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360º Calibration Tunnel for Around-view Monitoring System

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Abstract.

This paper introduces a novel 360º calibration tunnel for auto-calibration of multi-camera in the around-view monitoring system. A specific cylindrical pattern is designed to cover the tunnel and to uniquely encode 3D real world. The unusual model- and correspondence-free multi-camera calibration is employed based on our previous work in [1]. In particular, the scale-free fractal designs inside the 360º pattern result in resolution-free calibration and thus makes the tunnel practical for nearly arbitrary resolutions. One of the main advantage of such tunnel is to not only avoid of manually place the calibration multiple patterns around a vehicle which is complex and laborious but also to dramatically decrease the time of the calibration in a range of few seconds. Therefore, the proposed calibration tunnel can be widely applied to vehicle manufacture, verification, and repair and also in future thanks to the progressing of artificial intelligence, for installing in every gas station to calibrate the multi-cameras of autonomous cars.

Keywords: 360º Calibration tunnel, Around-view monitoring (AVM), Model- and correspondence-free, Multi-camera systems

1. Introduction

Nowadays, thanks to the rapidly progressing in artificial intelligence (AI) many car manufactures use around-view monitoring (AVM) systems for convenience of drivers [3]-[5] including the parking systems equipped by ultrasonic sensors and rear cameras [6]. The usual method for calibrating the car cameras is to place calibration patterns around a vehicle and to extract the extrinsic parameters and the relative pose between sensors [7]. However, such traditional methods are not only a complex and laborious task, but also very time consuming in particular for variety of cars in terms of different size and vision sensors [8]. Therefore, in this paper, we introduce a novel 360º tunnel which can automatically calibrate the car cameras in a range of only few seconds.

The proposed tunnel is covered by a special 360º cylindrical pattern which has free-scale fractal shapes inside. These fractal shapes cope with arbitrary resolutions and thus capable to calibrate different vision sensors with variety in resolution. In additional, the proposed method which is based on our previous work [1] [2], is completely model- and correspondence-free scheme. In the other word, no matter what is the distortion lens, it works for the normal camera with usual field-of-view (FOV) or fish-eye lenses with extremely wide FOV. In multi-camera calibration, not only a calibration is needed for each camera, but the individual images have to be aligned to fit together in a final image mosaic. Image alignment is usually considered a separate problem from distortion correction and thus handled separately. However, the proposed approach, combines distortion correction and image alignment in a single procedure and thus provides much more efficient calibration.

2. Model- and Correspondence-free Multi-Camera Calibration

Camera calibration should be easy to perform on the one hand and provide robust results on the other hand. These requirements motivate the proposed, "unusual" approach for multi-camera calibration. Common methods in camera calibration assume a geometrical model to correct distortion. However, here, the proposed algorithm introduces an approach that does not make any assumptions about the projection model of the lenses and their parameters and therefore allows nearly arbitrary distortions. This calibration procedure uses a particular 360º pattern including distributed variety of markers and fractal shapes in different resolutions. For such multi-camera setups, not only a calibration is needed for each camera, but the individual images have to be aligned to fit together in a final panoramic 360º image. Image alignment is usually considered a separate problem from distortion correction and thus handled separately. The proposed method, however, combines distortion correction and image alignment in a single procedure. Tabel.1 demonstrates the steps of the calibration algorithm.

Before explaining the calibration procedure, we describe how the calibration tunnel encodes the 3D real world and provides a unique target coordinate system. Figure.1 shows the proposed calibration tunnel. The 360º cylindrical pattern contains twelve special colourful checkerboards. Each individual checkerboard includes some markers or fractal shape. By defining a marker as an origin of the pattern, the location of each individual patch of the checkerboards is defined by counting the patches in respect with this origin. In addition, by considering the radius of the tunnel (which is known) the 3D space becomes encoded. The role of the markers is to avoid any ambiguities and to aid for deriving the relative pose of the cameras. Following the steps of the algorithm is explained. Note that in [1] and [2], the graph based segmentation algorithm for the calibration is described by detail.

