Particle Filter Approach Adapted to Catadioptric Images for Target Tracking Application

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This paper addresses the problem of object tracking by particle filter (PF) in catadioptric images. Interested readers are invited to refer to [3] and [2] for details about particle filter. Whereas a large literature exists for traditional images, only a very few systems have been developed for catadioptric vision. We present two techniques to correctly deal with the strong distortions inherent to catadioptric images: adapted particle state/update and adapted neighborhood definition/matching.

Particle state and update

In order to deal with distortions, we suggest working in the equivalent sphere space. This surface can be represented using the azimuth θ and the elevation ϕ angles. Therefore uniformly sampling the (θ, ϕ) space permits to uniformly distribute some particles while simply taking into account the distortion. Similarly, diffusing the particles is performed by simply manipulating θ and ϕ. Moreover, circular statistics are used to compute the mean and variance of the spherical particles for update.

Neighborhood definition and matching

Due to distortions, the traditional rectangular window is not appropriate for catadioptric images. We slightly modified the adapted neighborhood definition [1] to obtain an adapted template shape in the image. Two important remarks are that: (1) the size of the template depends on its location in the image and (2) no interpolation is required since only the pixels of the original catadioptric image are used. The template are then used to build their associated histogram. Since the patches can be of different sizes, we performed histogram normalization before matching them by histogram comparison.

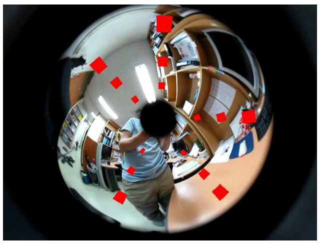


Figure 1: Example of adapted neighborhood with $\theta_t = \phi_t = 4°$. Notice the size and the shape of the patches with respect to its location.

Experimental results

A track is defined as a success when the distance between the estimated location (obtained by the best particle) and the ground truth position (obtained manually) is less than 10 pixels. Figure 2 compares the tracking accuracy obtained by traditional PF in the rectified panoramic image and the proposed PF in the original catadioptric image. Results analysis have confirmed the intuition that the tracking accuracy essentially depends on two aspects: the specificity of the signature of the tracked object (sequences 1-2) and the distortion amplitude of the target (sequences 3-6). For the sequences of high distortion, the proposed method provides an higher tracking success rate. It clearly demonstrates our approach can efficiently handles strong distortions while performing no interpolation (for neither image rectification nor template matching) and not having to consider the "splitting" difficulty (i.e. the target might be split during the rectification).

Fig 3 shows some cases where the target gets occluded and reappears. In traditional vision, it the target leaves the field of view, it could reappear anywhere near the image boundaries. In catadioptric vision, if the object leaves the field of view by the outer (respectively inner) circle, it will likely reappear near the outer (respectively inner) circle. Examples of redetection by the proposed approach are shown in Fig 3.

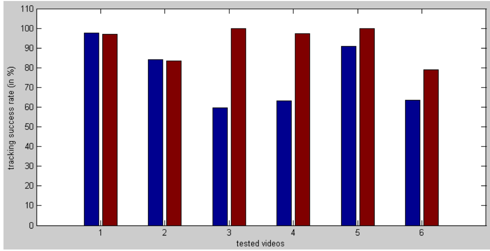
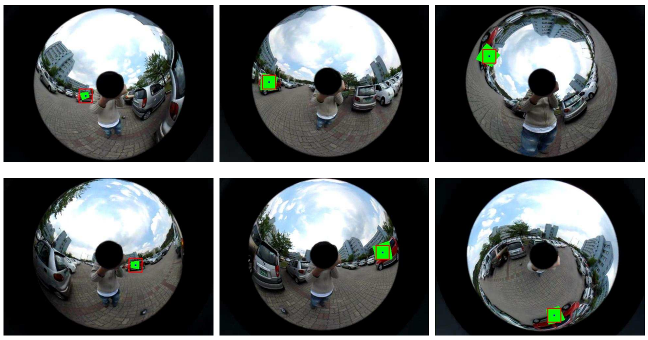


Figure 2: Comparison of tracking accuracy between traditional PF on rectified panoramic images (blue bars) and our proposed PF on original catadioptric images (red bars). Refer to the text for more details about tracking accuracy.



(a) (b) (c)

Figure 3: Examples of occlusion-reappearance (O-R) cases. Column (a): O-R by the blind spot of the inner circle and the camera holder after a yaw rotation; column (b): O-R by the field of view (outer circle) after a yaw rotation; column (c): O-R by the field of view (outer circle) after a pitch rotation.

Conclusion

First, we propose generating and diffusing the particles in the equivalent sphere space rather than in the original 2D catadioptric image. It allows to handle the specific distance associated to the distorted image in a general framework. Second, we use an adapted neighborhood to perform template matching by histogram comparison. It permits to compare templates quickly while using an active neighborhood for space-variant windows.

An additional important feature of our system is that no interpolation is performed: we directly work on the original catadioptric image.

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[2] A. Doucet, N. De Freitas, and N. Gordon. *Sequential Monte Carlo Methods in Practice*. Springer-Verlag, 2001.

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