2023 Asia and Pacific Mathematical Contest in Modeling

Problem A

Image Recognition for Fruit-Picking Robots

China is the world's largest producer of apples, with an annual output of approximately 35 million tons. At the same time, China is also the world's largest exporter of apples, with one out of every two apples in the world and more than one-sixth of the apples exported worldwide from China. China proposed the Belt and Road Initiative (BRI), a key pillar of building a global community with a shared future. Thanks to this initiative, Vietnam, Bangladesh, the Philippines, Indonesia, and other countries along the route have become the main export destinations for Chinese apples.

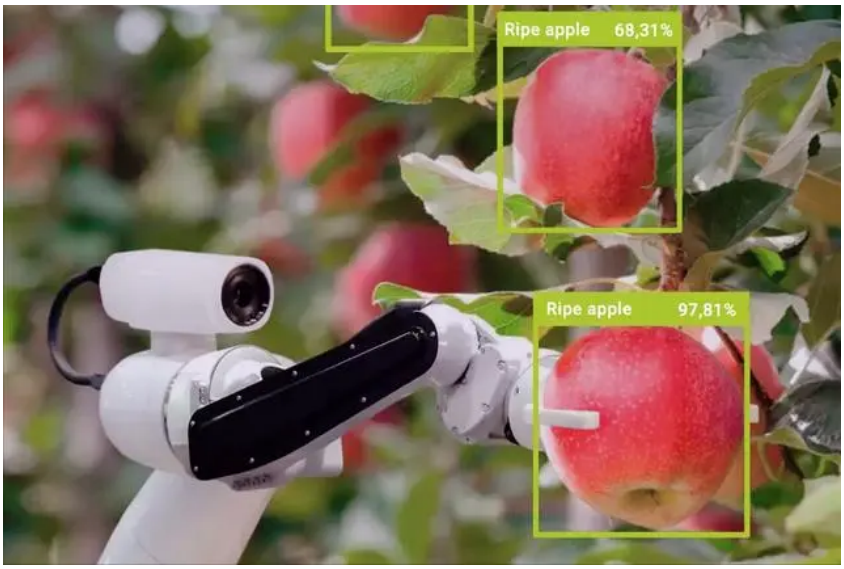


Figure 1. Diagram of image recognition of apples by fruit-picking robots.

Apple picking relies mainly on hand harvesting. When apples are ripe, a large number of picking workers are needed in apple-producing areas in a few days. But most of the local farmers plant apples in their own orchards. In addition, the aging of agricultural workers and the phenomenon of young people leaving their villages for work have led to a labor shortage during the apple-picking season. To solve this problem, China has been researching robots that can pick apples since around 2011 and has made significant progress.

However, the popularization and application of various apple-picking robots worldwide fall short of the ideal because orchard environments differ from the controlled experimental

settings. In complex and unstructured orchard environments, most existing robots are unable to accurately identify obstacles such as “leaf occlusion”, “branch occlusion” “fruit occlusion”, and “mixed occlusion” etc. If apples are picked directly without making precise judgments based on actual scenarios, there is a high risk of damaging the fruit, and even causing harm to the picking hands and mechanical arms. This adversely affects the efficiency of harvesting and the quality of the fruit, leading to greater losses. In addition, the recognition and classification of different harvested fruits is also significantly important, such as the procedures of classification, processing, packaging, and transportation. However, many fruits have quite similar colors, shapes, and sizes to apples, which poses great difficulties for the post-harvest identification of apples.

This competition aims to establish an apple image recognition model with a high recognition rate, fast speed, and accuracy by analyzing and extracting features from labeled fruit images, and to perform data analysis on the images, such as automatically calculating the number, positions, maturity levels, and estimating the masses of apples in the images. The specific tasks are as follows:

- **Question 1: Counting apples**

Based on the image dataset of harvest-ready apples provided in *Attachment 1*, extract image features, establish a mathematical model, count the **number of apples** in each image, and draw a **histogram** of the distribution of all apples in *Attachment 1*.