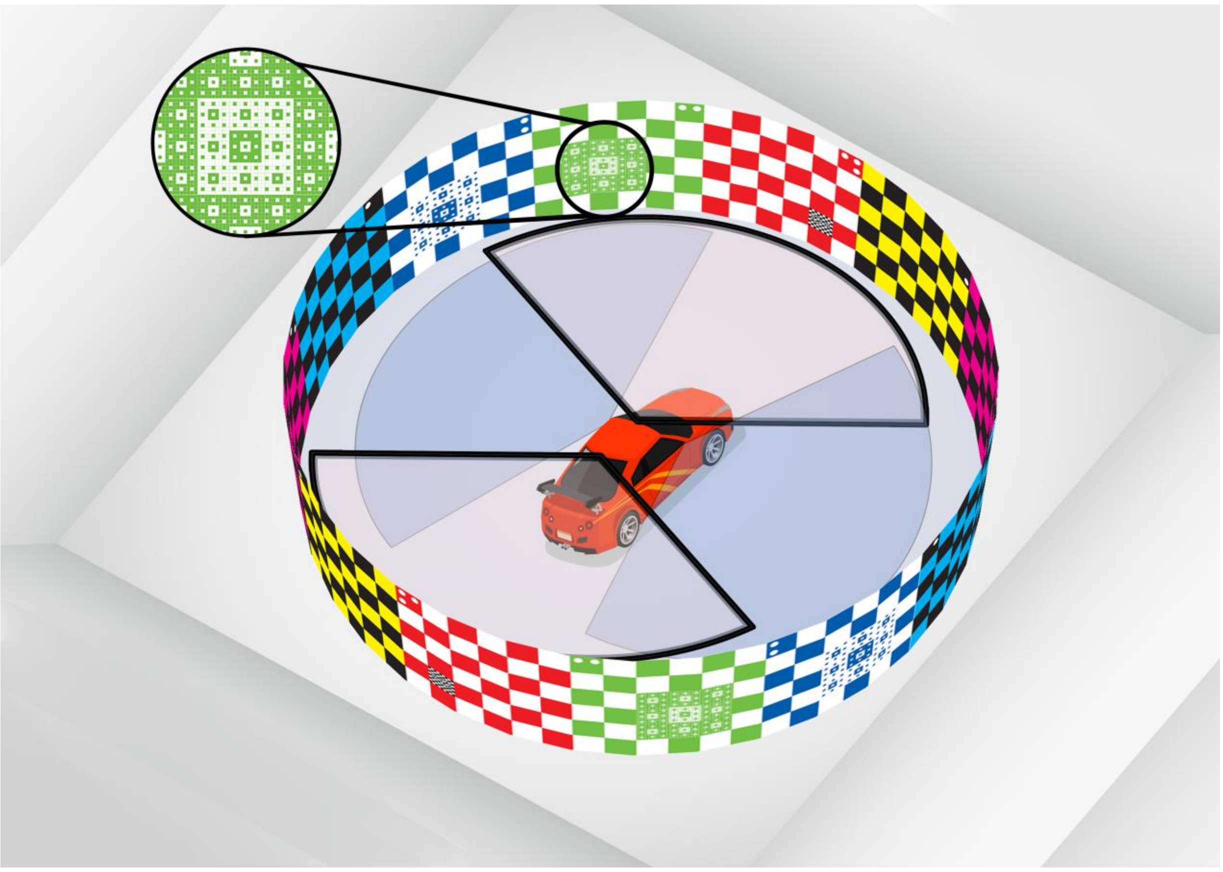

Figure 1: The calibration tunnel covered by 360º pattern. The fractal shape is magnified.

Table 1: Calibration Procedure

Steps of calibration
Detecting the corresponding part of the 360º pattern in each individual car's camera
Running the graph based segmentation algorithm
Counting patches as the correspondence matching
Refining the calibration task

2.1 Detecting the corresponding part of the 360º pattern in each individual car's camera

Since the car places inside the encoded 3D space, no matter that the adjacent cameras have the overlapping area or not. Therefore, the proposed method is generic and can be applied for both cases. Finding the correspondence points is one of the main step in multi-camera calibration. However, here thanks to the encoded 3D tunnel, each single camera by looking at a part of the 360º pattern in its field of view can locate its position in 3D space.

2.2 Running the graph based segmentation algorithm

The graph based segmentation algorithm [2] is used to the segmentation task. In such segmentation, first the primal graph of the image is created at the first level of the irregular pyramid. Second, by consecutively contracting the contraction kernels step by step the next levels are built. Finally, the region adjacency graph (RAG) at the top of the pyramid is represented. Such RAG has the property that each of its node is consider as one patch of the checkerboard.

2.3 Counting patches as the correspondence matching

After segmenting the image each node of the resulted graph on top of the pyramid represents a unique patch of the checker board. Now, since there are special markers in the 360º pattern, one can simply find outs the coordinate of each patch by just counting patches in between till reaches to the pre-defined origin.

2.4 Refining the calibration task

As it is illustrated in Figure.1 the 360º pattern includes special fractal shapes. The main property of the fractals is that they generate the same shape in different scales or different positions. Therefore, in the pattern two fractals in two different scales are designed. Every normal patch in such pattern has uniform region inside its patch. This means that the corresponding points of the resulted graph for each normal patch has 4 points from the world. Hence, the points between the corners have not any correspondence. Now, at this point, by moving the car around the pattern, each camera sees a new pattern in its FOV. This means that whenever the position of the high resolution (fractal) patches are changed, a new part of the space gets a high number of corresponding points. Therefore, moving the car through 360º tunnel, the space receives the corresponding matching points as the high resolution in the fractal patch.

3. Conclusion

This paper introduced a new 360º tunnel efficient for multi-camera calibration and around-view monitoring systems. The proposed algorithm is not only mode- and correspondence-free but thanks to the fractal shapes also resolution-free. In addition, since it does not assume any geometrical model for the lens distortion of the lenses it can be applied for almost any arbitrary distortion. Finally, such generic calibration can be extended and employed for the next autonomous car's generation and even by fusing with other sensors (LIDAR, RADAR and GPS) be beneficial for calibration the Unmanned aerial vehicles (UAVs).

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