Parasitic Tracking: Enabling Ubiquitous Tracking through existing Infrastructure

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***Abstract*—For a mixed reality user the available tracking quality usually is a balance between technical requirements, user needs and economic factors, as most tracking methodologies require setup of dedicated infrastructure. As pervasive and ubiquitous computing grow in importance, so does the associated information infrastructure. Combining these two facts we present strategies to leverage existing information infrastructure and exploit its characteristics to empower users with services to determine their position, without the need for dedicated infrastructure.**

I. Motivation

A common problem encountered in disciplines such as Augmented Reality (AR) or location based computing is how to provide reliable services to determine the user's position or pose. This is usually referred to as the tracking problem.

AR applications are very varied and consequently show a wide spectrum of different requirements, especially in the domain of tracking quality and reliability. On the one hand applications which can operate in a tightly controlled environment (such as industrial or medical AR) might require local but very high quality data, while on the other hand free roaming applications (e.g. conformal navigation instructions) require medium to large tracking volumes with best effort quality. While AR mostly requires high precision tracking, many application can also benefit from more coarse position estimation, either via graceful degradation or a Level-Of-Error approach. Furthermore initialization of model-based markerless tracking can also benefit from such estimates.

It is the aim of Ubiquitous Augmented Reality (UAR) to account for this diversity and to make AR environments collaborative and ubiquitously available. A major problem arises, when users have to install their own specialized tracking equipment. Such infrastructures cannot be assumed to be available in the general UAR case. While some islands of high quality tracking may exist, wide-area or even medium-area coverage in most cases is infeasible. Tracking infrastructure can be costly, difficult to maintain or generally undesired for various reasons.

We propose a parasitic approach of exploiting any kind of infrastructure that is already available in the environment in areas where only low tracking quality is required. In UAR, we combine such parasitic tracking dynamically with special high quality solutions where needed.

In this work we present three concepts towards exploiting pre-existing infrastructure for *Parasitic Tracking*.

II. Parasitic Tracking

In times of rapidly growing information services and diffusion of personal information displays, an increasing amount of infrastructures for various kinds of data communication exists and continues to be deployed. For example wireless LAN, mobile telephony networks or RFID devices become ever more widespread.

Relating to the aforementioned problems of ubiquitous tracking, it is a natural strategy to derive as much information as possible from whatever sources are available. By exploiting known characteristics of information infrastructures many details about the user's location can be gained.

We like to call this approach *Parasitic Tracking* as the tracking system benefits from the existence of unrelated infrastructure.

III. Related Work

The Ubiquitous Tracking paradigm was introduced in [1]. Further development of UAR was presented in [2].

The area of wifi tracking has already been the subject of a number of investigations, for example see [3].

Also the idea of determining the user's position with long-range RFID tags was discussed by [4] using learned snapshots of the environment.

There are some examples of parasitic tracking approaches which already have found widespread use in commercial applications. For example wifi fingerprinting can be found in Apples iPhones. And a growing number of cellular network providers offer location services to its customers.

IV. Ubitrack Framework

To fully leverage a diverse collection of tracking modalities, a unified interface has to be presented to the user. Parasitic tracking tries to use whatever sources present and does not rely on the availability of any single method, and thus represents a "toolbox" of methods rather than a single approach. Tracking setups which incorporate such ideas can become complex and highly dynamic.

The "Ubitrack" middleware [5], co-developed by the author, provides such an simplified and abstracted view of the tracking environment. The description of the setup as well as the user's needs and abilities are expressed in terms of spatial relationship graphs (SRGs). The SRG concept together with

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abstract formulations of tracking algorithms and sensor characteristics allows for automatic or computer-aided reasoning about complex and dynamic setups.

As structural reasoning about tracking setups is vital to successful application of Parasitic Tracking, all concerning methods are fully integrated into the Ubitrack framework.

V. Integration of Suitable Sensing Techniques

In this section some suitable sensing techniques, which are in process of being investigated for parasitic tracking are summarized. Also special focus on how to improve the individual techniques is presented.

A. 802.11 Tracking

Amongst the tracking techniques that have so far received the most attention is localization using IEEE 802.11 wireless LAN (WLAN). As WLAN is an infrastructure that provides basic information access to wireless devices while not addressing the issue of locating the individual entities, it is a prime example for parasitic tracking. WLAN tracking tries to estimate the position of a receiving device by assuming that WLAN base stations are at fixed and known locations and so can be used as anchors. Estimation of the distance to these known points can yield a location estimate of the user.

We conjecture that previously encountered problems in WLAN tracking stem from the circumstance that using current off-the-shelf hardware not enough control can be exercised over relevant radio parameters and that radio specific information is mostly lost. To address these problems we propose to combine WLAN tracking with software defined radio (SDR) technology.

This new approach to radio frequency communication has only recently become popular with the ongoing advance in computer processing power. By moving as much complexity of radio communication from hardware to software, highly configurable devices and even new transmission modes become feasible. At the same time radio parameters governing transmission and reception become more easily accessible to higher software layers.

Our system consists of an SDR hardware platform which runs the 802.11 receiver developed by BBN technologies with additions by Hamed Firooz of SPAN group at University of Utah for the gnuradio signal processing framework.

Using this setup we were able to get first promising results. By tightly controlling the receiver gain on the WLAN interface the relationship between received signal strength and the distance between receiver and transmitter becomes more rigid and deterministic as opposed to the behavior of a closed off-the-shelf WLAN card. Additionally cycling the gain setting through a series of values can both improve the range of meaningful readings as well as diversify closely located signals.

B. RFID Tracking

An increasing number of RFID tags are deployed for various areas of application such as access control, product identification or supply chain management. Of special interest are long-range UHF tags which can allow reading ranges up to 7 meters. This make them also useful as tracking infrastructure under certain circumstances.

In a scenario where different parts with known locations of a complex environment (e.g. an aircraft cabin) are tagged using these labels, we can estimate the user's position from the cloud of all currently read tags. Our first prototypical implementation consisted of a RFID reader with experimentally determined readability field. For every tracking step this antenna pattern is fit to the cloud of the currently detected RFID tag positions. By optimizing this fit a reasonable estimate of the user's position can be found [6]. We further extended this approach to also use SDR technology, which allows us to cycle the the strength of the emitted reading field which powers the RFID tags, effectively modulating the readers detection range. This results in better diversification of measurements.

C. Odometric Tracking

Similar to inertial sensors, which track the user's relative movements, are odometric sensors. Here the way traveled by the user is measured and integrated starting from the last known position of the user.

Using off-the-shelf components we constructed an optical odometric sensor platform consisting of four two-dimensional odometers. We developed methods to calibrate and integrate these sensors. The performance of this sensor as well as further methods of integration with other sensors are evaluated.

VI. Conclusion

This work gives answers on how ubiquitous tracking can be supported in situations where no tracking infrastructure is available. A method of integration of *Parasitic Tracking* methods into the Ubitrack framework is shown as well as several approaches of utilizing unrelated infrastructure for location services. Integration of these methods is still ongoing work as well as the evaluation of further possibilities like radio fingerprinting.

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