



Fruit Detection and Identification from Realtime Video Sequences: A Review

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Abstract. Object detection in real-time video sequence is still a big challenge as the images are captured with different modalities such as occlusion, clustering, scale, size, color, illumination changes due to complex environment, low quality camera, trees shake and noise. To overcome these challenges, researchers have used a variety of image processing techniques and algorithms to develop successful fruit detection system in order to achieve high accuracy. This paper presents a review of research work done on fruit detection and recognition systems. Also summarizes the features, image segmentation and classification methods used in the existing fruit detection systems such as Convolution Neural Network (CNN), k-means clustering, Support Vector Machine (SVM), deep learning etc. Finally, the future challenges, scope and proposed system for fruit detection and identification from realtime video sequences is discussed. The proposed fruit detection system will make use of deep learning algorithms along with Convolution Neural Network (CNN) in order to increase the classification and recognition accuracy.

Keywords: Real time video sequences · Fruit detection · Support Vector Machine · k-means clustering · Convolution Neural Network · Deep learning

1 Introduction

Agriculture is the primary occupation of people in India. The present condition of agriculture in India is not so satisfactory to produce maximum crop yield because of lack of technology awareness among farmers. This situation can be changed by adopting advanced technologies in the field of agriculture to increase the production of crops. Fruits are the integral part of farming which is the way of occupation for farmers. Various types of fruits grown as per the season and so the harvesting period of these fruits may also vary. Fruit may come with different shapes, colors and textures. The most commonly grown fruits in India especially in Maharashtra are Mango, Pineapple, Grapes, Orange, Sapota, Jamun, Banana etc. Unlike other crops fruits are delicate one and demandable in market. Harvesting fruits is one of the laborious activities in the farming which has to be carried out very carefully to reduce the damages to the fruits [1]. In the current situation, the harvesting of fruits is done by shaking the trees with hands, climbing the trees and using pickers to pluck the fruits. The drawback of these methods is that the

fruits get damaged due to falling on ground while plucking from the tree, which results in loss to the farmer. Another problem is that the harvesting process of fruits requires skilled person who knows how to harvest the fruits at right time or whether fruits gets over ripe which also results in loss of fruits [1, 9, 19].

Such problems reduce the availability of quality fruits due to which fruits will be sold in the market at higher price. To overcome these problems development of realtime application and product to assist the farmers for fruit harvesting is very much essential. This product will be designed to meet the increasing labor demand, to decrease the harvesting cost and saving time, money and efforts.

2 Literature Survey

Woo Chaw Seng, et al., 2009 [28] proposed a fruit recognition system which includes feature analysis methods based on color, shape and size in order to increase the recognition accuracy. In this system, for classification of fruits, a k-nearest neighbor algorithm is used. In this algorithm, the Euclidean distance metric has been used for measuring the distance between the features of the unknown fruit with the database fruits. This system provides recognition accuracy up to 90%. Zania S Pothen, et al. 2012 [34] proposed an Angular Invariant Maximal Keypoint detection algorithm which accurately detects the fruit locations of smooth round fruit with a high percentage and works with varieties of grapes and apples. The results showed that due to smooth surface of round fruits, the contours of the fruit may be partially occluded as there is a lack of contrasting features. Also, in case of some fruits, the color of the fruit and background foliage is similar which will be difficult for fruit detection. Calvin Hung, et al., 2013 [8] presented a segmentation algorithm for almond detection using which 87% segmentation accuracy is achieved. This algorithm does not run in real time and extra sensing modalities are required to handle large amount of occlusion. Hossam M. Zawbaa, et al., 2014 [15] used techniques SIFT, k-Nearest Neighborhood (KNN) and SVM for detecting and classifying fruits: Apple, Strawberry and Orange. The results showed that with the help of SVM classifier, the accuracy of similarity achieved is 90.91% for Apple and 78.89% for Orange. The accuracy achieved by using SIFT method is 96.97% for apple and 85.71% for strawberry. A. Gongal, et al. [1] presented a summary of various types of sensors such as Black and White, Color, spectral, and thermal cameras used for fruit detection along with image segmentation and classification methods. Duanli Yang, et al., 2016 [11] used k-means clustering, erosion and dilation with Hough transform algorithms for detection of papaya and achieved an accuracy of 89.18%. Susovan Jana, et al., 2017 [27] worked on fruits Apple, Cucumber, Mango, Orange, Pineapple, Pomegranate and Strawberry. They used GLCM, GrabCut, SVM and k-means algorithm for detection and classification. The results showed that k-means algorithm determine the number of resultant clusters automatically. Bargoti S., et al., 2017 [4] used Haar-like characteristics and PCA method for citrus detection. They showed that the visible fruits under direct sunlight are not identified with an accuracy of 100% because of poor fruit illumination and poor results. Kushtrim Bresilla, et al., 2018 [25] used CNN and YOLO900 modified model for detection of Apple. The drawback of YOLO900 mentioned was that it could not detect two apples in the same cell model. The results showed that fruits are detected

