Outdoor Mixed Reality Utilizing Surveillance Cameras

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Abstract

An outdoor mixed-reality system designed for pedestrians who carries a camera-attached PDA is presented. Our system utilizes surveillance cameras for two purposes; for showing hidden area to the pedestrians by mixed-reality technology and for updating textures of calibration markers in order to handle possible texture changes in outdoor real world.

1 PDA See Through

We propose a new way of using PDA with which pedestrians can see through buildings on streets so that they can check hidden areas based on mixed-reality technology. It is achieved by utilizing surveillance cameras embedded in real world. By calibrating surveillance cameras beforehand, objects in a hidden area can be shown on a PDA display once after PDA camera is calibrated.
The most difficult part of this approach is the pose and location estimation of PDA camera in outdoor scene, because it is almost impossible to install adequate special calibration markers such as checker boards in outdoor scene.
Instead of embedding special markers, we propose to use substructures of buildings, whose shape can be obtained from CAD data, as calibrations markers in outdoor scene.
One of the critical problems of this approach is that calibration markers may look different at PDA camera. It may derive from lighting conditions, color fading, aging, etc. These phenomena can not be inevitable even if relatively big and substantial parts of buildings in a scene are set as markers. Therefore, we propose to extract live textures of the markers from video images of surveillance cameras.

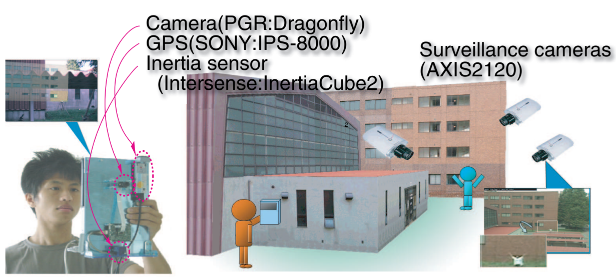

Figure.1: Overview

2 Pose Estimation

Our PDA has GPS, digital compass, and inertia sensors in addition to a CCD camera. GPS and digital compass give initial location and direction estimation of the PDA, and inertia sensor can estimate the pose of the PDA at high frequency. However, they are not sufficient to superimpose 3D models and live videos onto camera image precisely. Fig.2 left shows an example of failed overlay with only GPS, compass, and inertia sensor. The building is more than 20m away.

Certain substructures of buildings are treated as calibration markers in our approach. When they are projected on PDA camera image plane, they should be distinct in order to reduce the chance of fault extraction on image processing.
We define two kinds of markers. Primary markers are the substructures that will be observed at skylines of buildings. One primary marker has several secondary markers that are on visible surface of buildings. Fig.4 shows a set of one primary marker and three secondary markers. The 3D locations of these markers in world coordinates are given from CAD data.
The procedure of camera calibration is as follows. (1) Skyline area of PDA camera image is segmented. (2) Inside the area, distinct regions detected by image processing are selected as primary marker candidates. (3) Among all the primary markers in 3D building model database, visible ones are selected based on current status of pose estimation given by non-vision sensors. (4) Consider a pair of a visible primary marker and a primary marker candidate. Examine associated secondary markers to be found near predicted positions in PDA image. This prediction is calculated by fitting the visible marker to the primary marker candidate. If sufficient number of secondary markers is found, the pose and location of the PDA camera are calculated based on the pair.

Figure.2: Calibration result.

3 Experiment

Fig.3 shows our experiment field. When a user wants to improve geometric registration of mixed-reality on PDA display, he/she directs the PDA camera to one of the buildings near his/her location, frames its skyline at the PDA camera, and requests calibration process. (Before: Fig.2 left. After: Fig.2 right.) Once calibrated, it is not necessary to re-run calibration process until drift error of inertia sensor is accumulated. Fig.5 is a snapshot of PDA display overlaying a hidden area with a walker.

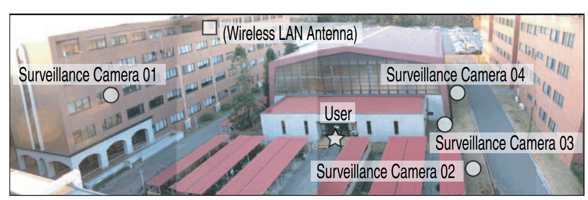

Figure.3: Outdoor field

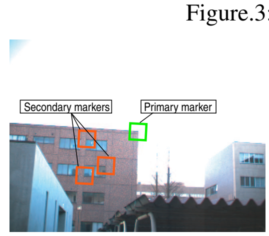

Figure.4: Primary and secondary markers

Figure.5: Snapshot

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