TÉCNICO LISBOA

DCCAL - Discrete Cameras Calibration using Properties of Natural Scenes

Milestone 2
First Year Report, Jan.2010-Dec.2010

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Webpage

Electronic address of the webpage of the DCCAL project:
http://users.isr.ist.utl.pt/~jag/project_dccal

Developed Tasks

Task 1, "Central cameras calibration", extends along 18 months and is the single one running during the first year of the project. This task involves updating the review of the state of the art on the calibration of central (standard and discrete) cameras, and updating, redesigning or designing novel calibration methodologies.

The calibration of standard central cameras (pinhole geometry and film or CCD/CMOS sensor) is well studied due to the numerous photogrammetry applications in military and civil engineering fields. Practical calibration for off-the-shelf CCD cameras to apply in small industrial applications is also well studied (R.Y. Tsai 1986), and one has already freeware software tools to calibrate cameras for example based in a planar chess pattern (J.Y. Bouguet 2005). Current research on central cameras calibration is focused in scenarios where it is not reasonable or convenient to use the calibrating chess patterns. For instance, it is not practical to build and display at various poses a large enough chess pattern to be imaged by a fixed surveillance camera mounted several meters height. In these cases, is convenient to explore the information available in the scenario. The scenario has in many cases known structure, known illumination changes, or moving objects, which allows the auto-calibration of a camera. In particular pan-tilt-zoom cameras are known to be possible to auto-calibrate (L. Agapito et al. 2001). There is however still necessary research and development of practical calibration methodologies for pan-tilt-zoom cameras that have significant radial distortion.

In order to further study and develop auto-calibration methodologies for pan-tilt-zoom cameras with radial distortion, an MSc work proposal has been created [MSc-Leite-10(started)]. The MSc work approaches the estimation of radial distortion by tracking image features and estimating their azimuth and elevation while the camera moves. The odometry of pan and tilt degrees of freedom is considered to be known. The MSc has a final goal of using the auto-calibrated pan-tilt-zoom camera to track mobile objects.

Radiometric calibration has been found to be an important aspect complementing the geometric auto-calibration. Geometric auto-calibration is usually based in tracking image features and frequently applied for imaging large fields of view by building mosaics. Mosaicing makes clear that pixels acquiring image data have usually different gains. When superimposing partially overlapping images one observes that locally scene points are tagged with different brightness values due to different pixel gains. The gain differences can be intrinsic to the pixel sensors, to the camera radiometric response function (and auto-gain), and to nonlinearities of the optics. An object is imaged with lesser gain when its angle relative to the lens optical axis increases. This effect, Vignetting, has been studied for pan-tilt cameras considering surveillance applications [Galego10] [Galego10-accepted].

Discrete cameras, being composed simply by a collection of pixels (photocells) characterized geometrically by a pencil of 3D optical rays, may form non-regular structures. In order to create images one needs first to estimate the topology of the complete sensor. In other words, one needs to calibrate topologically the camera.

This topological calibration can be based in estimating inter-pixel angles based in the correlation of time series captured by the respective pixels, i.e. pixel-streams (Grossmann et al., "Discrete camera calibration from pixel streams", CVIU, v114 n2, 2010). However, the process of estimating the all-to-all inter-pixel distances implies maintaining large matrices (number of entries equal to the square of the number of pixels). It is therefore important to design methodologies that allow using lesser memory. In this vein, Multiple Hypothesis Tracking (MHT, D. Reid 1979) methodologies started to be explored. MHT is a common technology for multiple target tracking using RADAR. MHT associates sensor readings and targets whose locations were known at the time of the last sensor readings. Hypotheses are represented as leafs of a tree which is bounded both in depth and breadth. Some preliminary tests and results have been published in [Antunes10]. The tree based representation will be explored in the future to represent the topology/locations of the pixels forming a discrete camera.

In order to prepare the work of the second year of the project, we started the study of the calibration of wide field of view lenses. In particular we consider super-fisheye lenses with more than 180deg field of view. This is a case not available in common calibration toolboxes which are normally based on a simple perspective projection model plus radial distortion, and therefore cannot represent explicitly the projection of points in the camera centre plane (orthogonal to the optical axis). This work started with a collaboration with Escuela de Ingeniería de Antioquia (EIA), Colombia. More precisely, IST received the visit of Mauricio Areas Correa, researcher/faculty of EIA, during approximately two months. During that period was started the mounting of a tubular shaped scenario within which travels a standard camera (CCD sensor) equipped with a super-fisheye lens for inspection (see Figure 1). The tubular structure allows designing specialized SLAM processes which are more robust to noise. Robust SLAM processes are expected to allow integrating novel auto-calibration methodologies.

