Hyogo Prefectural Sanda Shounkan Senior High School

Production of a Curved Mirror for an Omnidirectional Camera

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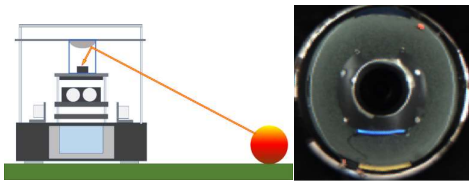
Problem

Participating in the 【RoboCupJunior Soccer WorldLeague Open】.It is a competition to find the ball using **one camera**.

The back is not visible.

Using a **spherical mirror**, made an Omnidirectional Camera.

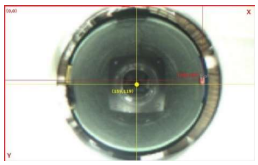


The entire periphery is visible, but not beyond it.

We need to make our **own curved mirror** that can see far away.

Framework

1 Measurement method of relative position coordinates



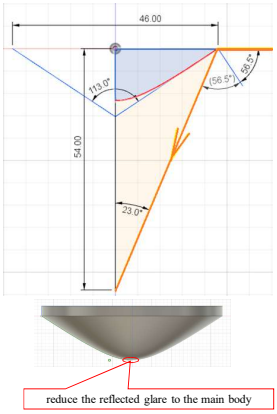
Camera Pixel (320×200)

$$Relative\ angle\ \theta° = \tan^{-1}\frac{y-99}{x-159}$$

$$A\ square\ distance\ r^2 = (x-159)^2+(y-99)^2$$

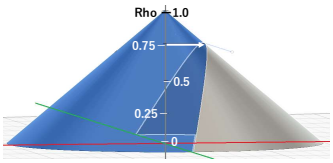
2 Original curved mirror design

We designed a convex mirror based on a conic curve using CAD（FUSION360）.



(1)Design a smooth curved surface with little distortion.

(2) Assume the camera has a vertical field of view of 46° , the light is incident below the horizontal and that the angle formed by the asymptote is 113° .



(3) Use as large a Rho value as possible within 0 to 1.0 by sharpening.

3 Production of an original curved mirror

(1)We made a mold using a CNC milling machine .
(2)We pressed a vinyl chloride mirror sheet (0.5 millimeter) heated with an electric heater against the mold we made.

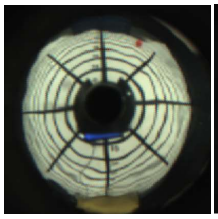
4 Verification in the measurement field

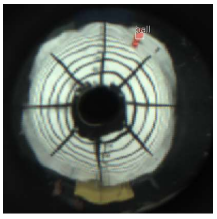
Center the robot in the measurement field

・180cm×180cm
(black lines on white base)
・concentric circles
(10cm intervals)

Findings

1 Comparison of camera images





Spherical mirror　　Convex mirror (ρ＝ 0.80)　　(ρ＝ 0.85)

(1)Ready-made spherical mirror has little distortion in the image and is considered to be optimal for measuring relative angles.
(2)If the distance exceeds 50cm, concentric circles cannot be distinguished.

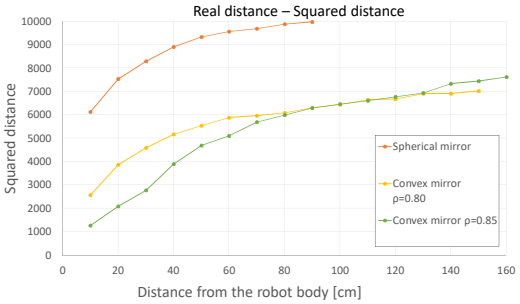
(1) The image of the original convex mirror is distorted.
(2)It is smooth when captured within 40cm and there is no effect on the measurement of the relative angle.
(3)Since the reflection of the robot body is small, the measurement range can be used effectively.
(4)The larger the Rho value, the smaller the reflection of the robot

2 Comparison of distance from the robot body and the squared distance

Distance (cm)	Spherical mirror	Convex mirror ρ= 0.80	Convex mirror ρ= 0.85
10	**6121**	**2561**	**1258**
20	7541	3869	2089
30	8285	4597	2768
40	8912	5161	3893
50	9333	5536	4688
60	9565	5882	5105
70	9684	5965	5689
80	9881	6082	5987
90	**9972**	6304	6290
100		6445	6449
110		6653	6610
120		6673	6773
130		6905	6938
140		6905	7332
150		7012	7445
160			**7618**

Measurable distance
Spherical mirror 90cm
Convex mirror　Rho0.80 150cm
Rho0.85 160cm

Measurement range
(Square distance Max10000)
Spherical mirror（6121～9972）
Convex mirror Rho0.80
（2561～7012）
Rho0.85
（1258～7618）



If the Rho value is large, it can be measured in a wide range.

Interpretation and Conclusion

・**We were able to produce a convex mirror that can recognize almost the entire area of the official field in this research.**
(The RCJ official field size was 180cm x 120cm until 2020.)

・In order to respond to the redesign of the vision system in a short period of time due to the change in the installed camera at the very end of production, **we confirm CAD is effective to build the convex mirror based on the conic curve.**

【RCJ rule changes】
(1)The official field becoming larger: **193cm x 132cm** in 2021.
(2)The official ball changing from a 65mm mat ball to a **42mm glossy golf ball** in 2023.
(3) **Multiple cameras** can be installed in 2023.

The smaller the ball, the harder it is to detect it at long distances.
In order to see long distances, **we must consider installing a front camera along with this camera.**

References

Teruki Ohara.Yuji Fujimura. (2018). Fusion 360 Master's Guide Basic Edition. SotecCo.,Ltd.
Yunit-tech, Manufacturing of mirror, http://yunit.techblog.jp/archives/70016697.html