Evaluation of Distortion Error with Fuzzy Logic

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Key Words: Distortion, fuzzy logic, radial distortion.

SUMMARY

Distortion can be explained as the occurring of an image at a different place instead of where it is required. Modern camera lenses are relatively free of geometric distortion. However, there is always a small remaining amount even with the most expensive lenses. Radial distortion is most visible when taking pictures of vertical structures having straight lines which then appear curved. Tangential distortion is not usually significant. It's not included into computing of distortion correction. So we compute intermediate radial distortion values in fuzzy logic. Distortion corrects with diametrical length in photogrammetry. Diametrical length computes digitally. This value corresponding distortion computes with interpolation.
In this study distortion values are compute by fuzzy logic without the need for interpolation.

1. INTRODUCTION

Photogrammetric methods such as photographic rectification and camera matching are used to analyze photographs. These methods can determine the size, shape and position of objects in the photograph (Neale et al.,2011). Distortions in the design and manufacturing processes of camera lenses inherently cause distortion in the image captured by the sensors or by film of the camera (Goldberg, 1992).The six major types of errors are spherical aberration, come astigmatism, field curvature, lens radial distortion and chromatic distortion (Choi et al., 2006). There can be found three types of distortions, radial distortion, tangential distortion, mustache distortion (moustache distortion). However, only radial distortion has a significant influence on the image geometry. Tangential distortion is usually insignificant and is not included into computing of distortion correction. The radial distortion causes straight lines in the object space rendered as curved lines on the film or camera sensor. Despite that every point is in focus, radial distortion deforms the whole image (Ergun,2010). Together with a spatial transformation, the correction of radial distortion is the key step in the image rectification or orthorectification. Especially when working with non-metric digital cameras, the radial distortion reaches significant values and a correction of this distortion should be the first step in image processing (Jedlika and Potuckova, 2006).

Intermediate radial distortion values are computed by fuzzy logic. Distortion corrects with diametrical length in photogrammetry. Diametrical length computes digitally. This value corresponding distortion computes with interpolation. Interpolation is a method that gets new data within known data. Desired radial distortion values can be easily computed by fuzzy logic instead of interpolation.
In this paper, I present types of radial distortion, basics of fuzzy logic. The accuracy of the calculated values with fuzzy logic is shown as a percentage in Section 4. It shows that calculated values with fuzzy logic approximated quite well. I used FIS (Fuzzy Inference System) editor of Fuzzy toolbox in MATLAB R2006a program.

2. RADIAL DISTORTION

Radial distortion is a deficiency in a straight line transmission. There are three major types of radial distortion. The first one is a negative displacement also refer to barrel distortion that image magnification decreases with the distance from the optical axis. The apparent effect is that of an image which has been mapped around a sphere (or barrel). Straight lines near the frame edges bend away the frame center (Mikhail et al., 2001,url1).

Figure 1. Effect of radial distortion on image geometry.

The second one is a positive displacement also refer to pincushion distortion, image magnification increases with the distance from the optical axis. The visible effect is that lines that do not go through the centre of the image are bowed inwards, towards the centre of the image, like a pincushion. A certain amount of pincushion distortion is often found with visual optical instruments, e.g., binoculars, where it serves to eliminate the globe effect (Mikhail et al., 2001,url1).
The third one is mustache distortion (moustache distortion) or complex distortion. This is a mix of barrel and pincushion radial distortion. Mustache distortion starts out as barrel distortion close to the

image center and gradually turns into pincushion distortion towards the image periphery, making horizontal lines in the top half of the frame look like a handlebar mustache (Mikhail et al., 2001,url1).

In these days using of non-metric cameras is more and more popular because of their low cost and easy manipulating. In case of non-metric camera, a calibration must be carried out before its use in photogrammetric applications (Atkinson,1996). The camera calibration report contains necessary information about camera's internal parameters including radial distortion. Camera calibration is based on the measurement of control points. Differences between measured and calculated control point coordinates is used for a construction of the polynomial approximation of radial distortion. When polynomial approximation of radial distortion is known, it can be used for correction of radial distortion in an image (Jedlika and Potuckova, 2006).

$$\Delta r = r - r'$$

$$\Delta r = r - c * \tan\tau$$

Radial lens distortion is usually expressed as a polynomial function of the radial distance from the point of symmetry, which usually coincides with the principal point (Choi et al.,2006).

$$\Delta r = K_1 r^3 + K_2 r^5 + K_3 r^7$$

Where Δr is the radial displacement of an image point, $r^2 = (x - x_0)^2 + (y - y_0)^2$, (x, y) are the fiducial coordinates of the image point. (x_0, y_0) are the fiducial coordinates of the point of symmetry, (commonly the principal point) and K_1, K_2 and K_3 are coefficients whose values depend upon the camera focal setting (Ergun, 2010).

Radial distortion is usually not perfectly rotationally symmetrical but for a computation of distortion it is assumed to be symmetrical. If the image should be used for the measurement of distances, radial distortion of lenses should be rotationally symmetrical. If it is not, the correction for symmetrical distortion can cause errors in the position of some points (Jedlika and Potuckova, 2006).

3. FUZZY LOGIC

The fuzzy subset theory was introduced by Zadeh in 1965 as an extension of the set theory by the replacement of the characteristic function of a set by a membership function whose values range from 0 to 1 (Dincer et al.,2008, Yalcin and Tasdemir,200).