with the accuracy in the range of 85% to 95%. Barna Keresztes, et al., 2018 [5] used Radial Hough operator and Deep Neural Network (DNN) classifier for detecting Grapes and Apple. The results showed that an estimation of number of fruits hidden under leaves, branches and other fruit is still required. Mingyuan Xin, et al., 2019 [23] presented a comparison of CNN with SVM and KNN. In results, the CNN showed more accuracy than that of SVM and KNN. The CNN is more suitable for those images whose feature dimension is small and the amount of data is large after extracting the vector. Dang Thi Phuong Chung, et al., 2019 [10] proposed a model for detecting Orange, Mango and Pear. They have used Deep Convolution Neural Network for recognizing fruits with 95% accuracy. They mentioned that there is a need to address an issue of recognizing fruits which have the similarities in size, shape and other features. Fouzia Risdin, et al. 2020 [12] worked on fruits Grapes, Apple, Lychee and Lemon. CNN showed higher accuracy than that of traditional SVM methods by providing an accuracy of 99.89%. Chiagoziem C. Ukwuoma, et al. 2022 [36] described how deep learning models can be developed for solving complex tasks using supervised learning techniques and artificial neural networks. The need of multi-class automated fruit classification systems as well as the problems that occurs at the time of detecting fruits such as improper camera setup which results in blurred image and partial or entire occlusion of the object are mentioned.

3 Methodology and Tools

Fruits are available with diverse features such as shape, size, texture and color. The literature survey mentioned above described features and various techniques used for fruit detection, segmentation and classification. These are briefly summarized below:

3.1 Features Used in Fruit Detection

Color, shape and texture are fundamental characteristic of fruits which provides strong statistical values for its detection, segmentation and classification.

3.1.1 Color Features

Color based fruit detection methods are useful while working with fruits having different colors than that of their background [11]. If the fruits have the same color as that of its background, then fruits may get clustered together as well as it will become difficult for segregation. Color moments such as color mean, color variance, color skewness, and color kurtosis is used as an identifier to describe the images [27].

3.1.2 Shape and Size Features

Shape and size features of fruits such as Centroid, Eccentricity, and Euler Number are invariant to lighting condition and provide a set of distinct features of fruits. If we consider shape features while detecting fruits then the problems like occlusion of fruit by leaves, branches and other fruit changes may occur. The shape of some fruits like papaya and peak portion of the leaf is similar i.e. elliptical or oval in shape. In such

cases, it is difficult to detect the fruits from leaves. Shape based methods provide good results in uncluttered environments where occlusions do not occlude the shape of the fruits [1, 15].

3.1.3 Texture Features

The texture based fruit detection techniques are associated with an external illumination source such as light [34]. The texture features of fruits can serve as an effective cue when color is not discriminatory enough and is usually more stable under illumination variations. Texture features of fruits must be added with other cues in order to handle occlusion problem [19].

3.2 Image Segmentation and Classification Methods for Fruit Detection

3.2.1 k-Means Clustering

This is an unsupervised classification technique which produces a precise number of hierarchical clusters [1]. The problem may arise with k-means algorithm is that it does not determine the number of resultant clusters automatically. Erosion and dilation with randomized Hough transform method used for detection of elliptical objects and separate touching or overlapping [11].

3.2.2 K-Nearest Neighborhood (K-NN) Clustering

This is a supervised classification method used to achieve more accurate detection results as compare to image processing techniques but requires more computational resources and labeled training data [1]. K-NN classifier is used to determine the k-nearest neighbors based on minimum distance between the query instance and the training data set with high execution speed. The distance measure is computed using one of the two functions: Absolute distance measuring and Euclidean distance measuring [15].

