

MATRIS – Markerless Tracking Technology for Augmented Reality Applications

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There are many applications in which it is necessary to overlay a computer-generated object onto a real scene in real time, requiring accurate measurement of the position of the camera or headset. Existing methods require bulky hardware, severely limiting their usability. The objective of this project is to develop and implement a system for determining the position, orientation, and focal length of a camera in real time by the analysis of the camera images and the exploitation of unobtrusive inertial motion sensors. This will enable the system as a whole to determine its location and orientation in a very natural way, mimicking the way a human orientates himself when he uses his vestibular organ (in the ears), which is essentially an inertial measurement unit, and when he uses his eyes, essentially comparable to a camera. The results of the project will be a marker-free tracking system that works with a high frame rate on a low-performance computer unit. It will allow the capture of camera and head motions respectively for TV pro-

duction and mobile Augmented Reality applications. In particular, the system will work over a large area in indoor as well as in outdoor environments. By providing this unique technology, the project will act as a strong enabling force for the wider deployment of Augmented Reality in application areas including content production, education, cultural heritage and industry.

Integrated Video and Inertial Sensors

In order to create such a tracking solution, a hybrid, markerless tracking method is being developed in the European IST project known as MATRIS (Markerless real-time Tracking for Augmented Reality Image Synthesis). This tracking method is based on the following data sources:

- *Live Video Data Streams*

The live video data is recorded with a miniature firewire camera. This camera takes color pictures with a resolution of 640x480 pixels at a frequency of 30 Hz.

German Abstract

Augmented Reality (AR) stellt virtuelle Objekte in Überlagerung mit einer realen Szene dar oder Liveaufnahmen einer Videokamera werden mit digitalen Informationen überlagert. Eine große Herausforderung in diesem Kontext bildet das so genannte »Tracking«. Das Trackingverfahren bewirkt es, dass die virtuellen Gegenstände in Relation zur realen Umgebung örtlich fixiert bleiben. Dazu ist es erforderlich, die Position der Videokamera in Echtzeit zu registrieren und mit der Position der virtuellen Kamera abzugleichen. Das Trackingverfahren soll dabei in weiten Arealen, im Freien und unter sich verändernden Lichtbedingungen zuverlässig sein. Ebenso sollen in der realen Umgebung keine Marker (z.B. LEDs oder Schwarz-Weiß-Bilder) eingebracht werden, da dieses Vorgehen in den meisten Anwendungsfällen nicht praktikabel ist.



Figure 1: MATRIS – integrated sensor unit combining inertial sensors and video camera.

– *Inertial Sensors*

The inertial sensors register accelerations in a translatory direction and velocities in a gyratory direction. Orientation in the earth's magnetic field is also registered (compass sensor). The data is exported at a very high frequency of around 100 Hz via a USB interface.

The camera and sensors are combined in a tracking box, and the electronics are merged (see figure 1). The recorded data is correlated with the video grabber (interface in the computer for reading camera images), creating a synchronized data stream of video images, linear accelerations, angular velocities and orientation in the earth's magnetic field which serves as input data for the tracking software.

Hybrid and Markerless Tracking

The tracking system is realized algorithmically by imitating the human sense of orientation. Priority is given to processing the visual information, though in cases of bad lighting or high acceleration, the inertial systems come to the fore.

For processing the visual information, the live images from the video camera are processed in real time. Features are extracted from the images which make it possible to identify characteristic features in the real environment (landmarks). These landmarks are identified by using point and edge detectors.

With the help of the landmarks that have been identified in the two-dimensional camera images, the position of the camera is reconstructed in three-dimensional space. Epipolar geometry techniques are used to do this. Landmarks are either set in relation to previous video images (frame-to-frame tracking), or they are correlated with a digital 3D model of the real environment. For example, the digital 3D model of the environment is created in a preprocessing stage on the basis of 3D CAD models of buildings or machines.

Inertial sensors support this image-based tracking method. The assumed pose (position and orientation) of the tracking unit can be predicted by analyzing the measured motion path of the tracking unit. This estimated pose



Figure 2: MATRIS technology used for tracking in TV-production.

Figure 3: MATRIS technology used by the BBC for live illustration of sport events.



is the starting point for the image-based tracking algorithms. The inertial sensors are also evaluated if no landmarks are detected in the camera images. The problem with using inertial sensors, however, is that measurement errors can accumulate, since they are not absolute poses which are registered here, but rather relative movements. For this reason, the poses determined using the inertial sensors are continually corrected with the help of the absolute pose results from the image-based tracking.

Achievements

The MATRIS project has developed and demonstrated a real-time camera tracking system that does not require markers or special studio infrastructure. It has shown that by combining image analysis with an Inertial Measurement Unit (IMU), better results can be achieved than with image analysis alone. Furthermore, several alternatives of the same core system have been developed and evaluated during trials, for example in the field of live TV production (see figure 2). In particular, the

line tracking system is already used in commercial sport TV programs (see figure 3). The texture-based tracking system has shown good results in indoor environments, and the use of a fish-eye camera gave promising results in terms of robustness.

Partners

The following project partners are working together in the MATRIS project:

- Fraunhofer IGD, Darmstadt, Germany
- BBC R&D, Great Britain
- Christian-Albrechts-Universität, Kiel, Germany
- Xsens Technologies B.V., Netherlands
- University of Linköping, Sweden

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