Fuzzy logic is introduced by Zadeh (1965), it became more common in solving many engineering problems, based on fuzzy set theory. Dealing with simple 'black' and 'white' answers is no longer satisfactory enough; a degree of membership (suggested by Prof. Zadeh in 1965) became a new way of solving the problems. A fuzzy set is a set whose elements have degrees of membership. An element of a fuzzy set can be full member (100% membership) or a partial member (between 0% and 100% membership). That is, the membership value assigned to an element is no longer restricted to just two values, but can be 0, 1 or any value in-between. Mathematical function which defines the degree of an element's membership in a fuzzy set is called membership function. The natural description of problems, in linguistic terms, rather than in terms of relationships between precise numerical values is the major advantage of this theory (Nedeljkovic,2004).

There are two types of structure fuzzy logic. The first one is Mamdani. The second one is Sugeno. A model in Mamdani structure of fuzzy logic was built with FIS (Fuzzy Inference System) editor of Fuzzy toolbox in MATLAB R2006a program (Figure 2).

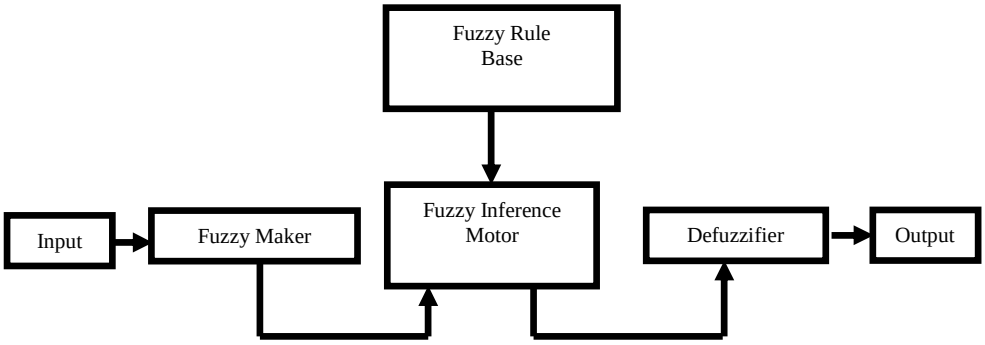

Figure 2. The general structure of the Fuzzy Logic

This study was done in Fuzzy Logic Toolbox of Matlab R 2006a. I used mamdani fuzzy logic structure (Figure 3). 5 rules were written. There were four inputs and one output in fuzzy logic.

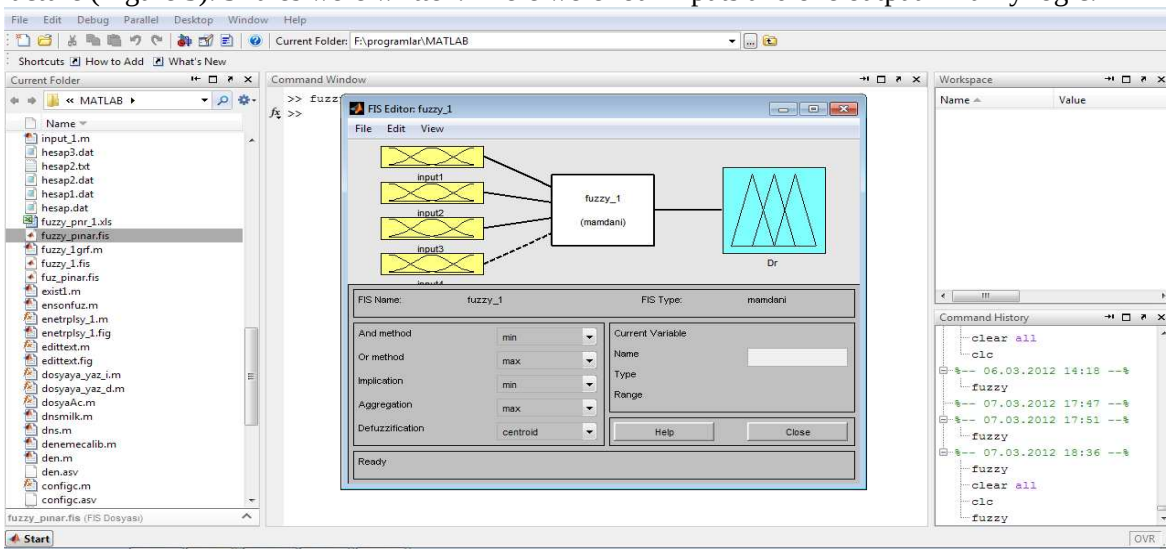

Figure 3. FIS Editor of the Model

Table1. Comparision of fuzzy logic and calculated values.

Interpolation	Fuzzy	% Success
67,79	66,8	98
33,44	32,6	97
-73,39	-71,3	97
306,78	304,9	99
58,85	59,6	98
29	28,6	98
172,22	171,9	99
24,47	22,4	91
49,93	48,6	97
13,84	12,7	91
51,58	53,6	96
5,20	5,8	88

4. CONCLUSION

When polynomial approximation of radial distortion is known, it can be used for correction of radial distortion in an image. Distortion corrects with diametrical length in digital photogrammetry. Diametrical length computes digitally. Radial distortion is computed by diametrical length. In this study radial distortion is computed by fuzzy logic instead of interpolation. In this study, desired intermediate radial distortion values can be calculated. Calculated values with fuzzy logic are given result very approximated. Results show that fuzzy logic can be used for calculated of radial distortion. % 96 success has been achieved in this study.

5. REFERENCES

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url1: http://en.wikipedia.org/wiki/Distortion_(optics)

BIOGRAPHICAL NOTES

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TS02F-Engineering Surveying- Photogrammetry-5759

Monday, 07 May, 14:00–15:30

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