- **Question 2: Estimating the positions of apples**

Based on the image dataset of harvest-ready apples provided in *Attachment 1*, identify the **position of the apples** in each image with the left bottom corner of the image as the coordinate origin, and draw a two-dimensional **scatter diagram** of the geometric coordinates of all apples in *Attachment 1*.

- **Question 3: Estimating the maturity state of apples**

Based on the image dataset of harvest-ready apples provided in *Attachment 1*, establish a mathematical model, calculate the **maturity of apples** in each image, and draw a **histogram** of the maturity distribution of all apples in *Attachment 1*.

- **Question 4: Estimating the masses of apples**

Based on the image dataset of harvest-ready apples provided in *Attachment 1*, calculate the two-dimensional **area of the apples** in each image with the bottom left corner of the image as

the coordinate origin, estimate the **masses of the apples**, and draw a **histogram** of the mass distribution of all apples in *Attachment 1*.

- **Question 5: The recognition of apples**

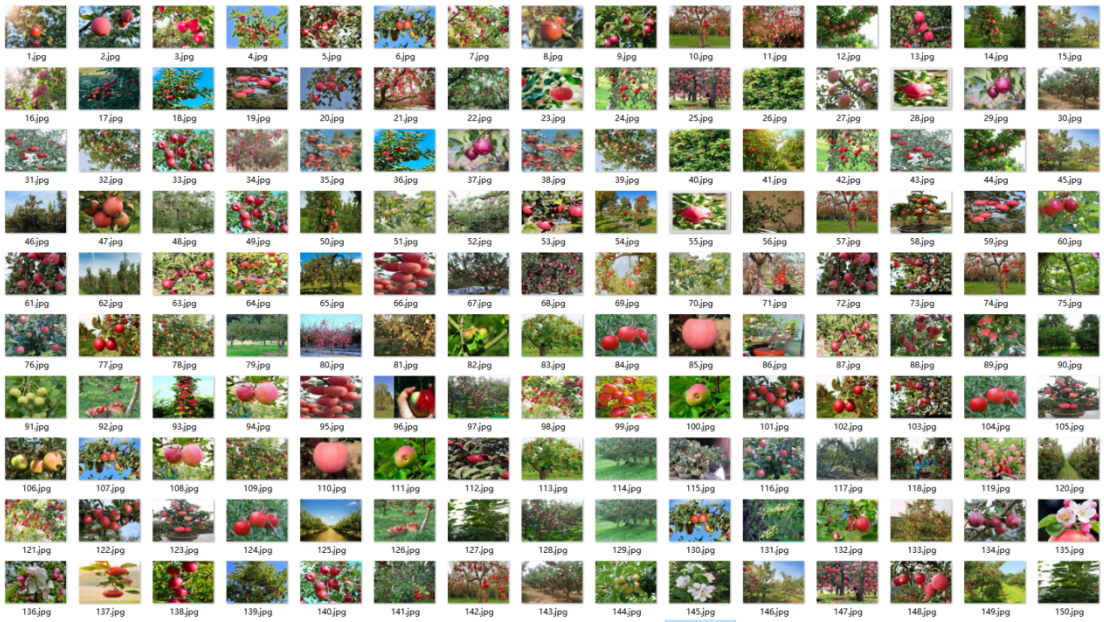
Based on the dataset of harvested fruits' images provided in *Attachment 2*, extract image features, train an **apple recognition model**, identify the apples in *Attachment 3*, and draw a distribution histogram of the ID numbers of all apple images in *Attachment 3*.