3.2.3 Support Vector Machine

A Support Vector Machine (SVM) is used to create the classification model and is suitable for classification when the training data has multiple dimensions. While classifying fruits, color features produce better classification accuracy than texture features. If we combine both the texture and color features of fruits for classifying fruits, then it will provide an improved accuracy [1]. [33] presented an approach for recognizing and classifying the features extracted from fruit images The classification of fruits is done using SVM and achieved 94.79% of accuracy.

3.2.4 Deep Learning and Convolution Neural Network

In most of the existing work, fruit detection and segmentation was done with conventional machine learning algorithms such as Support Vector Machines, etc. [1, 33].

The Convolution Neural Network (CNN) is a kind of artificial neural network which deals with image classification and recognition problems and improved the accuracy

of many machine learning tasks [23]. [15] used CNN which consist of convolution layers, pooling layers, ReLU layers, fully connected layers and loss layers. In a typical CNN architecture, these layers are connected in sequence as: each convolution layer is followed by a Rectified Linear Unit (ReLU) layer, then a Pooling layer and then one or more convolution layers. Finally, these convolution layers connected with one or more fully connected layers.

In recent years, it has been seen that the deep learning methods improved the performance of object detection, classification and segmentation. Due to large number of parameters and architectures, the deep neural network could have the more learning capacity [29]. These methods do not require to perform the process of extraction of features because the CNNs automatically perform this task of feature extraction, selection, representation and object classification [25]. These algorithms apply machine learning classifiers to detect or segment fruits in images and deals with a limited number of samples and computing units. Deep learning provides high performance both in detection accuracy and detection time [12, 21, 26]. [4] presented fruit detection system in which the image data is captured in orchards. To achieve high accuracy, the faster R-CNN method is used.

4 Future Challenges and Direction

Based on the survey following observations are made. The major challenges are due to unconstrained environment that encountered while detecting fruits are: objects with various shapes, sizes and texture; highly unstructured scenes; changing illumination conditions; occlusion of fruits due to branches and other background [7, 19]. These factors affect the recognition accuracy as well as performance in real time [9]. Most of the existing systems are not able to detect fruits which are partially occluded by other objects. Some of the researchers recognized fruits from still images in off-line mode as well as in controlled environment. Some fruits have similarities in appearance such as shape, size, texture and color. Immature green fruits or fruits having same color as that of green leaf background are difficult to detect and achieve high accuracy. Some of the researchers recognized fruits from still images in off-line mode without considering external environment changes and other factors, such as light, wind. It means that these systems do not run in real time. Some systems designed in such a way that works only in controlled environment. Some systems work on a particular fruit which does not work on another fruits. SVM and traditional machine learning methods showed poor results than that of the recent deep learning and CNN methods.

From the above mentioned observations, it is concluded that high speed performance both in controlled and uncontrolled environment is still necessary.

The sample image frames extracted from YouTube video showing various modalities are shown above in the Fig. 1.

Image Source: (a) https://www.youtube.com/watch?v=O6t4L2yji_Q&t=81s (b) <http://weknowyourdreams.com/apple-tree.html> (c) and (f) <https://www.youtube.com/watch?v=b9fwGpB0UMQ> (d) <https://www.youtube.com/watch?v=GbSQImGM3O8>

