# Active Self Calibration of a Multi Sensor System

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The combination of a multi camera system with different sensor types like PMD cameras or motion sensors is called multi sensor system. Such systems offer many different application scenarios, e. g. motion studies of animals and sportsmen, 3D reconstruction or object tracking tasks. In order to work properly, each of this applications needs an accurately calibrated multi sensor system. Calibration consists of estimating the *intrinsic parameters* of each camera and determining the *relative poses* (rotation and translation) between the sensors. The second step is known as *extrinsic calibration* and forms the focus of this work. Self-calibration of a multi sensor system is desirable since a manual calibration is a time consuming and difficult task.

Mounting cameras on top of a *pan-tilt unit* and using *mobile robots* offers many additional degrees of freedom to a multi sensor system. These degrees of freedom can also be used for an *active self-calibration* of the multi sensor system. The open question is what kind of active movements can be used for an extrinsic calibration. Special camera motions or robot motions could be used. The advantage of this kind of motion is that the motion is controllable whereby good *prior information* is provided. Another way to apply motion for calibration consists of using uncontrollable motion in the scene in order to establish correspondences between cameras.

A typical way for determining the relative pose between a camera pair is estimating the *essential matrix* [1]. This matrix contains the rotation and the translation (up to an unknown scale) between the two cameras. A comparison of algorithms for estimating the essential matrix can be found in [2]. Each of these algorithms needs *point correspondences* between the images of the cameras as input. Extracting point typically correspondences consists of three steps: detection of interest points, calculation of a descriptor for each interest point and matching of the points by comparing their descriptors. An established approach for point correspondence extraction was described by Lowe [3].

If two points are matched incorrectly, the resulting point correspondence $(\mathbf{x_i}, \mathbf{x'_j})$ is useless. Probabilistic point correspondences provide a way to avoid a final match decision. Point correspondences between two images are represented by conditional probability distributions $p(\mathbf{x'_j}|\mathbf{x_i})$ instead of point pairs. However, the estimation of the relative pose between two cameras given probabilistic point correspondences is an open field of research.

Fig. 1 illustrates a problem of cameras with additional degrees of freedom. Each of the two cameras is mounted onto a pan-tilt unit. By simple rotation, it can observe a different part of the scene. Point correspondences can only be

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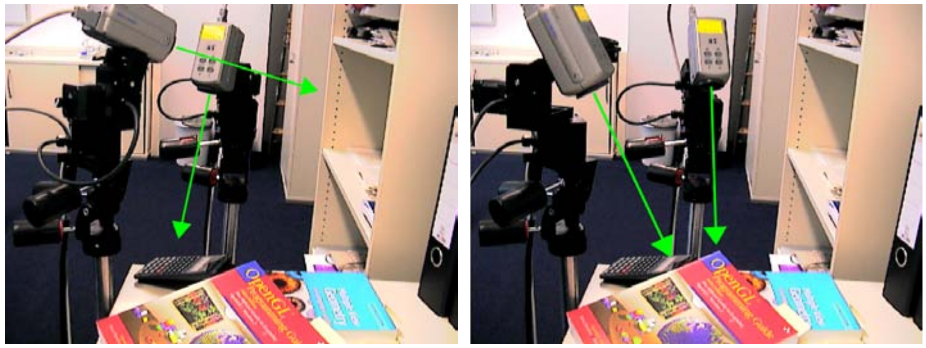

**Fig. 1.** Example for adjusting the fields of view of two pan-tilt unit cameras to enable an extrinsic calibration.

extracted if both cameras observe the same part of the scene. Hence the task consists of detecting common fields of view. It is obvious that there will be more than one possibility to adjust the cameras in such a way that they share a common field of view. That is why there should also be a measure of the quality of the common field of view to achieve the best extrinsic calibration between two cameras. Bajramovic and Denzler [4] proposed a likelihood function for relative poses based on a Blake-Zisserman distribution. They suggested three measures for the uncertainty of an estimated relative pose operating on this likelihood. These *geometric uncertainty measures* can also be used to detect common fields of view since a low uncertainty can only be achieved if an extrinsic calibration with the two camera images is possible, i. e. the cameras have a common field of view.

Besides this geometric uncertainty measures it is also possible to use an uncertainty measure based on probabilistic point correspondences. If the two camera have a common field of view it is more likely that the conditional probability distributions $p(\mathbf{x}'_\mathbf{j}|\mathbf{x}_\mathbf{i})$ have single peaks whereas in the other case these distributions will approximate an uniform distribution. This property is reflected in the joint entropy of the conditional probability distributions. The images of cameras observing the same scene will result in a low joint entropy.

## References


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