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An artificial intelligence enhanced star identification algorithm

Key words: Star tracker; Lost-in-space; Star identification; Convolutional neural network

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Motivation

- Star trackers have been widely used in both orbiting and interplanetary spacecraft as a kind of high-precision attitude determination instrument. The most critical stage of attitude establishment using a star tracker is star identification.
- Many star identification algorithms have been developed in the last 40 years to solve the star identification problem. However, it is difficult for most algorithms to achieve good identification when there are many kinds of noise, including position noise, magnitude noise, false stars, and the tracker's angular velocity.

Main idea

- Star identification can be treated as a machine vision problem. A deep convolutional neural network (DCNN) is used to classify the chosen reference stars in the star image.
- To make the network robust to magnitude uncertainty, false stars, position deviation, and the tracker's angular velocity, a training dataset is constructed through several ways of data augmentation.

Method

1. Generation of the training dataset

1.1 Construction of the basic dataset

1.2 Data augmentation

- Discard stars to improve robustness
- Add magnitude deviations to stars
- Add false stars with random positions and magnitudes
- Add white noise to each image

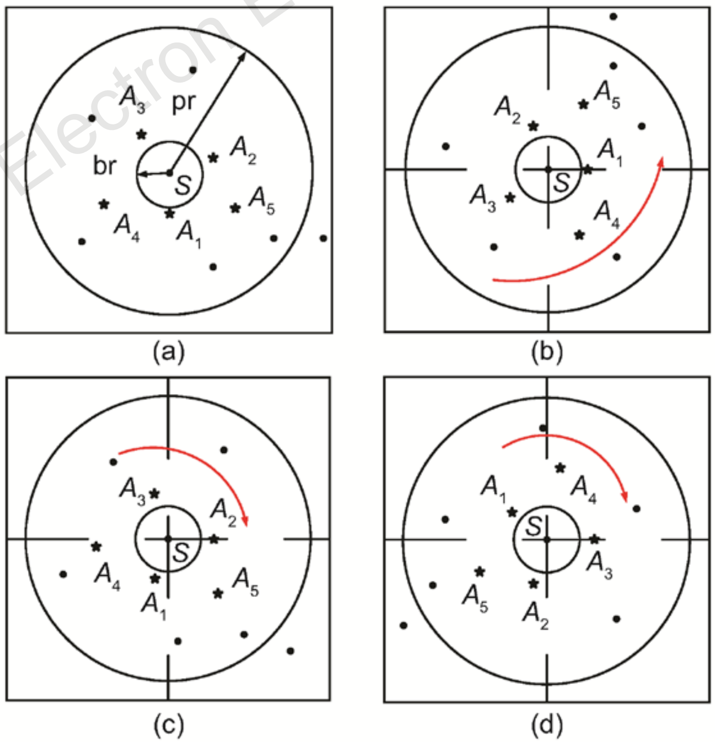

Fig. 2 Construction of the basic dataset: (a) original image; rotated images when A_1 (b), A_2 (c), and A_3 (d) are orientation stars