Attachment:

Attachment.zip, download on the website: https://share.weiyun.com/T6FKbjLf

Attachment 1:

The folder contains 200 images of harvest-ready apples, and each image has a size of 270 * 180 pixels. Partial screenshots of *Attachment 1* are shown below:



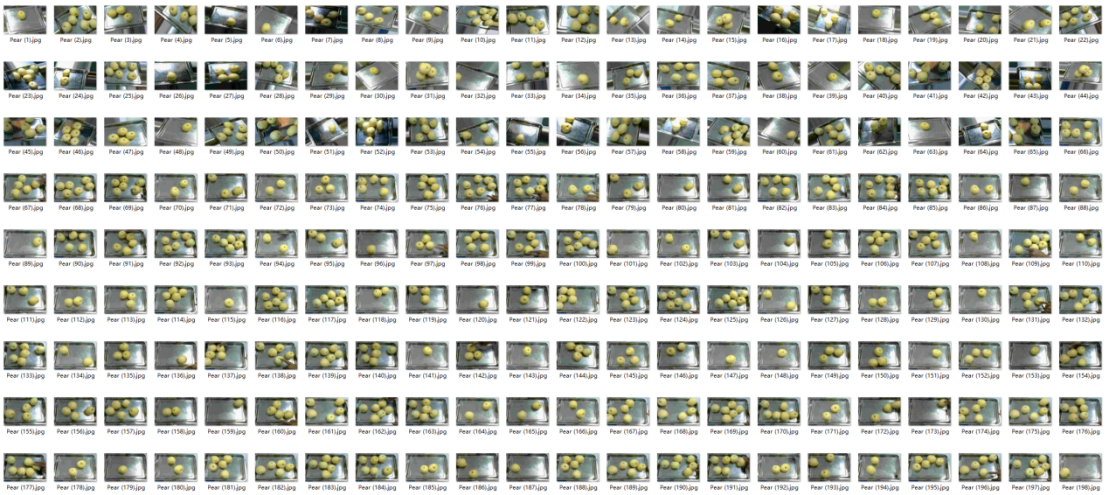
Attachment 2:

The folder contains 20705 images of different harvested fruits with **known** labels and classifications, and each image has a size of 270 * 180 pixels. Partial screenshots of *Attachment 2* are shown as follows:

The dataset of apples:

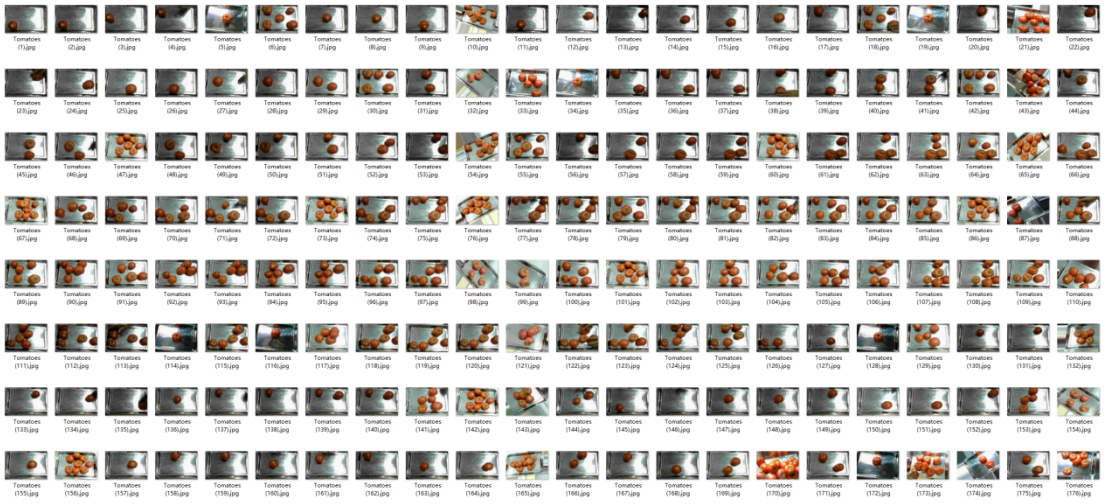
The dataset of carambolas:

The dataset of pears:



The dataset of plums:

The dataset of tomatoes:



Attachment 3:

The folder contains 20705 images of different harvested fruits with unknown labels and classifications, and each image has a size of 270 * 180 pixels. Partial screenshots of *Attachment 3* are shown as following: