PANDORA: A Panoramic Detection Dataset for Object with Orientation

Supplementary Material

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Abstract. In this supplemental material, we introduce the derivation of the formula of the normal vectors $[\vec{t}, \vec{b}, \vec{l}, \vec{r}]$ of the planes that the neighboring sides of each RBFoV lie on. We also describe the details of how to convert the planar rectangle to the spherical rectangle in the ERP image. Finally, we describe the details of how to obtain the minimum external bounding BFoV according to the RBFoV.

1 Normal Vector of RBFoV

We first need to obtain four normal vectors $[\vec{n}_t, \vec{n}_b, \vec{n}_l, \vec{n}_r]$ of the planes that the neighboring sides of each RBFoV $(\theta, \phi, \alpha, \beta, 0)$ lie on. As shown in Fig. 1(a), the X', Y' and Z' are the new axis of the coordinate system that we established based on the azimuthal and polar angle (θ, ϕ) of the center point of the RBFoV $(\theta, \phi, \alpha, \beta, 0)$.

$$\begin{cases} X' = [\sin(\phi)\cdot\cos(\theta), \sin(\phi)\cdot\sin(\theta), \cos(\phi)]^\top \\ Y' = [-\sin(\theta), \cos(\theta), 0]^\top \\ Z' = [-\cos(\phi)\cdot\cos(\theta), -\cos(\phi)\cdot\sin(\theta), \sin(\phi)]^\top \end{cases} \tag{1}$$

As shown in Fig. 1(b), the normal $\vec{n}_l$ of the left plane OAC be derived as

$$\vec{n}_l = \sin(\frac{\alpha}{2})\cdot X' - \cos(\frac{\alpha}{2})\cdot Y'. \tag{2}$$

⋆ This work was done when Hang Xu and Qiang Zhao were at ICT.
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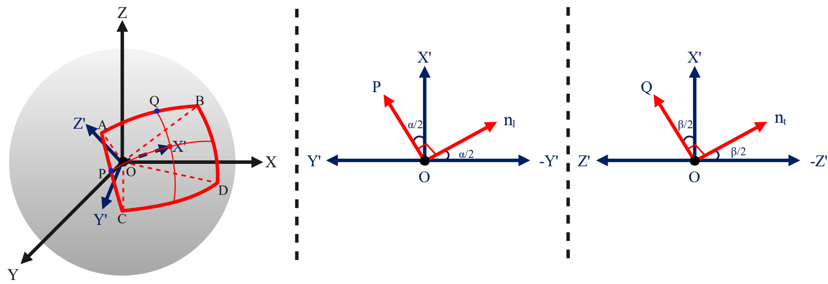

(a) (b) (c)

Fig. 1. (a) The red spherical rectangle is RBFoV $(\theta, \phi, \alpha, \beta, 0)$. X', Y' and Z' are the new coordinate system we establish. (b,c) The normal vectors of four planes be represented by the new coordinate system X', Y' and Z'.

Similarly, as shown in Fig. 1(c), we can also get the normal $\vec{n}_t$ of the top plane OAB as

$$\vec{n}_t = \sin(\frac{\beta}{2}) \cdot X' - \cos(\frac{\beta}{2}) \cdot Z'. \tag{3}$$

Then the normal $\vec{n}_r$ of the right plane OBD and the normal $\vec{n}_b$ of the bottom plane OCD are given similarly.

$$\begin{aligned} \vec{n}_r &= \sin(\frac{\alpha}{2}) \cdot X' + \cos(\frac{\alpha}{2}) \cdot Y', \\ \vec{n}_b &= \sin(\frac{\beta}{2}) \cdot X' + \cos(\frac{\beta}{2}) \cdot Z'. \end{aligned} \tag{4}$$

Finally we can calculate the four normal of the planes that the neighboring sides of each RBFoV $(\theta, \phi, \alpha, \beta, \gamma)$ lie on through the 3D rotation matrix $T(X', \gamma)$.

$$\begin{cases} \vec{t} = T(X', \gamma) \cdot \vec{n}_t \\ \vec{b} = T(X', \gamma) \cdot \vec{n}_b \\ \vec{l} = T(X', \gamma) \cdot \vec{n}_l \\ \vec{r} = T(X', \gamma) \cdot \vec{n}_r \end{cases} \tag{5}$$

where $T(X', \gamma)$ represents the rotation matrix in 3D space. The T has the following expressions:

$$\begin{aligned} T &= \begin{bmatrix} t_1 \ t_2 \ t_3 \end{bmatrix} \\ t_1 &= \begin{bmatrix} n_x^2(1-\cos\gamma)+\cos\gamma \\ n_x n_y(1-\cos\gamma)+n_z \sin\gamma \\ n_x n_z(1-\cos\gamma)+n_y \sin\gamma \end{bmatrix} \\ t_2 &= \begin{bmatrix} n_x n_y(1-\cos\gamma)+n_z \sin\gamma \\ n_y^2(1-\cos\gamma)+\cos\gamma \\ n_x n_y(1-\cos\gamma)+n_x \sin\gamma \end{bmatrix} \\ t_3 &= \begin{bmatrix} n_x n_z(1-\cos\gamma)+n_y \sin\gamma \\ n_y n_z(1-\cos\gamma)+n_x \sin\gamma \\ n_z^2(1-\cos\gamma)+\cos\gamma \end{bmatrix} \end{aligned} \tag{6}$$

