ハンドアイシステムにおけるビジュアルフィードバックを用いた果実の検出(2)

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Detecting Fruit by Visual Feedback on Hand-Eye System (II)

—— Fruit Detecting Simulation by Computer ——

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Introduction

In the Part I of this series of study[2], a fruit detecting experiment by visual feedback using anthropomorphic type manipulator[1] was reported. It was observed that the hand was able to grip the orange color ball which positioned at 30 cm in front of the visual sensor. It was given as defects that the error depended on the fruit diameter arose, and that many image inputs were needed.

In this paper, accuracy of detecting fruit by visual feedback on hand-eye system was investigated by computer simulation, in order to obtain the errors of the calculated distance from the visual sensor to the fruit under the various conditions.

Calculation Method

Visual feedback on hand-eye system[2] is a method that a manipulator to which a visual sensor was attached approaches to a fruit while the deviated angle of the manipulator and the distance from the visual sensor to the fruit were calculated and the manipulator was repeated to be controlled at the deviated angle until the picture element number recognizing the fruit becomes bigger than the set value. In this calculation, however, the fruit was positioned in the center of the visual field of the visual sensor concentrating on calculation accuracy of the distance from the visual sensor to the fruit.

1. Picture element number recognizing fruit and calculation of distance from visual sensor to fruit

In this simulation, calculation was done assuming that the fruit was a perfect sphere, that the image was input while the manipulator was moving and that the visual sensor was scanned one picture element by one. The picture element recognizing fruit was counted only when more than a half of area of a picture element was occupied by a part of the image of the fruit. In the last report, the picture elements recognizing fruit were counted on a line, but in this report, those were on an area taking a serious view of calculation accuracy. Fig. 1. shows relation between the distance from the visual sensor to the fruit and the both picture element numbers recognizing fruit. The both relations between the distance from the visual sensor to the fruit and the picture element numbers recognizing fruit on area and line are shown as following equations (1), (2):

$$X = r\sqrt{\frac{\pi N_a}{2N_{ra}\tan^2(\theta/2)}+1} \qquad \cdots\cdots(1)$$

$$X = r\sqrt{\frac{N_l^2}{2N_{rl}^2\tan^2(\theta/2)}+1} \qquad \cdots\cdots(2)$$

X : distance from visual sensor to fruit

r : radius of fruit

N_a : picture element number of visual sensor on area
N_l : picture element number of visual sensor on line
N_{ra} : picture element number recognizing fruit on area
N_{rl} : picture element number recognizing fruit on line
θ : field angle of visual sensor

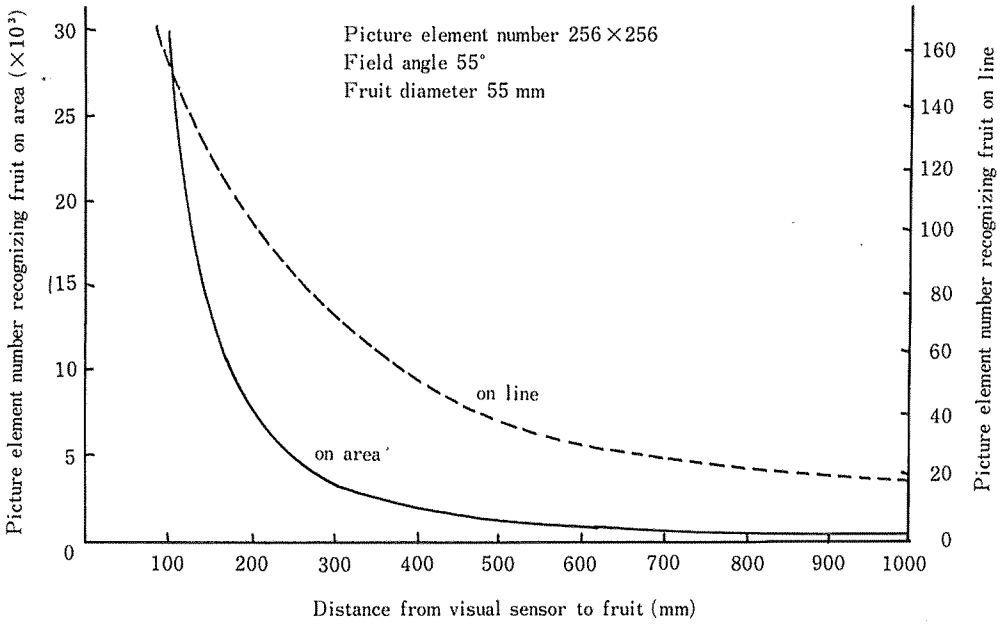

Fig. 1. Relation between distance from visual sensor to fruit and both picture element numbers recognizing fruit.

