LookUp – LED-light based indoor localization system
WhatsUp – Multimodal indoor localization system

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ABSTRACT
In this contest abstract, we describe LookUp and WhatsUp, low cost, reliable, and accurate indoor localization systems. The systems use anchors, deployed or naturally present at the ceiling in known positions, and a detector node, utilizing conventional sensors readily available in most smartphones. The main sensor is the camera, but accelerometers, magnetometers, and RSSI signals are also used to aid the localization. Two different versions of the system are entered into the competition: LookUp utilizes active anchors (LED lights), while WhatsUp does not use any artificial anchors but operates only with existing objects of the infrastructure, to detect the position of the sensor node.

Categories and Subject Descriptors
C.2.4 **[Computer-Communication Networks]**: Distributed Systems – *distributed applications;* I.4.6 [**Image Processing And Computer Vision**]: Segmentation – *edge and feature detection, pixel classification*; I.4.8 [**Image Processing And Computer Vision**]: Scene Analysis – *sensor fusion*

General Terms
Algorithms, Design, Measurement

Keywords
indoor localization, vision, sensor fusion, visible light communication

1. INTRODUCTION
Several approaches were proposed for indoor localization. Most of today's systems utilize radio-based localization, either using RSSI, flight of time, or phase of interference signals as information source, but other modalities are also common, e.g. light, magnetic fields, or acoustic signals. Vision based system are also used in self-positioning applications, by comparing the picture taken by a camera with pictures stored in a data base. LookUp and WhatsUp utilize fast, scalable, lightweight vision based systems augmented by additional sensors to detect the position of the sensor node. LookUp utilizes deployed infrastructure anchor nodes in known positions, thus provides reliable detections, independent of the environment. WhatsUp does not require infrastructure nodes but rather utilizes existing reference points (e.g. lamps) on the ceiling.

2. OPERATION PRINCIPLE
The sensor node contains a fisheye camera, looking upwards, taking images of the ceiling. A 3D accelerometer is used as an inclinometer; while magnetometers are used to determine the approximate sensor orientation. Wi-Fi RSSI signals may be used to provide rough initial position estimation.

On the image of the ceiling anchor positions are identified, and using various types of triangulations (depending on the number of anchor nodes on the image) the position of the camera (i.e. the position of the sensor node) is calculated.

2.1 LookUp
The block diagram of the system is shown in Figure 1. In the current solution modulated LED lights are used as active anchors. The LEDs are modulated (switched on and off) thus each LED transmits its ID using Visible Light Communication. The modulation was chosen such that flickering problems do not arise and at the same time the decoding can be made by using conventional video cameras.

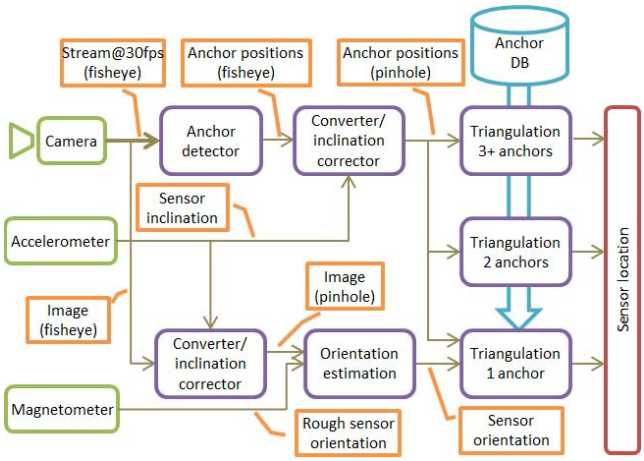

Figure 1. The LookUp system diagram

The anchors are searched for in the input video stream. The anchor detector provides the IDs and positions (on the picture) of the detected anchors.

The anchor positions are converted to the pinhole model and inclination errors are corrected. The camera is a priori calibrated for this process. The anchor positions are used in the triangulation algorithms to detect the sensor position.

