

# A Multi-Sensor Platform for Wide-area Tracking

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## ABSTRACT

Indoor tracking scenarios still face challenges in providing continuous tracking support in wide-area workplaces. This is especially the case in Augmented Reality since such augmentations generally require exact full 6DOF pose measurements in order to continuously display 3D graphics from user-related view points. Many single sensor systems have been explored but only few of them have the capability to track reliably in wide-area environments. We introduce a mobile multi-sensor platform to overcome the shortcomings of single sensor systems. The platform is equipped with a detachable optical camera and a rigidly mounted odometric measurement system providing relative positions and orientations with respect to the ground plane. The camera is used for marker-based as well as for marker-less (feature-based) inside-out tracking as part of a hybrid approach. We explain the principle tracking technologies in our competitive/cooperative fusion approach and show possible enhancements to further developments. This inside-out approach scales well with increasing tracking range, as opposed to stationary outside-in tracking.

**Index Terms:** H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.3.1 [Computer Graphics]: Hardware Architecture—Input devices

## 1 INTRODUCTION

In this paper we describe a multi-sensor platform that incorporates various inside-out tracking modalities. The combination of the different sensors should overcome typical shortcomings of single tracking systems and avoid the installation effort for outside-in tracking systems. We have built a prototype consisting of a carriage and a tripod, shown in figure 1. We have integrated a camera and an odometric measuring system. The camera is attached to the carriage at person height but can be detached for convenience. The camera is used for marker and natural feature tracking. The odometric system is mounted to the carriage near above the floor level and is used for relative tracking.

## 2 RELATED WORK

First advances in widearea tracking were achieved in outdoor tracking scenarios. Some early AR outdoor systems [3, 2] provided a user with global position and orientation measurement by integration of GPS and inclinometer/magnetometer for outdoor navigation. Vision-based approaches [8, 9] resulted in higher precision for the augmentations but are in need of initialization, e.g. from GPS and a magnetometer.

As a widearea indoor tracking system Newmann et al. [5] applied an optical tracking system to have high accuracy for augmentations in combination with Ultra-Wideband (UWB) tracking and a gyroscope. The installation and calibration of such a stationary system



Figure 1: The carriage mounted with tripod, sensors and computing unit

for the position is of a tremendous engineering effort and the position of the UWB-tracking is affected by the reflective properties of modern building materials as mentioned by the authors. Pustka and Klinker [7] build a small mobile platform that consisted of a gyroscope, an optical marker-based tracking. Two stationary outside-in tracking systems (infrared and UWB) assisted the mobile system. The system switched dynamically between different sensor types depending on the availability of the tracking modalities in the first step and their accuracy in the second.

## 3 SENSOR SETUP

We have chosen several sensors for competitive and cooperative sensor fusion [1] based on their different properties to balance the disadvantages of each single sensor. Similar to Schoenfelder et al. [10] we have built a carriage (see figure 1) that incorporates a camera, the odometric sensors and a computing unit.

The camera is a central sensing element. Although it is one piece of hardware it provides us with the ability to use two different types of sensing modalities. The first sensing modality is the Marker Tracker. It is supported by the Natural Feature Tracking as the second tracking modality. The odometric tracking uses different sensor elements based on computer mice. Figure 2 illustrates the final spatial relationships of the different sensors and their landmarks to each other and the room coordinate system. The arrows symbolize transformations between the different coordinate systems. The reflexive edge of the carriage symbolizes the relative tracking in relation to prior measurements of the odometric sensor. The edge labeled with 'init' symbolizes the required last pose from the system,

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respectively the carriage, in respect to the world/room coordinate system. The final pose for the augmentations is represented by the dashed arrow.

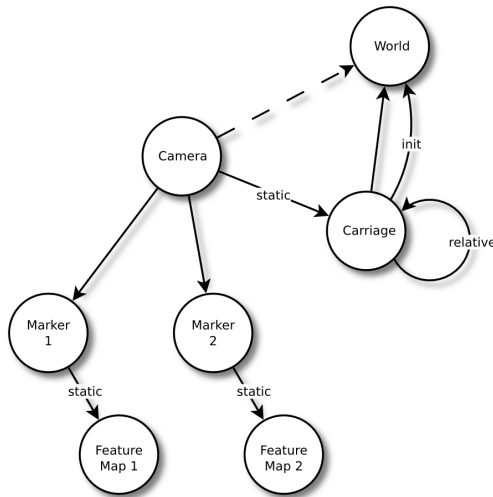


Figure 2: This Spatial Relationship Graph illustrates the final sensor setup after calibration

**Marker Tracking** We decided for marker tracking as the basic tracking modality for our multi-sensor platform. Marker tracking is a well-known and widely used tracking technology in the field of Augmented Reality [6, 11] As a first step we deploy several markers in the environment (where allowed) and register them to the room coordinate system such that we can rely on them as well known and reliable landmarks. The registration can either be done by using a tachymeter or taking several pictures of the markers and perform a bundle adjustment. These landmarks are further used for the initialization of the Natural Feature Tracking and the odometric measurement system.

**Natural Feature Tracking** The marker tracker is complemented by a Natural feature-based tracking (NFT) approach to make use of the advantages of both modalities. Whenever our tracking system detects no marker to calculate the global pose of the device the NFT is activated. For using the NFT feature maps have to be trained in an offline procedure which should incorporate a marker for determining the registration of the feature map within the room coordinates and the correct scaling. Once a map has been found, it allows also relative tracking in previously unknown areas of the room. As a NFT we decided to integrate the PTAM algorithm developed by Klein and Murray [4], but we could also imagine other systems to act in a similar way.

**Optical Odometric Sensor** As a third mode of localization, we added an optical odometric motion sensor system to the fusion platform. This odometric localization method complements the high precision vision based tracking methods by providing a location estimate with lesser precision, but with very high robustness.

The rationale behind the inclusion of this sensor system is that even a rough position estimate can improve the performance of the vision based systems and suffices for global navigation between areas of high precision tracking accuracy. Thus the high accuracy of the other approaches is traded for almost universal availability. This bridges a potential gap in situations where no other tracking modality is viable.

The system consists of a number of optical flow sensors units which are positioned around the edge of the platform. The sensors

themselves are facing down. They register the motion of the platform relative to the floor as displacements in two dimensions. Since the odometric system can only measure the movement of the sensor platform on the floor the resulting tracking data consequently exhibits three degrees of freedom, as opposed to the six DoF poses of the camera system. Since each sensor unit contributes two DoF data, at least two distinct units are necessary. A third sensor unit was added to improve the accuracy and reliability of the resulting tracking data.

The measurements of the distributed sensor units are collected by a central control unit and forwarded to the host computer, where the tracking data is computed.

## 4 CONCLUSION

First experiences show a promising quality of our multi sensor platform for solving the task of widearea indoor tracking for Augmented Reality. In future steps we planed the fusion of the various sensors using Bayesian Filtering approaches. This could still improve the overall tracking quality and would enable an automatic sensor fusion without manual interaction.

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