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Real-time Fast Selection System with Object Recognition and TSP algorithms

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ABSTRACT

The stage before the conversion of agricultural products into post-harvest consumer products is the process of separating the raw products into appropriate classes. Today, this difficult manual separating process is a process in which a large number of workers work at an intense pace on the product line and the workforce is intensively spent. Disruptions in separating as a result of carelessness cause product loss, loss of time and cost increases. In this study, as an alternative to manual separating processes, a real-time separating system, which detects the products in the factory band with object recognition methods and enables fast positioning of the separating tool on the products, works simultaneously with object recognition and traveling salesman problem algorithms has been created. In this way, a low-budget separating system is recommended for large selecting processes with a time- and cost-effective selecting model. In the study, the creation of a real-time fast separating system with the support of the traveling salesman algorithm, performance evaluation and research and findings on the fast separating model are presented.

1. Introduction

The development of agricultural products in a particular agricultural area (field, greenhouse, etc.) may differ. Factors affecting the development of fruits are mainly sunshine duration, temperature, irrigation, pesticides. The development processes of agricultural products planted at the same time in different lands can be different even at the same time of the year. Fruits of different maturity, collected from many agricultural fields in factories with large production capacity, must be separated into classes such as size, maturity, color, foreign matter in the factory sifting area before being delivered to the consumer (Figure 1).

In some cases, there are other plant seeds mixed into the product collected in the field, which is undesirable[1-8]. For this, it should be ensured that the right taste and desired quality food products are obtained by selecting processes. This stage is an application that requires intensive labor and time, in which a large number of workers come together and select out large quantities of fruits by manual selecting method. In some cases, a deterioration in the taste of the products produced as a result of overlooking a rot in the part of the fruit that cannot be seen by the selecter worker causes the product to be of poor quality and the loss of a large amount of product and profit.

Figure 1. Olives to be selected after harvest

In order to prevent this, all of the fruits should be examined in detail by the selecting personnel, which may lead to a decrease in the production speed, an increase in costs and a decrease in revenues. Factories apply expensive, multi-stage quality control processes to prevent this negative situation and to prevent the taste and quality of the products. Factories employ a large number of selecting personnel on the production line to ensure that

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the quality does not decrease and the fruits are separated according to their different characteristics in order to ensure correct production (Figure 2).

Figure 2. A large number of personnel work in the selecting process.

Another problem in selecting processes is wrong product selecting. Due to wrong selecting, production is wasted and therefore the production performance decreases. In addition, the waiting situation of the products that have entered the selecting process in the warehouse also causes wastage. These wastage rates occur at different rates according to the type of products[9]. In some cases, products that are mistakenly identified as diseased harvest crops or foreign materials can cause unnecessary earnings reductions. Prolonged selecting processes can cause the loss of fruits and products that are prone to drying. Selecting processes are processes that require speed. Although there are selecting methods using color measurement in food establishments, classification and sifting based on color alone will not yield sufficient results[10]. The selecting model proposed in this study is mainly recommended for the production processes of fruits and products that are specified in Table-1 and that give high waste during selecting. The products mentioned here are wasted due to delays in processing.

When selecting is done manually or incompletely, undesirable situations occur when some foreign materials are mixed into the food (Figure 3). This event is an undesirable situation that affects health. Sifting processes in raw products is one of the most risky processes for businesses. Food manufacturers transfer a significant portion of their capital to businesses related to selecting processes in order not to lose their image as a result of possible bad situations. This causes cost increases. Firms strive to optimize the expensive processes here and seek solutions.