Method

2. Star identification algorithm

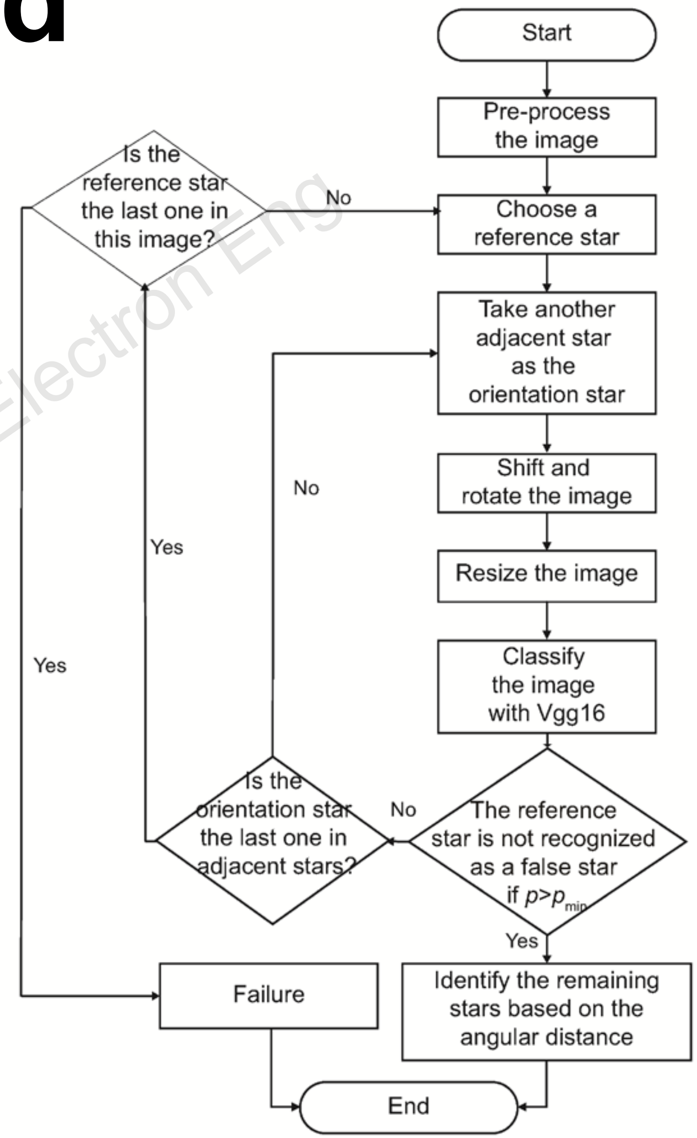

Fig. 3 Flowchart of the star identification algorithm

Major results

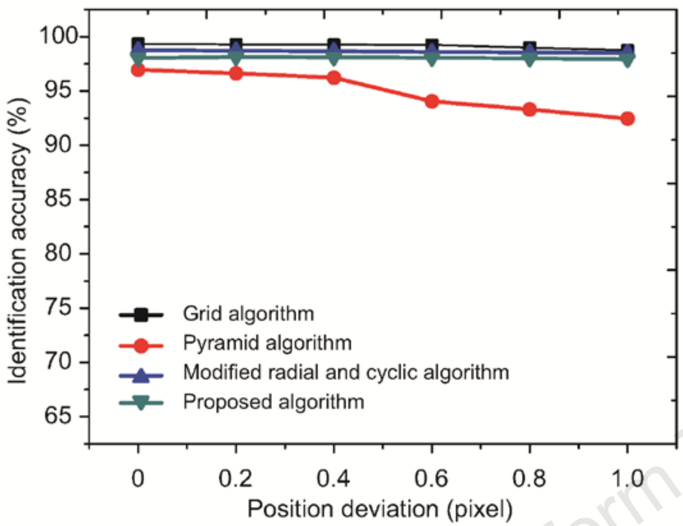

Fig. 7 Identification accuracy vs. position deviation

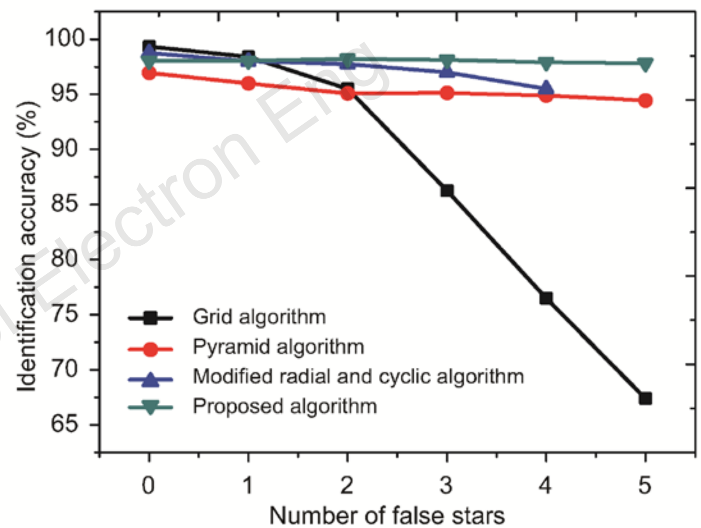

Fig. 8 Identification accuracy vs. the number of false stars

The DCNN algorithm maintains its identification accuracy over 97% when the position deviation increases from 0 to 1 pixel.

The DCNN algorithm is robust and maintains its accuracy over 97% when the number of false stars increases from 0 to 5.

Major results (Cont'd)

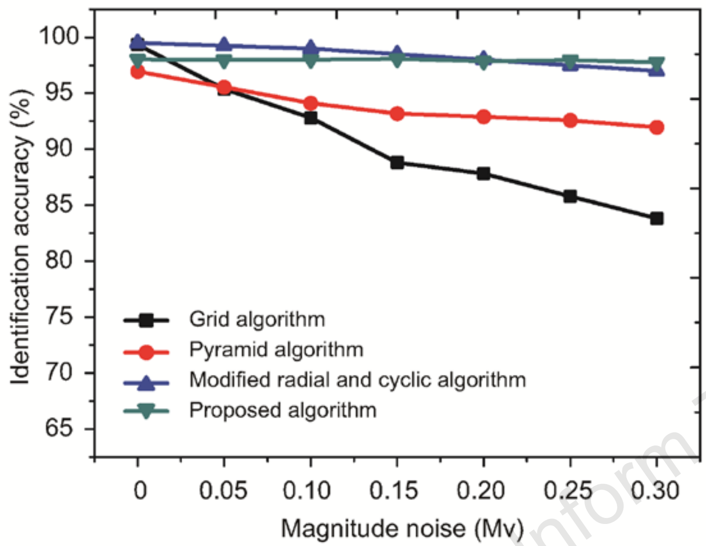

Fig. 9 **Identification accuracy vs. magnitude noise**

Table 2 **Identification accuracy under different angular velocities**

Angular velocity (°/s)	Identification accuracy (%)
1	96.95
2	96.65
3	96.23

The DCNN algorithm maintains its identification accuracy over 97% when the magnitude noise increases from 0 to 0.3 Mv.

The identification accuracy decreases from 96.95% to 96.23% when the tracker's angular velocity increases from 1 to 3° /s.

Conclusions

- A convolution neural network (CNN) model based on Vgg16 has been applied to classify star images, and a training dataset has been constructed accordingly.
- This algorithm is highly robust to various kinds of noise, including position noise and magnitude noise, false stars, and angular velocity of the trackers.