Evaluating Indoor Localization Systems for AAL Environments

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Abstract. EvAAL is an international competition aimed to evaluate and assess AAL systems components, services and platforms. Since at present the complexity of AAL systems makes their full comparison hardly possible, EvAAL adopts a gradual approach. This is done by dividing the problem into sub-problems. The full problem is deferred to a time when the knowledge on AAL systems evaluation is more developed. Specifically the second edition of EvAAL promotes competitions on specific AAL components such as indoor localization and activity recognition. This paper describes the technical aspect of the second edition of EvAAL on the special theme of Indoor Localization and Tracking for AAL.

Keywords: AAL, localization, tracking.

1 Motivation

Localization is a key component of many AAL systems, since the user position can be used for detecting user's activities, activating devices, opening doors, etc. While in outdoor scenarios Global Positioning System (GPS) constitute a reliable and easily available technology, in indoor scenarios GPS is largely unavailable.

Several systems have been proposed for indoor localization, which can be classified based on the signal types (infrared, ultrasound, ultra-wideband, and radio frequency), signal metrics (AOA - angle of arrival, TOA - time of arrival, TDOA - time difference of arrival, and RSS - received signal strength), and the metric processing methods (triangulation and scene profiling) [1]. Each solution has advantages and shortcomings, which, in most cases, can be summarized in a trade-off between precision and installation complexity (and thus costs).

In practice, although indoor localization has been a research topic for several decades, there is still not a de-facto standard. Moreover, localization in AAL applications has specific requirements due to the fact that AAL systems must be deployed in homes. In particular, localization system for AAL should be well hidden, easy to install and configure, and reliable. For these reasons EvAAL includes a track on indoor localization.

* This work was supported in part by the European Commission in the framework of the FP7 project universAAL under Contract 247950.

S. Chessa and S. Knauth (Eds.): EvAAL 2012, CCIS 362, pp. 1–5, 2013.

2 Benchmarks

The score for measurable criteria described in Section 3 for each competing artifact was evaluated by means of benchmark tests. We chose the Smart Home Living Lab at the Technical University of Madrid [2] in Spain as site of the competition because it is well suitable for a real-time competition, meaning that a real human user has to be localized in a real home scenario. During the benchmark test, a user wears the equipment the competitors require to carry (if any) and moves along a set of predefined paths (Figure 2). While moving, the localization data produced by the localization system of the competitor are collected in real time by the data collection tool that automatically evaluates the score. Each localization system is requested to produce localization data (in bi-dimensional coordinates) with a frequency of 2 Hz.

The competing systems have also access to the domotic equipment of the Living Lab, therefore the localization algorithms can exploit the information produced by these devices as consequence of the movements and actions of the user. For this reason the benchmarks also include actions such as turning on/off lights or opening doors that are detected by the domotic equipment of the Living Lab and provided to the localization systems in form of "contextual" events. The benchmarks are divided into three phases.

- Phase 1. In this scenario the localization systems have to locate a person inside an Area of Interest (AoI). AoIs represent areas that can have a specific meaning in an AAL application. Examples of AoI can be specific rooms (kitchen, bedroom, etc.) or areas where appliances are located (close to the fridge, on the bed etc.). Each system is requested to identify 6 big AoIs (representing rooms) and 4 small AoIs (representing points of interest for the user). The user moves along predefined paths and stops inside each AoI for at least 5 seconds (Figure 1).
- Phase 2. In this scenario, the user has to be located while moving in the living lab along pre-defined paths. During this phase only the person to be localized is inside the Living Lab. This benchmark uses two paths: one 54 steps long (path 1 in Figure 2), and one 94 steps long (path 2 in Figure 2). Each path includes 3 waiting points, where the user has to stay still in the same position for 5 seconds.
- Phase 3. This scenario is similar to the second phase, with the difference that another user (a disturber) moves in the living lab together with the primary user. In this scenario only the primary user has to be localized as in the previous scenario. The disturbing user follows different, predefined paths, also activating domotic equipment, but at least 2 meters away from the user. In this scenario the paths followed by the user are path 3 (80 steps long) and path 2, while the disturber paths are path 2 and path 1, respectively.

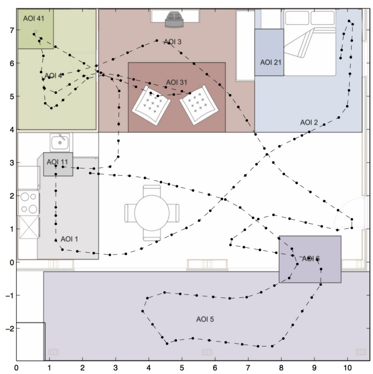

Fig. 1. The AoIs and the path of the user

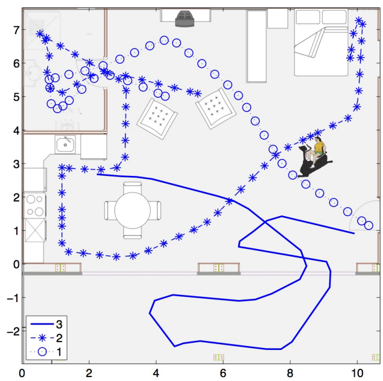

Fig. 2. The three different paths

3 Evaluation Criteria

In order to evaluate the competing localization systems, the localization track uses a set of criteria weighted according to their relevance and importance for AAL applications. The localization track uses five criteria:

