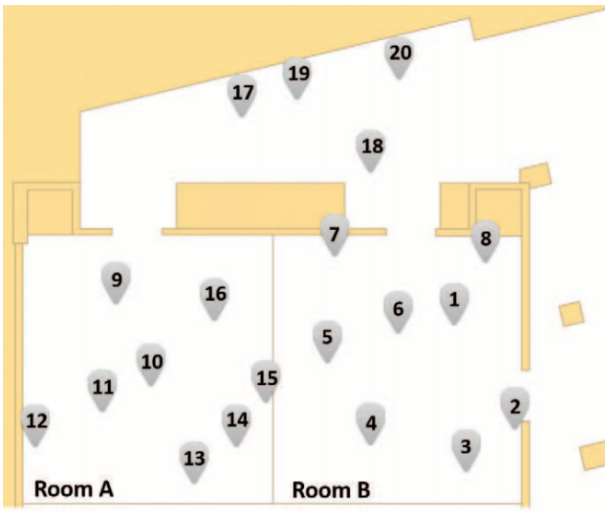

Figure 3.1: The 20 test points on the evaluation area

The results in Figure 3.2 also show the feasibility of automating the evaluation process of indoor location technologies using properly equipped robots. Even though the evaluation area was a very challenging navigation and locomotion environment due to the presence of lot of people and installed localization infrastructure (including a lot of loose cabling on the floors), the TWISTbot mobility platform was able to position the SUT devices to the different evaluation points with acceptable precision and reliability. With an average positioning error of less than 25 cm, the results confirm that the quality of the TWISTbot navigation, even under such challenging conditions, is sufficiently high so that the robot can be indeed used as a source of ground-truth information for automatic evaluation of many indoor localization solutions that typically have location estimate errors that are several multiples of this value.

Approach	Manual	Robot
Bestmann et al.	0.72	0.72
Klepal et al.	1.56	1.71

Figure 3.2: Automatic evaluation using the EVARILOS benchmarking platform. For Klepal et al., the robot evaluation included only 18 out of the total 20 evaluation points. Obstacles or failures in robot's navigation, prevented the robot from placing the SUT above the remaining two evaluation points.

4. Conclusion

The way indoor location technologies are evaluated and compared can be rather tricky. Even though various metrics have been proposed in the literature (i.e., average location error, Root-Mean Square (RMS) error, 95th percentile etc.), there are variations in the real world that are not being properly captured by these metrics. For instance, it has been shown during the Microsoft/IPSN indoor localization competition that not all evaluation points are equal. There are easy points that almost any indoor location approach can easily handle, and there are points that are really hard to accurately localize. As a result, the way evaluation points are selected and weighted in the evaluation metric becomes crucial. After receiving a valuable external feedback and based on our experience, we believe that a lot of work needs to be done in terms of standardizing the evaluation process and metrics of indoor location technologies to properly capture these parameters. In addition, it is clear from the Microsoft/IPSN competition that a manual evaluation of indoor localization technologies is a tedious, time-consuming process. This overhead naturally limits the density of the measurement points and the number of systems that can be evaluated in a reasonable time frame. The initial results from using an automated robot-based benchmarking platform are encouraging, and indicate that such platforms can potentially reduce the evaluation overhead while increasing the fidelity of the evaluation process.

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