2. Calculation conditions

In this simulation, the calculation was done in the various conditions shown as follows:
image input time : 1/60 s
image processing time : 0, 0.5, 1 s
picture element number of visual sensor : 32×32, 64×64, 128×128, 256×256, 512×512
field angle of visual sensor : 35, 45, 55°
diameter of fruit : 55, 65, 75 mm
speed of manipulator : 100, 300, 500 mm/s
distance from visual sensor to fruit : from 100 to 1000 mm
where image processing time is interval from an image input to the next one. In this time, 65 mm which was the average of mandarin orange, was substituted into radius of the fruit, since X was not able to be calculated if r was unknown.

Calculation Results and Consideration

Fig. 2. shows the errors of the calculated distance when the field angle was 55°, the manipulator speed 100 mm/s, the image processing time 0.5 s, and the picture element number of the visual sensor and the fruit diameter were various. In this figure, the picture element number of the visual sensor was 64×64, 128×128, and 256×256 for the fruit diameter 55 mm, and the fruit diameter was 55, 65, and 75 mm for the picture element number 256×256. From these results, it was obtained that the smaller the distance from the visual sensor to the fruit was, the smaller the error by visual feedback became proportionally, that the error depended on the fruit diameter, and that the bigger the picture element number was, the

smaller the scattering. In this condition, it was considered that the picture element number was 256×256 enough.

Fig. 3. shows the relation between the distance from the visual sensor to the fruit and the difference of the picture element number recognizing fruit when the manipulator speed was varied. In this result, the picture element number was 256×256, the field angle was 55°, and the fruit diameter was 55 mm. The bigger the manipulator speed was, the bigger the picture element number recognizing fruit became as shown in this figure because the visual sensor was moving also for the image input time, so that the error became bigger. When the

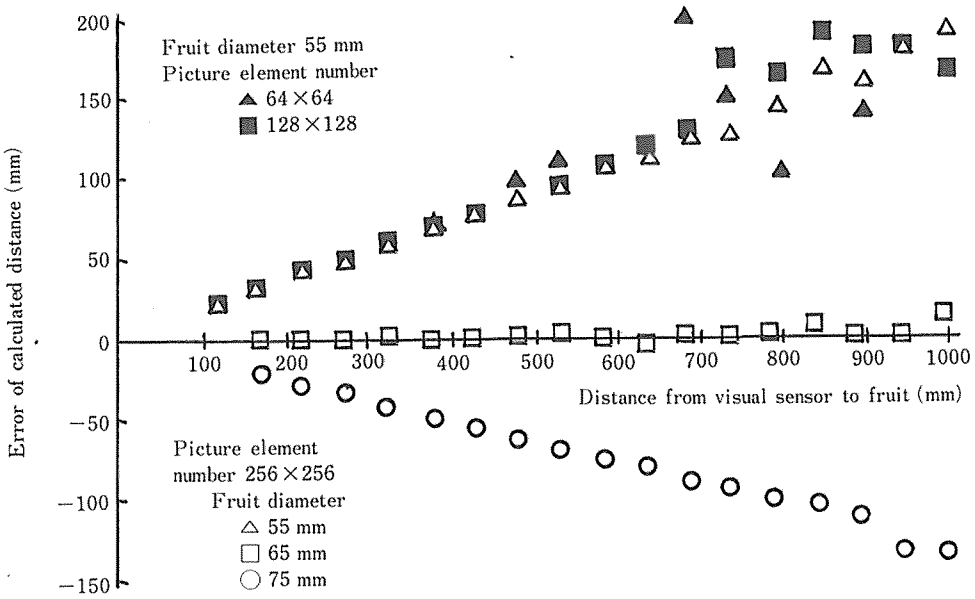

Fig. 2. Error of calculated distance.

