DCCAL - Discrete Cameras Calibration using Properties of Natural Scenes

Milestone 4
Second Year Report

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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

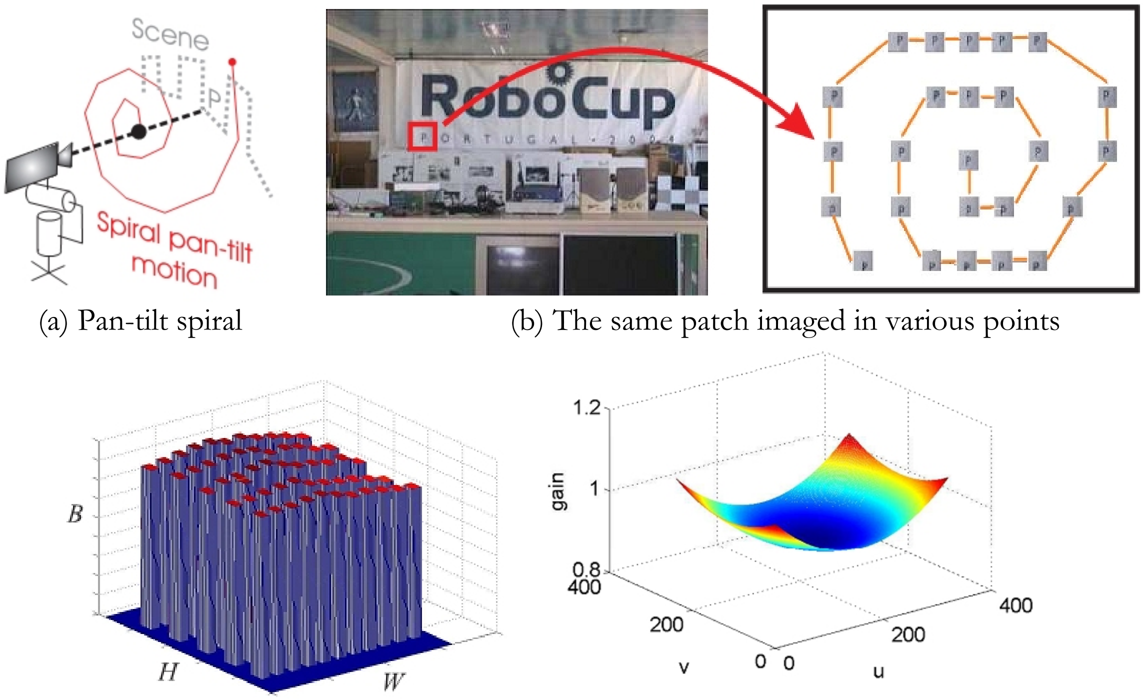
The second year of the project comprises three tasks (i) calibration of central cameras, review of the state of the art and proposal of calibration methodologies, (ii) comparing calibration methodologies, and (iii) application of the methodologies to the classification of lenses mounted on mobile cameras.

Reviewing the state of art on calibrating central cameras encompasses both standard and discrete cameras. Standard cameras are usually based in CCD/CMOS sensors and are described geometrically by the pinhole model. The discrete cameras are also described geometrically by the pinhole model, but are composed by collections of pixels forming unknown, regular or irregular, topologies. Central cameras can also be fixed, and observe moving objects, or mobile in the rotation and translation degrees of freedom, or just mobile in the rotation degrees of freedom (usually pan and tilt). Central cameras can also have the zoom degree of freedom (e.g. pan-tilt-zoom, PTZ, cameras).

Standard fixed cameras are usually calibrated by imaging a known planar chess pattern. Mobile cameras can be auto-calibrated using just information of a static scene and forming e.g. Kruppa equations. In the work [Greggio11] are estimated the parameters of a conic characterizing the silhouette of one spherical object which allows therefore estimating the localization of the object, i.e. the dual problem of estimating the localization of a camera with respect to the scene.

Mobile PTZ cameras can be auto-calibrated. There are however still under research and development practical calibration methodologies for PTZ cameras which have significant radial distortion. In the work [Leite11] a PTZ camera is calibrated for various zoom levels, including a minimum zoom level (maximum view angle) where the camera has a large radial distortion. Using the odometry of the pan and tilt motors proved to be important to accelerate the iterative calibration process.

Still on PTZ cameras, has been identified the need for radiometric calibration in order to attenuate the effects of auto-gain and vignetting in the comparison of pixel-values. In [Galego11b] is proposed a methodology to enforce consistency of gains among images taken at different orientations. In [Galego11] is proposed a vignetting correction methodology.



(a) Pan-tilt spiral

(b) The same patch imaged in various points

(c) Patch brightness as a 3D mesh

(d) Image correction gain

Fig.: Radiometric issues: Building a Constant Radiance Image (CRI). Camera motion (a) and sample (patch) collection (b). (c) Regular grid of patches, with brightness B, in a W × H CRI, obtained with approx. constant pan-tilt steps (d).