- Accuracy (weight: 25%). It expresses the degree to which the competing system is able to correctly localize the user. Accuracy is calculated by computing the error distance between each localization sample sent by the competitor and the reference position. Accuracy is evaluated in two different ways:
  - Phase 1: the accuracy is measured as the fraction of time in which the localization system provides the correct information about presence or not in a given AoI. The number of correctly guessed AoIs is averaged on the number of guessable AoIs.
  - Phases 2 and 3: the euclidean distance between the coordinates sent by the competitor and the reference position is computed at every sample, then the 75^{th} percentile of the errors is computed.
- Availability (weight: 20%). Represents the fraction of time the localization system is active and responsive. The availability is measured as the ratio between the number of produced localization data and the number of expected data.
- Installation complexity (weight: 15%). It measures the effort required to install the AAL localization system in a home. It is measured as a function of the person-minutes of work needed to complete the installation.
- User acceptance (weight: 25%). It expresses how much the localization system is invasive in the user's daily life and thereby the impact perceived by the user. This parameter is estimated with a simple questionnaire that considers aspects of usability.

– Interoperability (weight: 15%). Measures the degree to which the system is easy to integrate with other systems. This parameter is fundamental in AAL scenarios, as localization can be exploited by other applications to offer advanced services. Also the interoperability is measured with a questionnaire that considers aspects of integrability.

All these metrics are then normalized to a common 0 to 10 scale and mixed with a weighted average.

4 Reference Localization System

The reference localization system was composed by predetermined coordinates of the paths followed by the user during the competition. As shown in Figure 3, the Living Lab's floor is covered with marks (with different colors to distinguish the right and left foot) that indicate each single step the user has to follow. In order to facilitate the installation and removal of the paths the marks are put on a wooden bar. The user is synchronized by a digital metronome that indicates the right cadence (one beep one step), guaranteeing that the user repeats the same paths at almost the same speed for every competitor.

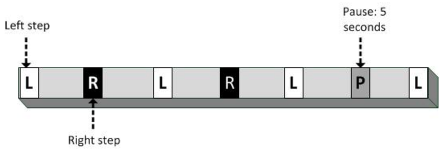

Fig. 3. The reference localization system: the black marks are related to the right foot while the white ones are related to the left foot. Marks denoted with "P" denote a stop of the user for a given time.

5 Contestants and Technologies

Seven teams were accepted to the indoor localization competition, namely CAR (from the Centre for Automation and Robotics, Spain), LOCOSmotion (from the University of Duisburg-Essen, Germany), OwlPS (from the Institute Femto-st, France), CPS Group @ Utah (from the University of Utah, USA), TAIS (from the University of Sevilla , Spain), iLoc+ (from Stuttgart University of Applied Sciences and iHomeLab at Lucerne University of Applied Sciences), and Smart-Condo (from the University of Alberta, Canada). Moreover, Lambda4 (from Hamburg, Germany) participates as guest team. A short description of these systems is as follows:

CAR, Spain - ***Gold Medal.*** This system is based on the fusion of two complementary technologies; i.e. Inertial integration and RFID trilateration. The Inertial solution uses an IMU (Inertial Measurement Unit) mounted on the foot of the person while the IMU approach estimates the user's trajectory shape.

LOCOSmotion, Germany. It is an acceleration-assisted WLAN-based tracking system based on fingerprinting technique. In order to achieve high update rates and to capture movements, this system augments the fingerprinting information with acceleration measurements.

OwlPS, France - ***Bronze Medal.*** This system is WLAN-based localization system, that exploits the RSS to infer the user's position. OwlPS can be used as both fingerprinting-based system or trilateration-based system.

Lambda4, Germany - ***Guest Team.*** It is a system that use the measured phase between the transmitter and a receiver which has to be carried by the person to be localized.

CPS Group @ Utah, USA - ***Silver Medal.*** It is a device-free localization and tracking system, where people to be located do not carry any device. A static deployed wireless sensor network measures the received power on its links and locates people based on the variations caused by the movements of people.

TAIS, Spain. This system is based on RSS fingerprinting technique. The Manhattan distance metric is used to evaluate the user's position.

iLoc+, Germany/Switzerland. it is an ultrasound based system using a transmitter which has to be carried by the person to be localized, and about 25 reference nodes in the lab.

Smart-Condo, Canada. The knowledge of both the coordinates and the mounting angle of where the motion sensors have been placed is used by this system. In order to estimating the user's position the localization algorithm use a center-of-mass calculation and a tracking system.

6 Conclusions

Feedbacks from competitors and workshop audience were encouraging. For this reason we are currently planning EvAAL 2013, which will keep the tracks on indoor localization and on activity recognition. EvAAL 2013 will also add a new track on companion robots for AAK. Further reading about the organization aspects of the competition are available on the official EvAAL website [3].

References

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