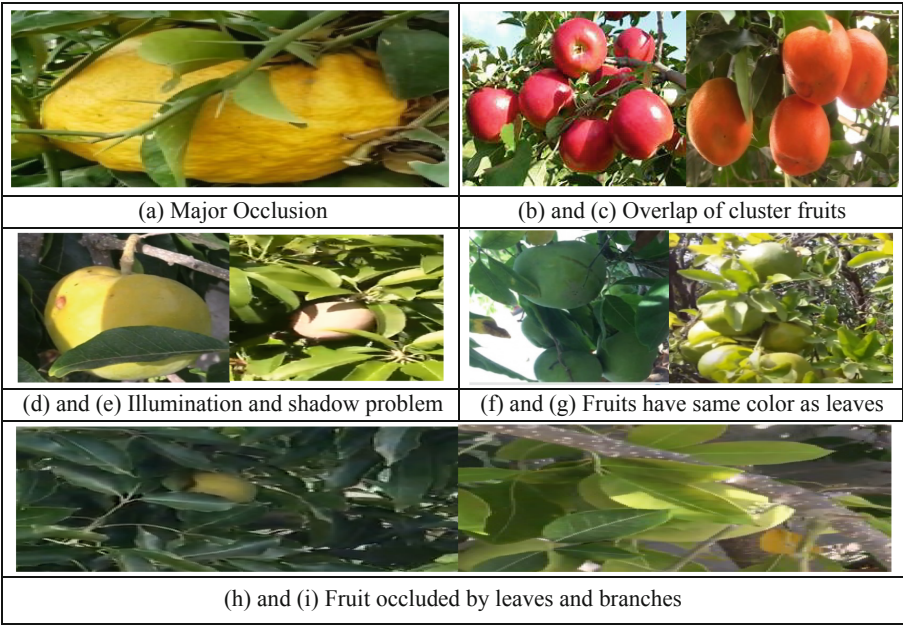


Fig. 1. Various occlusion and illumination problems

(e) and (h) <https://www.youtube.com/watch?v=1TALYXLAXZg> (g) <https://www.youtube.com/watch?v=BpapvGoMhq0>
(i) https://www.youtube.com/watch?v=ZJYVpxj6_2c

5 Proposed System

The development of realtime fruit detection and identification system is divided into two parts: video stream processing and image processing tasks such as recognition and classification. The steps of proposed system include selection of features, method of generating features, learning features of class and methods to perform template matching. Fruits are available in a variety of shapes, sizes and color variations. In this system, invariant features of fruits like shape and color are considered. New algorithms and techniques are needed to design for identification and classification of fruits based on these invariant features. The working steps of the proposed system are:

5.1 Video Capturing

The problems of un-uniform illumination, improper position, occlusion and motion arises at the time of object detection so keeping these challenges in mind in the proposed system, video data will be captured with the help of the camera installed in the proposed system [17]. The camera used for proposed system will be a miniature camera performing live streaming of video data. For the experimental simulation other video sources to be



Fig. 2. Image frames formed from video of Citrus tree

used may include video media obtained from existing videos stored on secondary storage devices.

By using Python code, the following image frames shown in Fig. 2 are extracted from video of Citrus tree which is taken from YouTube: (Source: <https://www.youtube.com/watch?v=b9fwGpB0UMQ>).

5.2 Video Processing

As the streamed video sequence may contain some noise and due to this the recognition task becomes difficult. While capturing fruits through a video camera in realtime, problems such as motion blur or illumination may arise which will affect the quality of the output video. This step deals with noise removal techniques such as video stabilization, video sharpening etc. [6] presented a background subtraction model used for detecting or localizing moving objects in video scene. The task of moving object detection is difficult as it suffers from shadows by moving object, illumination changes, etc. [3]. [24] has shown the results that the white noise cannot be removed even on the attenuated image data. This issue can be removed by using fusion technique which combines images from multiple cameras.

5.3 Segmentation

This task includes edge detection using edge detection operators like Sobel, Canny, Prewitt and Roberts. Active contour models and radial Hough like operator for identifying the region of interest can be used. In the proposed system, thresholding and GrabCut color image segmentation techniques can be used [8]. This system will accurately detect and localize fruits in uncontrolled environment using local image measurements such as changes in brightness, color, and texture associated with natural boundaries.

5.4 Feature Extraction

Feature extraction is the process of extracting features from an image. There are many feature extraction methods available such as HOG (Histogram of Oriented Gradients), which extracts all regions of interests through image gradients. SURF (Speeded Up Robust Features). The algorithms like Scale Invariant Feature Transform (SIFT), Principal Component Analysis (PCA) and K-PCA can also be used in the proposed system to speed up the feature extraction process [15].

5.5 Fruit Recognition

For robust fruit detection classifiers like AdaBoost can be used to select features and train the classifier [16]. The object detection and classification using neural network algorithms, deep learning methods along with Convolution Neural Network may lead to achieve good results depending upon the size of the training database. Some supervised learning techniques such as Perceptron Learning Algorithm (PLA), Logistic regression and Multilayer Perceptron (MLP) are used [23]. Unsupervised learning techniques like Principal Component Analysis (PCA) and k means clustering can be used.

5.6 Classification

Classification step determine the fruits belong to which one of the predefined designated classes. The k-Nearest Neighbor (k-NN) classifier can be used to find the shortest distance between the feature values of test fruit images with feature values of database fruit images. The Support Vector Machine (SVM) can be used for classifying fruits and assigning them to one of the set of designated classes based on features [15].