Table 1. Waste rates in products as a result of waiting

Product	Loss Rate (%)	Product	Loss Rate (%)
Barley	3	Tahini	3
Almond	2	Grape	4
broad beans	4	Cherry	3
Okra	5	Fresh fruit	12
Pea	2	Oat	3
Wheat	3	Olives	15
Vetch	3	Sesame	3
Walnut	7.5	Noodle	5
Rye	3	Chickpeas	3
Pumpkin seeds	12	Thyme	50
Mulberry	15	Lentil	3
Dried apples	10	pistachios	4
dried plum	4	animal feed	10
Beans	3	Kidney bean	2

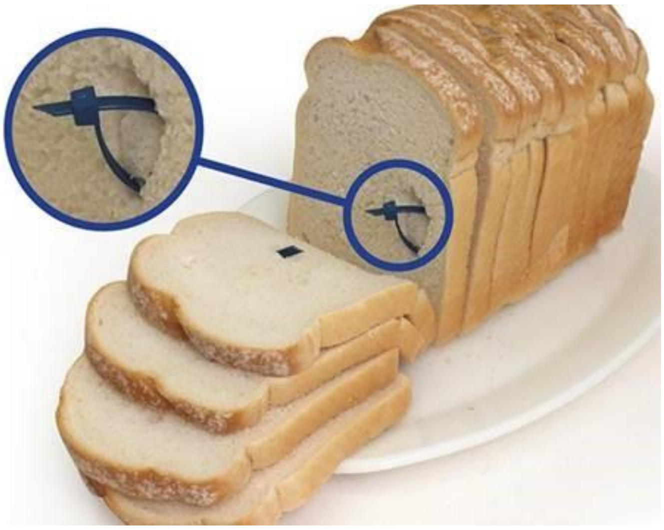

Figure 3. Foreign matter from bread

Apart from the selecting for classification, foreign matter sifting is also available. Foreign matter is defined as any other material that is in the collected product and has no relation with the product. Foreign substances often cause problems in small grain cereal products. It is an extremely challenging process to remove small foreign materials from small grains. For example, there are strict controls on edible wheat, which has a large consumption rate. According to the Turkish Standards Institute (TSE) text numbered 2974, foreign substances found in bread wheat include weed seeds, stone, soil, husk, stem, straw, etc. all kinds of substances other than itself, wheat grains and all kinds of other substances that pass under a 2.2 mm round perforated metal sieve. Of these, spoiled grains are moldy, rotten, sprouted, heated, undeveloped, insect-eaten and diseased grains remaining on a 2.2 mm round perforated metal sieve. Defeated grains; They are grains that have been gnawed or damaged by pests (Figure 4). Bad grains; They are reddened, putrid and blackened grains as a result of bacterial or fungal activity (Figure 5). Diseased grains; They are vernier grains and can be easily distinguished from their colors. Weed seeds and harmful diseased grains; All grass seeds and rye spurs and plant stems grown in the field with cereals are also included in this group. It has been reported in some sources that these weed seeds are harmful [11].

Figure 4. Insect-eaten grain

Figure 5. Foreign grain in grain

Since such grains are not selected out, it will cause the increase of diseases in the products, product losses and post-consumption health problems, they must be selected. It is important to carry out weeding operations on all grains, fruits and seeds due to the risk factors mentioned.

In this study, an object recognition based selecting system and model is proposed as an alternative to expensive selecting processes that take a long time and require a lot of personnel work. In the sifting process, real-time Haar graded object recognition algorithm is used to classify agricultural products and remove foreign materials. The traveling salesman problem (TSP) algorithm is used for the selecting unit to quickly identify foreign materials and to sift in a time-cost effective way. The traveling salesman problem determines the shortest paths between many coordinates in a given plane. A low-cost selecting unit should use the shortest processes on the sieving bench to remove the detected foreign matter. In this way, the work of a large number of sifting personnel can be done with the moving head selecting unit with optimum low energy consumption. Within the scope of the study, a prototype of the selecting unit, in which object recognition and TSP algorithms work together and in real time, was produced. A model was proposed and image processing method was used to determine the foreign matter contamination status of agricultural products entering the sifting process. The model proposal was put forward by experimental studies and its performance was compared with other studies. With the selecting unit carried out, a fast and safe selecting system supported by artificial intelligence has been proposed as an alternative to the classical sifting processes that take a long time and cause product losses.

2. Object Recognition Model Determination

Various models are used in object recognition applications [12-15]. The YOLO model is relatively faster than other models[16]. The speed of this model is due to the fact that the network model used in object recognition application is single layer. However, while this single-layer network structure provides an advantage in terms of speed, it negatively affects the recognition success. YOLO is not as successful as some other recognition models in recognizing small objects such as a flock of birds [17]. In addition, the single-layer network structure sometimes causes erroneous detections [18]. Object recognition models such as RCNN identify areas where the target object is likely to be found and are region-based models that run individual CNN classifiers in these areas. Regional scanning and running separate classifiers impose a number of limitations on detection in large areas. In addition, excess workforce causes this model to run slower than YOLO model[19]. The Haar cascade classifier, which is successful in detecting small objects, has been used in face recognition applications for many years. Haar, which is relatively slower than other recognition models, uses a multi-stage control structure for object recognition [20,21]. Within the scope of the study, the Haar cascade object recognition model was preferred in the system described here because of its success in detecting small objects in large areas. The success of the Haar model depends on the wealth of target object images used in network training. For this reason, 500 images of green and black olives collected as target objects were used in order to realize the system in visual education. In order to keep the target object detection success high, the resolution of the pictures was used as a minimum of 640x480 pixels. In the training model, images of objects such as rotten fruit, fruit of different maturity and foreign matter were also used during the development of the system. Here, a foreign fruit or foreign substance to be separated is shown to the system, and the unwanted objects in the agricultural product line are detected in accordance with the purpose and quickly removed.

3. Selecting Unit Design

In the fruit selection benches of the factories, the separation of large quantities of products according to certain classes and the removal of foreign materials are provided in a limited time by paying attention to hygiene conditions and by hand and eye examinations of the employees[22]. After the object recognition supported and vacuum selecting device determines the fruit or foreign objects to be selected on the counter, the vacuum head, which will enable the selection, should be brought to the position where the relevant fruit and foreign materials are located. In today's factories, selecting machines are used repeatedly to sift agricultural products (Figure 6).The area occupied by the machines used in this method and the energy they consume are among the negative factors.

Figure 6. Selecting unit covering large area in factories

In the design phase of the selecting system, the traveling salesman problem (TSP) algorithm was used as a model to vacuum the fruits or foreign materials taken into the selection process after object recognition and detection and to direct the vacuum head to the target fruit or foreign material location. The traveling salesman problem, which is in the optimization problem class, is used to determine the shortest paths between points on a certain plane [23,24]. Therefore, it tends to be used in different areas in the detection of short routes [25]. The traveling salesman problem has been used as a solution in many studies with its dynamic analysis structure [26-30]. In a sifting system where object recognition and TSP algorithms work simultaneously, the locations of unsuitable fruits and foreign materials to be selected can be shown as target coordinates in the TSP algorithm and an optimum route can be created for the orientation of the vacuum head. It is possible to repeat the applied processes in cycles until the selecting processes are completed (Figure 7 and Figure 8).

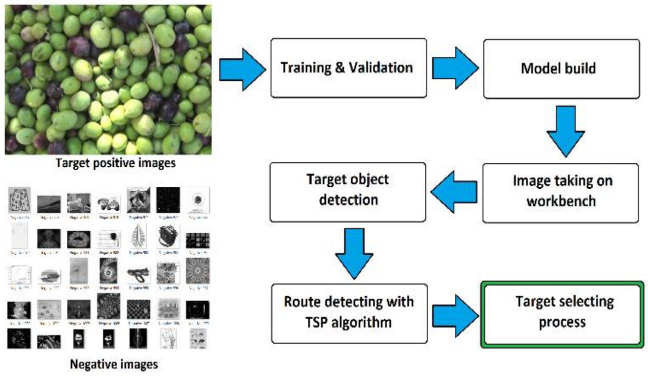

Figure 7. Program working diagram

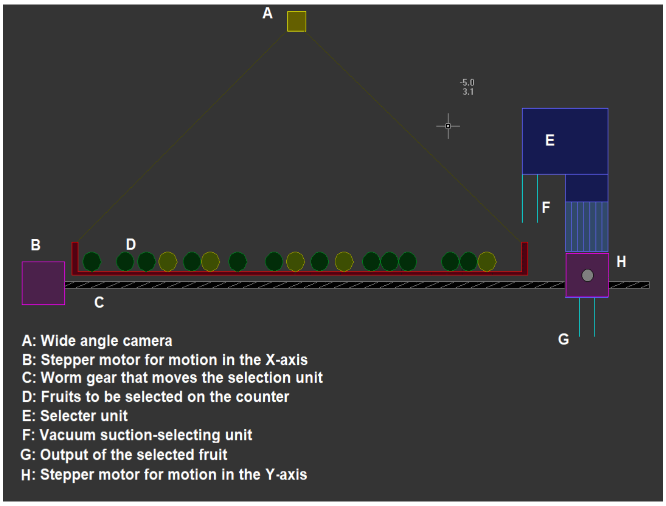

Figure 8. System diagram of the selecter unit

The selecting application starts with the image of the unselected fruits placed on the large-scale counter with a wide-angle camera on the counter. The real-time Haar cascade object recognition model enables the identification and coordinates of fruits or foreign materials that will enter the selecting process. In order to select the fruits or foreign materials whose coordinates are determined in the shortest time and with low energy consumption, the TSP algorithm enables the determination of the most suitable routes to move the selecting unit. The path coordinates obtained after determining the appropriate routes are used to drive the stepper motors on the X-Y axis that move the selecting unit. After the action of the stepper motors, the separator system head, which comes to the target fruit or the foreign material to be sifted, takes the target fruit or foreign material on the counter from the counter with the vacuum suction apparatus on it. The selecting program, in which object recognition and TSP algorithms work, shows the user operator the information about general fruit quality, foreign matter amount and selecting status when necessary. The object recognition algorithm required for the selection of target objects and the TSP algorithms that enable the selecting unit to be directed to the target coordinates were created in a C# program that they work simultaneously and were developed to work on a low-budget Mini PC Pro T6 computer (Figure 9). This mini computer has a 1.68Ghz quad-core processor, 4GB of RAM, and is capable of running real-time image processing and object recognition algorithms. The crop selecting unit is built on the skeleton of the 3D Ender Pro model printer. The stepper motors on the unit provide the movement of the vacuum pipe. The crop, which will be separated from the foreign substances in it by entering the selecting process, is placed on the tray in the system (Figure 10). When the vacuum pipe is brought over the foreign material, the vacuum pump activates and ensures that the foreign material and the contaminated crop are removed from the table. The vacuum pipe is fixed to a movable part moving on the X and Y axes, and the air is connected to the vacuum motor. The vacuum pump is activated at the coordinates where the sifting process will start.

Figure 9. Diagram of selecting unit

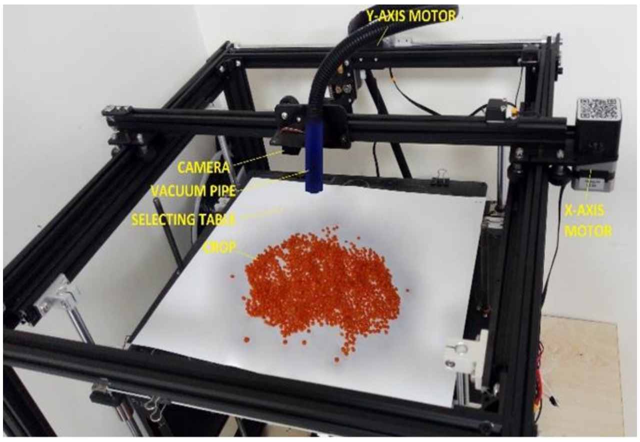

Figure 10. Prototype of selecting unit

4. Conclusion

In this article, the object recognition and TSP algorithm-based selecting unit system is examined by bringing a different perspective to today's selecting machines. As an alternative to machines with sequential selecting units, which take up a large area, a small-sized and single-bench selecting system has been proposed. The traveling salesman problem (TSP) algorithm, which is used to determine the most appropriate route, is used for the selecter unit to select in a low cost and short time interval. The Haar cascade object recognition model has been successful in detecting small-sized fruits and foreign matter, thanks to its multi-layered network structure. The selecting speed and capacity of the system vary depending on the number and location of foreign objects on the selecting bench. The collection of fruits in close proximity takes place in a shorter time than the collection of fruits scattered over wider areas of the counter. The superiority of the selecting unit using TSP algorithm in the simulated environment over the selecting unit not using the appropriate routing model is seen in Figure 11. The system using the TSP algorithm ensures that the most optimal routes are created while going to the target coordinates.

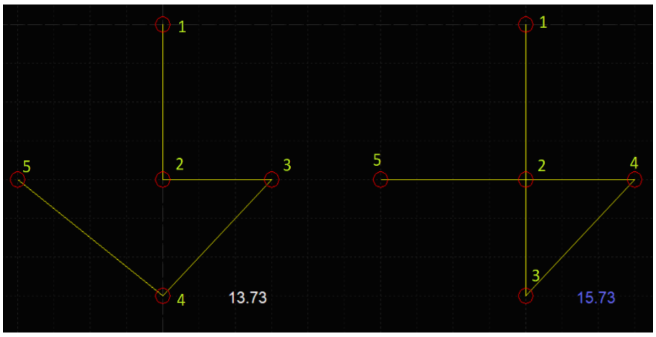

Figure 11. The difference between routing with TSP (left) and without TSP(right) for 5 items to be selected and paths taken

In the experiment, red lentils were added to the selecting system. Foreign materials were randomly placed on this red lentil cluster. comparison was made to extract 5 objects detected on the bench. The model using TSP traveled 13.73cm units to select out the 5 detected objects, while the system not using TSP and acting according to the nearest neighbor principle traveled 15.73cm units in classical selecting. In the sample application, it is seen that the selecting model with TSP is 12.7% more efficient than the model that does not use TSP. The detection accuracy of the fruit or foreign matter to be selected depends on the image dataset used, but it is over 97% in this study. In the selecting system, which does not use TSP, a route is created to the nearest fruit after the selected object. Although this may seem like an advantage at the beginning, this route drawing leads to a decrease in performance at the end of the extraction process, as it leads to an extra path. In the model using TSP, on the other hand, the positions of the fruits on the counter are processed collectively in the algorithm in order to determine the selecting rows of the fruits to be selected on the counter and the most optimal routes created for the mobile selecting vacuum head. In this way, time, path, and cost factored selecting is carried out. Comparison experiments on the objects to be selected in equal numbers on the bench are given in Table 2. According to this, it has been seen that the performance of the system using TSP algorithm is more successful than sequential fruit-selective selector systems that do not use any intelligent algorithm(Figure 12 and Figure 13). The distance taken for the system that does not use the TSP algorithm to select the determined fruits and position the selector system to the relevant fruit is more than the system with TSP. This shows that the system using TSP algorithm is more efficient in terms of selecting speed and cost. The selecting system can perform the selecting process by using the appropriate dataset for the different crop types to be separated. Selecting system with TSP has a time and cost advantage of 10-29% compared to the selecting system without TSP.