Fig.1: Tubular-Shape inspection setup. Camera equipped with wide angle lens (FOV > 180º) and illumination LEDs (left). Mockup tubular shape to inspect (middle). Captured image (right).

Preliminary Experiments

The topological calibration of discrete cameras assumes that the camera follows a uniform motion on all degrees of freedom. In order to approach the uniformity, i.e. avoid significant sub-sampling of motion directions, usually one acquires long time series with all the pixels (photocells). When the length of the time series grows to infinity, the relationship between inter-pixel angle and correlation of pixel-streams approaches one-to-one.

There is therefore the natural question of how short can the time-series be and still obtain informative data for the topological calibration. Or, in other terms, how much ambiguity do the short time series introduce in the relationship of inter-pixel angle vs pixel-streams correlation.

Figure 2 shows the 2D histogram characterizing the relationship of pixel-streams correlation vs inter-pixel angle in a synthetic setup. The discrete camera randomly pans and tilts while observing a panorama characterized by a bright spot that slowly decays to black in all directions. The acquired brightness values are noiseless. The time-series acquired by each of the pixels (photocells) have only 50 samples length.

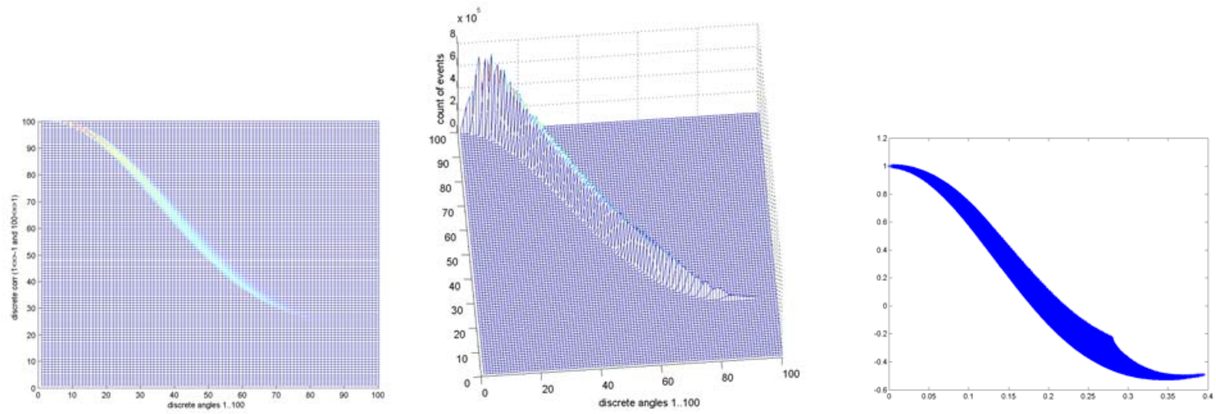

Fig2: Correlation of pixel-streams (y-axis) vs inter-pixel angles (x-axis [rad]).

The first two subfigures of Fig.2 show a top view and a perspective view of the correlation vs angle relationship, while the last subfigure shows the histogram binarized where all non zero values are marked. It is interesting to note that the relationship is nearly one-to-one for small inter-pixel angles, despite the extremely short sequence chosen on purpose to introduce ambiguity.

Publications

(The PDF files of publications realized under DCCAL can be found in the webpage of the project)

[Galego10] Ricardo Galego, Alexandre Bernardino, José Gaspar, "Surveillance with Pan-Tilt Cameras: Background Modeling", In 16th Portuguese Conference on Pattern Recognition (RecPad 2010), Vila Real, Portugal, October 2010.

[Antunes10] David Antunes, David Martins de Matos, José Gaspar, "Multiple Hypothesis Group Tracking in Video Sequences", In 16th Portuguese Conference on Pattern Recognition (RecPad 2010), Vila Real, Portugal, October 2010.

[Galego10-accepted] Ricardo Galego, Alexandre Bernardino, José Gaspar, "Vignetting Correction for Pan-Tilt Surveillance Cameras", accepted in Int. Conf. on Computer Vision Theory and Applications (Visapp), Vilamoura, Portugal, March, 2011.

[MSc-Leite-10(started)] "Target Tracking with Pan-Tilt-Zoom Cameras", Diogo Leite (superv: J. Gaspar, Alexandre Bernardino), MSc work started, IST/MEEC 2010/2011.

[MSc-Antunes-10(started)] "Multi-sensor based Localization and Tracking for Intelligent Environments", David Antunes (superv: J. Gaspar, David Matos (DEI)), MSc work started, IST/MEIC 2010/2011.