6 Conclusion

A literature survey on fruit detection system is presented in this paper from which it is concluded that most of the researchers are still facing the problem of occlusion while detecting the fruit images. Some of the work recognized fruits from still images in off-line mode and works in controlled environment. The primary objective of the proposed system is to detect and identify fruits from realtime video sequence using deep learning algorithms where accuracy and performance speed are of prime importance and also to develop a mechanism to pluck the fruit with at most care. The proposed system along with the methods used in existing systems will detect and identify various types of fruit images taken from realtime video sequence.

References

1. Gongal, A., Amatya, S., Karkee, M., Zhag, Q., Lewis, K.: Sensors and system for fruit detection and localization: A review. *Computers and Electronics in Agriculture*, 116, 8–19 (2015)
2. Kamilaris, A., Prenafeta-Boldu, F.: Deep Learning in Agriculture: A Survey. *Computers and Engineering in Agriculture* 147, 70–90 (2018)
3. Amato, A., Mozerov, M., Xavier Roca, F., Gonzalez, J.: Robust Real-Time Background Subtraction Based on Local Neighborhood Patterns *EURASIP Journal on Advances in Signal Processing*, Volume 2010, Article ID 901205 (2010)
4. Bargoti, S., Underwood, J.: Deep fruit detection in orchards. *IEEE International Conference on Robotics and Automation (ICRA)*, 3626–3633 (2017)
5. Keresztes, B., Abdelghafour, F., Randriamanga, D., Da Costa, J., German, C.: Real time Fruit Detection using Deep Neural Network. *14th International Conference on Precision Agriculture* (2018)

6. Basavaprasad, B., Hegadi R., S.: Color Image Segmentation Using Adaptive GrabCut Method. International Conference on Advanced Computing Technologies and Applications (ICACTA-2015), 328–335 (2015)
7. Lee, B., Y., Liew, L., H., Cheah, W., S., Wang, Y., C.: Occlusion handling in videos object tracking: A survey. 8th International Symposium of the Digital Earth (ISDE8), IOP Conf. Series: Earth and Environmental Science, 18, (2014)
8. Hung, C., Nieto, J., Taylor, Z., Underwood, J., Sukkarieh, S.: Orchard Fruit Segmentation using Multi-Spectral Feature Learning. IEEE/RSJ International Conference on Intelligent, Robots and Systems (IROS) (2013)
9. Zheng, C., Chen, P., Pang, J., Yang, X., Chen, C., Tu, S., XEu, Y.: A mango picking vision algorithm on instance segmentation and key point detection from rgb images in an open orchard. Biosystems Engineering, 32–54 (2021)
10. Chung, D., Tai, D.: A fruits recognition system based on a modern deep learning technique. IOP Conf. Series: Journal of Physics: Conf. Series 1327 (2019)
11. Yang, D., Li, H., Zhang, L.: Study of Fruit Recognition System based on Machine Vision, Advance Journal of Food Science and Technology, 10(1), 18–21(2016)
12. Risdin, F., Mondal, P., K., Hassan, K., M.: Convolutional Neural Networks (CNN) for Detecting Fruit Information using Machine Learning Techniques. IOSR Journal of Computer Engineering (IOSR-JCE), Volume 22, Issue 2, 01–13 (2020)
13. Kang, H., Chen, C.: Fruit Detection and Segmentation for Apple Harvesting using Visual Sensor in Orchards. Sensors 19(20):4599 (2019)
14. Muresan, H., Oltean, M.: Fruit Recognition from Images using Deep Learning. Acta Univ. Sapientine, Informatica, 10(1), 26–42 (2018)
15. Zawbaa, H., M., Abbass, M., Hazman, M., Hassenian, A., E.: Automatic Fruit Image Recognition System based on Shape and Color Features. The 2nd International Conference on Advanced Machine Learning Technologies and Applications, 278–290 (2014)
16. Laptev, I.: Improving Object Detection with Boosted Histograms. Image and Vision Computing, Elsevier, 27(5), 535–544 (2009)
17. Santoyo-Morales, J., E., Hasimoto-Beltran, R.: Video Background Subtraction in Complex Environments. Journal of Applied Research and Technology, Vol. 12, 527–537 (2014).
18. Huang, K., Shi, Y., Zhao, F., Zhang, Z., Tu, S.: Multiple Instance Deep Learning for Weakly-Supervised Visual Object Tracking. Signal Processing: Image Communication, 84, 115807(2020)
19. Kapach, K., Barnea, E., Mairon, R., Edan, Y., Shahar, O., B.: Computer vision for fruit harvesting robots-state of the art and challenges ahead. International Journal of Computational Vision and Robotics, Vol 3 Nos (1/2), 4–34(2012)
20. Bresilla, K., Perulli, G., D., Boini, A., Morandi, B., Grappadelli, L., C., Manfrini, L.: Single Shot Convolution Neural Networks for Real Time Fruit Detection within the Tree, Frontiers in Plant Science, 10:611(2018)
21. Hou, L., Wu, Q., X., Sun, Q., Yang, H., Li, P.: Fruit Recognition based on Convolution Neural Network. 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), IEEE, 18–22 (2016)
22. Robel Mia, Md, Jueal Mia, Md, Majumder, A., Supriya, S., Habib, T., Md.: Computer Vision Based Local Fruit Recognition. International Journal of Engineering and Advanced Technology (IJEAT), Volume-9 Issue-1 (2019)
23. Xin, M., Wang, Y.: Research on image classification model based on deep convolution neural network. EURASIP Journal on Image and Video Processing. 2019:40 (2019)
24. Li, P., Lee, S., Hsua, H.: Study on citrus fruit image data separability by segmentation methods. Procedia Engineering, 23, 408– 416 (2011)
25. Gonzalez, R., C., Woods, R., E.: Digital Image Processing. 4th Ed., Pearson Education.