The calibration of mobile discrete cameras has been proven to be feasible in a previous work (Grossmann et al. "Discrete camera calibration from pixel streams", CVIU, v114 n2, 2010). However, some recent results obtained in the project show that novel calibration methodologies can be designed without the need of calibration information taken from an auxiliary calibrated camera. More precisely, preliminary results show that natural scenes having contour edges whose directions are uniformly distributed, and where the camera moves also uniformly, provide a linear relationship between the inter-pixel angles and the correlation of the respective time series (pixel-streams). The linear relationship is therefore a simple prior that can be used to calibrate discrete cameras.

In parallel with the studies of the pixel-streams correlation, continued the development of software to propagate the probabilities of hypothesis of multiple target positions, Multiple Hypothesis Tracking - MHT [Antunes11]. MHT is expected to provide efficient representations and algorithms for hypothesising and estimating the topological relative localizations of the pixels of a discrete camera.

The task of comparing calibration methodologies is developed in the MSc works [MSc-Silva-11(started)] and [MSc-Sousa-11(started)]. Besides listing various calibration methodologies for standard fixed cameras, there is studied the problem of calibrating the extrinsic parameters of all cameras with respect to a universal coordinate system. This aspect is relevant in particular for task 4, "Calibrating multiple central cameras".

The task of classifying lenses mounted on mobile cameras is approached in the project as an application of the auto-calibration of cameras. The MSc work [MSc-Tomaz-11(started)] is based in the work started in the first year of the project considering the calibration of a wide field of view camera (FOV larger than 180deg). The main objective of the MSc work is the mosaicing of the interior of a tubular structure. The observation of image feature points and their 3D reconstruction are intrinsically associated to the geometric model of the (central) camera. A robust 3D reconstruction procedure is expected to benefit from classification and self-calibration of the camera.

Experiments Considering Non-ideal Conditions

As noted in the report corresponding to milestone 3, the scene texture is important for the calibration process. In particular we have demonstrated analytically that a scene composed by a circular bright spot and a discrete camera moving uniformly provide a linear relationship between pixel-streams correlation and inter-pixel angle (considering large correlation values).

Figure 2 shows a panoramic scene built from real data (3510 images). The data has been acquired using a pan-tilt camera. Sub-sequences of the pan-tilt complete sequence can be used to auto-calibrate topologically the pan-tilt camera. It is important to stress that the scene texture is very different from the one in the analytically studied setup.

Fig.2: Mosaic of the test data to display the complete scene. The test data is a set of 3510 images.

The use of small time series (sequences), combined with noisy non-ideally textured scenario, imply a larger uncertainty in the conversion of correlations to inter-pixel angles. Figure 3 shows that for each ground-truth inter-pixel angle the variance of estimated angles is large. This aspect is more severe as the inter-pixel angle gets larger. The topological reconstruction based in multidimensional scaling has been found to be much affected by this aspect. In particular has been found that using just local neighbour distances, i.e. discarding the information of large inter-pixel angles, is more precise/accurate as the large inter-pixel angles are usually too noisy.

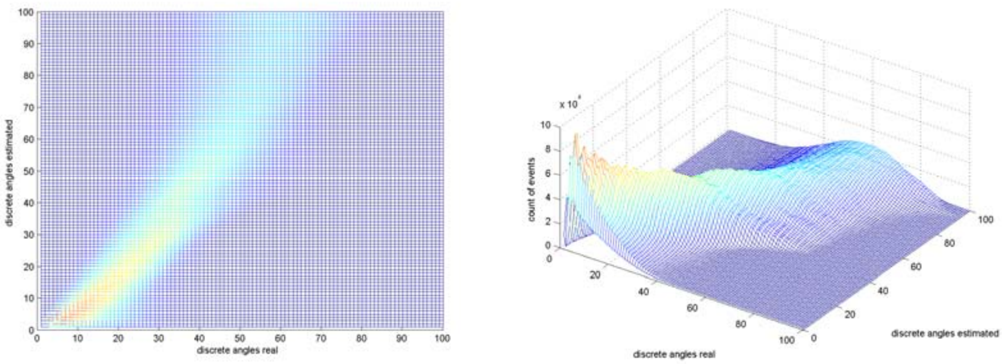


Fig.3: 2D histogram of estimated vs ground-truth inter-pixel angles.
Top view (left) and perspective view (right).

One last aspect that has been confirmed to influence significantly the topological reconstruction is the motion (steps) of the moving camera. As referred, the camera is expected to have uniform motion in its degrees of freedom. If the ranges or steps differ among degrees of freedom, one can have reconstructions which have biased sizes (see Fig.4, middle, a taller than larger reconstruction).