If there are three or more anchor nodes on the image, the maximum likelihood estimator for the position of the camera is determined from the viewing angles of the sensors. If there are only two anchors on the image, the pinhole model coordinates of the two anchors are used to calculate the sensor position estimator. In case only one anchor node is detected on the image,

a lower quality position estimator is still possible. First, the orientation of the sensor is approximated, using the magnetometer as a digital compass. Then the orientation estimator is enhanced, using image processing techniques on the pinhole image. Finally the sensor location is calculated from the pinhole image, using the sensor orientation is and the elevation of the anchor and the sensor.

2.2 WhatsUp

The block diagram of the system is shown in Figure 2. The inclination and orientation of the sensor is estimated similarly to LookUp. An RSSI-based rough position estimation is used to detect the approximate (e.g. room-level) location of the sensors. Then, using the environment model, the exact sensor location is determined. The environment model contains descriptors of natural anchors in the infrastructure (e.g. position and shape of a light armature). The system looks for similar objects on the pinhole-model image of the ceiling and thus determines the sensor position.

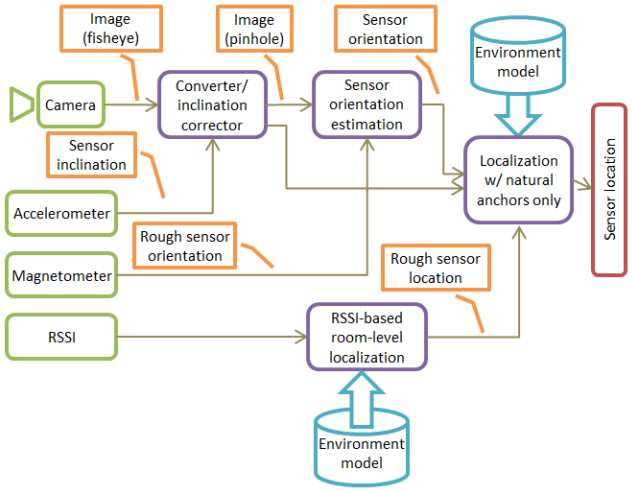

Figure 2. The WhatsUp system diagram

3. HARDWARE

3.1 Anchor nodes

For the contests the anchor nodes were designed to be portable and remote controlled. The anchor node contains its own power supply (batteries), a power LED, an LED driver, and a modulator, which encodes the anchor ID. For sake of convenience, the anchor node also contains a WSN radio to allow the remote control switching (on/off) of the anchors. Note that during system operation the anchors operate autonomously, the system does not use sensor-anchor radio communication for the localization.

3.2 Sensor node

The sensor node contains a USB camera equipped with a fisheye lens, a 3D accelerometer, and a 2D magnetometer. The sensor node is connected to a laptop through a USB cable. The laptop's Wi-Fi receiver is used for RSSI measurements. The sensor fusion is performed on the laptop, and the location estimator is displayed on the laptop as well.

4. DEPLOYMENT REQUIREMENTS

For LookUp, the anchor nodes must be attached to the ceiling (or alternatively, high to the walls, if rooms are not too large). The beacons contain batteries, no cabling is required. The weight of an anchor node is approx. 300g.

The sensor node must be held steadily for a few seconds with the camera looking towards the ceiling, with the anchor nodes in line of sight. The results are displayed on the screen of the attached laptop.

WhatsUp does not require beacon deployment, but instead during the setup phase models of the environment ("ceiling map" and RSSI fingerprints) are created.

5. SUMMARY

Two indoor localization systems were proposed, both utilizing anchors that are located at the ceiling. LookUp utilizes deployed LED anchor nodes and visual light communication to identify anchor positions. Using supplementary sensors (accelerometers and magnetometers) the position of the sensor can reliably be detected. When no anchors can be deployed, WhatsUp system utilizes objects in the environment as anchors. A fusion with RSSI based localization and magnetic-based orientation estimation provides the position estimate for the sensor node.

Although the prototype sensor node was built from custom elements, the utilized sensors can all be found in today's smartphones. Thus the proposed systems can potentially be implemented in small handheld devices.

6. ACKNOWLEDGMENTS

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