26. Wana, S., Goudosb, S.: Faster R-CNN for Multi-class Fruit Detection using a Robotic Vision System. Volume 168 Issue C (2019)
27. Jana, S., Basak, S., Parekh, R.: Automatic Fruit Recognition from Natural Images using Color and Texture Features. Devices for Integrated Circuit (DevIC), IEEE, 620–624 (2017).
28. Seng, W., C., Mirisae, S., H.: A New Method for Fruits Recognition System. International Conference on Electrical Engineering and Informatics, 130–134 (2009)
29. Wang, X.: Deep learning in object recognition, detection, and segmentation. Foundations and Trends in Signal Processing, Vol 8 no 4, 217–382 (2014)
30. Ni, X., Li, C., Jiang, H., Takeda, F.: Deep learning image segmentation and extraction of blueberry fruit traits associated with harvestability and yield. Horticulture Research, 7:110 (2020)
31. Xiong, Y., Ge, Y., Grimstad, L., Pal J.: An Autonomous Strawberry - Harvesting Robot: Design, Development, Integration and Field Evaluation. Journal of Field of Robotics, 37, 202–224 (2019)
32. Chiu, Y., Chen, S., Lin, J.: Study of an autonomous fruit picking robot system in greenhouses. Engineering in Agriculture, Environment and Food, 6(3), 92–98 (2013)
33. Onishi, Y., Yoshida, T., Kurita, H., Fukao, T., Arihara, H., Iwai, A.: An automated fruit harvesting robot by using deep learning. ROBOMECH Journal, 6:13 (2019)
34. Pothen, Z., S., Naske, S.: Texture based fruit detection via images using the smooth patterns on the fruits. IEEE International Conference on Robotics and Automation (ICRA), 5171–5176 (2012)
35. Ukwuoma, C., C., Zhiguang, Q., Md Belal Bin Heyat, M., B., B., Ali, L., Almaspoor, Z., N. Monday, H., N.: Recent Advancements in Fruit Detection and Classification Using Deep Learning Techniques. Hindawi Mathematical Problems in Engineering, Volume 2022, (2022)
36. Wang, C., Liu, S., Wang, Y., Xiong, J., Zhang, Z., Zhao, B., Luo, L., Lin, G., He, P.: Application of Convolution Neural Network - Based Detection Methods in Fresh Fruit Production: A Comprehensive Review. Frontiers in Plant Science (2022)
37. Zhang, L., Ren, Y., Tao, S., Jia, J., Gao, W.: High-Quality Coarse-to-Fine Fruit Detector for Harvesting Robot in Open Environment. KSII Transactions on Internet and Information Systems Vol. 15, No. 2, pp 421–441 (2021)
38. Zhang, W., Wang, J., Liu, Y., Chen, K., Li, H., Duan, Y., Wu, W., Shi, Y., Guo, W.: Deep-learning-based in-field citrus fruit detection and tracking. Horticulture Research, 9: uhac003 (2022)

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