Table 2. Comparison of two selector systems with experiments

Test No	**System without TSP distance/time taken (second)**	**System with TSP distance/time taken(second)**	**Yield Rate (%)**
1	70	50	29
2	204	156	24
3	310	250	20
4	184	136	27
5	410	290	30
6	426	366	15
7	470	370	12
8	970	850	13
9	1127	1130	12
10	1990	1810	10

In addition to the sifting processes, a model was created on the determination of the pollution/compatibility of the agricultural products to be taken into the sifting process. In order to determine the amount of products taken into the sifting process, it starts with the calculation of the area(A) they occupy on the counter. Area calculation for the quantity of products according to the images obtained from the camera; it depends on the horizontal axis pixel number (M_x) of the computer monitor, the vertical axis pixel number (M_y), the actual lengths of the horizontal axis(C_x) and vertical axis(C_y) of the bench area viewed by the camera, and the total number of pixels(P_n) occupied by the products in the sifting process(1).

$$A = \frac{P_n \, x \, (C_x \, x \, C_y)}{M_x \, x \, M_y} \quad (1)$$

The pollution/conformity(P_r) ratio of the agricultural products taken into the sifting process depends on the number of detected foreign matter/inappropriate agricultural product (F_n), the amount of the products taken into the sifting process (A) and a pollution coefficient (P_c)(2).

$$P_r(\%) = \frac{F_n x \, P_c}{A} \quad (2)$$

The pollution/conformity is a predetermined coefficient for the measurement process depending on the type of foreign substance detected, the threat status of the foreign substance (poisoning potential, disease potential, etc.). Depending on the obtained pollution/conformity percentage, the selecting processes can be repeated many times or it can be understood that the product has passed the quality test.

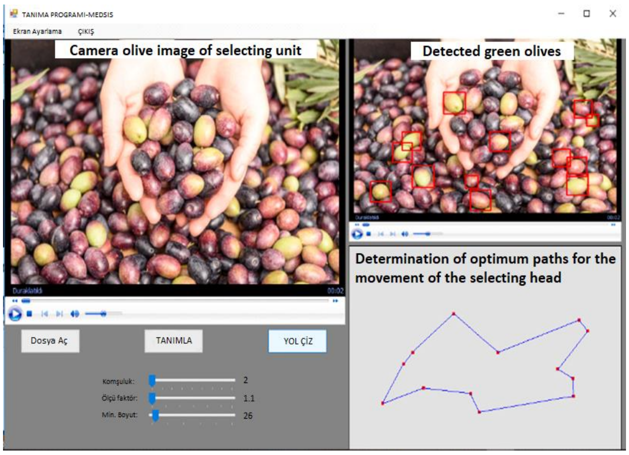

Figure 12. Establishing a route for selecting out the detected unripe olives on C# program (sifting green olive)

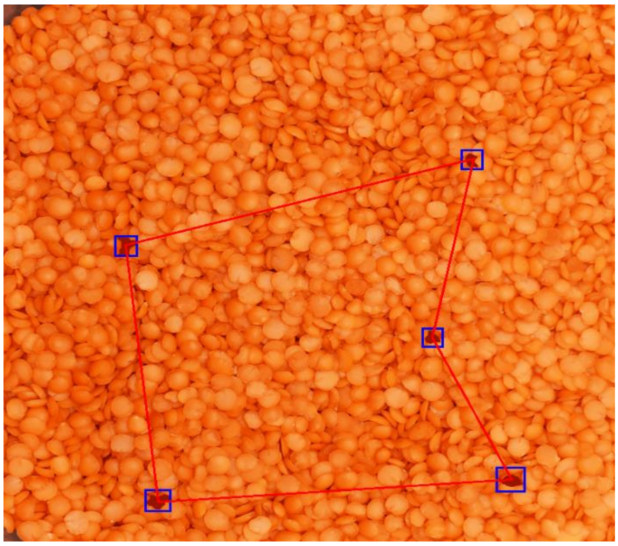

Figure 13. Detection of foreign substances in lentils and creation of a sifting route (sifting foreign matter)

Author's Note

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