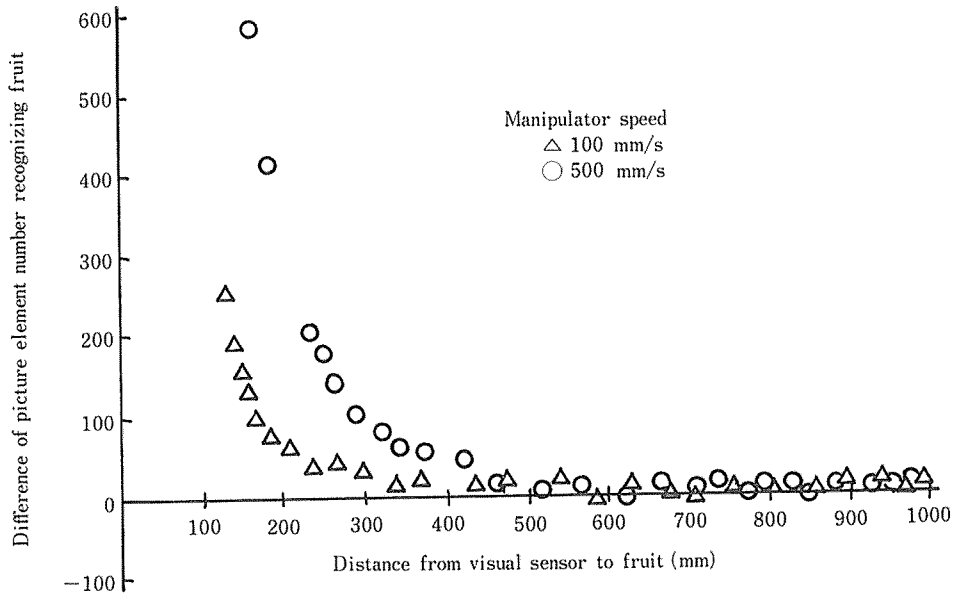

Fig. 3. Relation between distance from visual sensor to fruit and difference of picture element number recognizing fruit.

manipulator speed, the image input time or the image processing time became bigger, the number of the image input became smaller while the visual sensor was approaching to the fruit.

Besides, it was observed that there were little difference in the result except that the scattering of the error became smaller, when the field angle was smaller.

From these results, it was considered that it was not suitable that visual feedback on hand-eye system was independently used for detecting fruit, since the fruit diameter had the scattering fairly in the field.

Summery

The computer simulation of detecting fruit by visual feedback on hand-eye system was done in order to investigate detecting accuracy under the various conditions. From the result, it was obtained as follows :

1. The smaller the distance from the visual sensor to the fruit was smaller, the error by visual feedback became smaller proportionally.
2. The error depended on the fruit diameter.
3. The bigger the picture element number was, the smaller the scattering.
4. The bigger the manipulator speed was, the bigger the picture element number recognizing fruit became, and the error became bigger.
5. It was not suitable that visual feedback on hand-eye system was independently used for detecting fruit whose diameter had the scattering fairly.

References

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ハンドアイシステムにおけるビジュアルフィードバックを用いた果実の検出（II）

――コンピュータによる果実検出のシミュレーション――

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前報では関節型マニピュレータを使用して，ビジュアルフィードバックによる果実の位置検出実験を行い，その検出精度を調べたが，本報では実験で行えなかった種々の条件について，コンピュータシミュレーションを行うことによって検出精度を検討した．その際，対象物は完全な球と考え，マニピュレータの移動中に画像入力すると想定し，計算を行った．また計算精度を重視し，果実認識画素数はライン上でなく，エリア上でとらえた．そのシミュレーションの結果，次のようなことがわかった．

1．ビジュアルフィードバックによる検出誤差は，視覚センサから対象物までの距離が小さくなるにつれて直線的に小さくなる．
2．その誤差は対象物の径に左右される．
3．視覚センサの画素数が大きくなるほど誤差のばらつきは少なくなる．
4．マニピュレータの速度が大きくなると１枚の画像を入力するのに1/60秒を必要とするため，果実認識画素数は大きくなり，誤差も増大する．
5．果実の径はかなりばらつきをもっているため，本方法単独で位置検出を行うのは望ましくない．