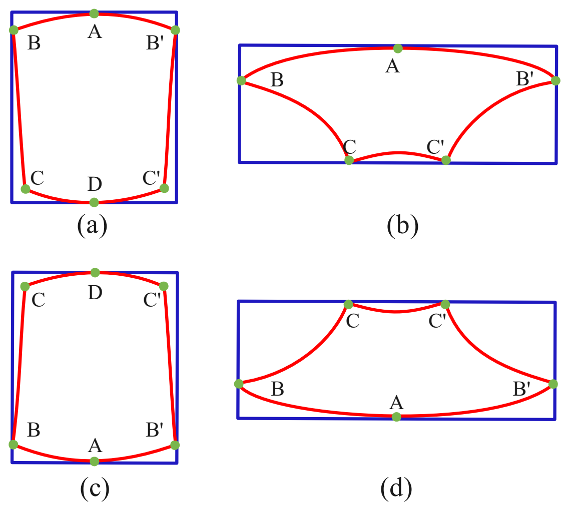

Fig. 2. The situation for converting planar rectangles to spherical bounding rectangles. (a) and (c) are the center of the spherical rectangle falling on both sides of the equator. (c) and (d) are the center of the spherical rectangle falling on the polar regions.

where (n_x, n_y, n_z) is rotation $n-$axis, γ is rotation angle along $n-$axis.

2 Planar Rectangle to Spherical Rectangle

According to the particularity of panoramic images, we find that the planar rectangle in the ERP image can be converted to the spherical rectangle. As shown in Fig. 2, the situation can be divided into two cases: the center of the spherical rectangle falling on the both sides of the equator as shown in Fig. 2(a,c) and falling on the polar regions as shown in Fig. 2(b,d). We can determine the spherical rectangle by obtaining the intersection of the spherical rectangle and the planar rectangle.

As shown in Fig. 2, we first determine to point A and thus obtain the normal vector $\vec{t}$ of the plane of the top side. The points B, A, and B' are in the same plane. We obtain points B and B' by the following formula:

$$\begin{aligned} \vec{t} \cdot \vec{OB} = 0, \\ \vec{t} \cdot \vec{OB'} = 0. \end{aligned} \tag{7}$$

where O is the center the sphere of panoramic image.

Then, the two bottom points (point C and point C') can be found by using the fact that the angle between them equals to the angle between the two top points B and B'. Given four computed points (B, B', C, C'), the spherical rectangle can be determined.

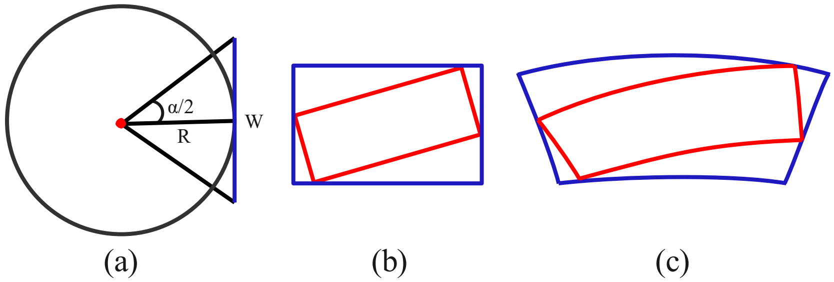

Fig. 3. Calculating the minimum external bounding BFoV according to the RBFoV. (a) We get the width W and height H of its tangent plane rectangle according to α, β in RBFoV. (b) We obtain the tangent plane rectangle according to (W, H, γ) and find its minimum external rectangle (blue). (c) We get the α', β' in BFoV according to the width and height of the minimum external rectangle.

3 RBFoV to BFoV

Ground truths for BFoV experiments are generated by calculating the minimum bounding BFoVs over original annotated RBFoVs.

First, as shown in Fig. 3(a), we get the width W and height H of its tangent plane rectangle according to α, β in RBFoV by the following formula:

$$\begin{aligned} W &= 2R\tan(0.5\alpha), \\ H &= 2R\tan(0.5\beta). \end{aligned} \tag{8}$$

where R is is the radius of the panoramic image.

Then, we obtain the tangent plane rectangle according to (W, H, γ) and find its minimum external rectangle, as shown in Fig. 3(c).

Finally, as shown in Fig. 3(c), we get the α', β' in BFoV according to the width and height of the minimum external rectangle by the following formula:

$$\begin{aligned} \alpha' &= 2arctan2(\frac{W'}{2}, R), \\ \beta' &= 2arctan2(\frac{H'}{2}, R). \end{aligned} \tag{9}$$

where W' and H' are width and height of minimum external rectangle, $atan2$ is 2-argument arctangent.