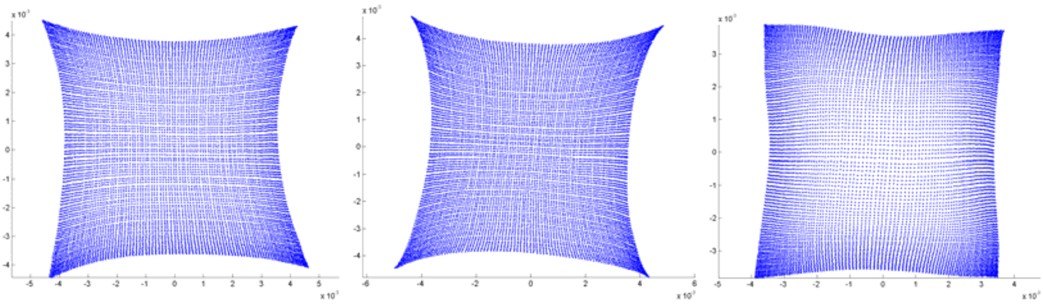


Fig.4: Reconstructed topologies considering various calibration datasets formed by subsequences of the complete pan-tilt sequence. The pan and tilt sequences have equal small steps and equal range (left). The tilt range differs the pan range (middle). The pan and the tilt angles comprise a mixture of small and large steps (right).

In order to have a better qualitative display of the precision / accuracy of the topological calibration (reconstruction) two experiments have been conducted. In a first experiment a bright spot was used to calibrate a 100x100 pixel CCD camera, while in the second experiment were used images taken outdoors, in a garden. Figure 5 shows textured reconstructions corresponding to the two cases: the two leftmost images document calibration based in the white spot, while the two rightmost images document calibration based in a garden sequence of images.

(a) original (b) remapped (c) original (d) remapped

Fig.5: Texture remapping after two topological calibrations. (b) and (d) document the reconstructed topologies using calibration data based in a scene having a single bright spot vs a generic garden sequence (more details in the report corresponding to milestone 3).

Figure 5 shows qualitatively that both sequences used for calibration work. Both sequences are short, and therefore do not give guarantees of fulfilling the uniform motion constraint. In Fig5d one observes a vertical stretching of the image, which does not happen in Fig5b. Given similar constraints on the motion uniformity, was the texture of the calibrating scenes that motivated the different results.

Publications:

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

[Galego11] Ricardo Galego, Alexandre Bernardino, José Gaspar, "Vignetting Correction for Pan-Tilt Surveillance Cameras", Int. Conf. on Computer Vision Theory and Applications (Visapp), Vilamoura, Portugal, March 5-7, 2011, pp638-644.

[Antunes11] David M. Antunes, Dario Figueira, David M. Matos, Alexandre Bernardino, José Gaspar, "Multiple Hypothesis Tracking in Camera Networks", Int. WS on Omnidirectional Vision, Camera Networks and Non-classical Cameras (OMNIVIS) 2011, in conjunction with ICCV 2011, 6-13 November 2011, Barcelona, Spain, pp367-374.

[Greggio11] Nicola Greggio, José Gaspar, Alexandre Bernardino, José Santos-Victor, "Monocular vs Binocular 3D Real-Time Ball Tracking From 2d Ellipses", Int. Conf. on Informatics in Control, Automation and Robotics (ICINCO), Noordwijkerhout, Netherlands, July, 2011, vol2 pp67-73.

[Galego11b] Ricardo Galego, Ricardo Ferreira, Alexandre Bernardino, José Gaspar , "Enforcing Consistency of Image Gains in Panoramic Mosaics", In 17th Portuguese Conference on Pattern Recognition (RecPad 2011), Porto, Portugal, October 2011.

[Leite11] Diogo Leite, Alexandre Bernardino, José Gaspar, "Auto-Calibration of Pan-Tilt-Zoom Cameras: Estimating Intrinsic and Radial Distortion Parameters", In 17th Portuguese Conference on Pattern Recognition (RecPad 2011), Porto, Portugal, October 2011.

[MSc-Galego-11] Geometric and Radiometric Calibration for Pan-Tilt Surveillance Cameras Ricardo Galego (superv: J. Gaspar, Alexandre Bernardino) IST/MEEC 2010/2011 2ºSem. (concluded 12-07-2011)

[MSc-Antunes-11] Multi-sensor based Localization and Tracking for Intelligent Environments David Antunes (superv: J. Gaspar, David Matos (DEI)) IST/MEIC 2010/2011 2ºSem. (concluded 02-11-2011)

[MSc-Leite-11] Target Tracking with Pan-Tilt-Zoom Cameras Diogo Leite (superv: J. Gaspar, Alexandre Bernardino) IST/MEEC 2010/2011 2ºSem. (concluded 22-11-2011)

[MSc-Silva-11(started)] "Network Cameras Calibration", Manuel Silva (superv. J. Gaspar), MSc work started, 2011/2012

[MSc-Sousa-11(started)] "Smallville II- Lab Surveillance Setup", Nuno Sousa (superv. A. Bernardino and J. Gaspar), MSc work started, 2011/2012

[MSc-Tomaz-11(started)] "Mosaicing the interior of tubular structures", João Tomaz (superv. J. Gaspar and R. Ferreira), MSc work started, 2011/2012