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Autonomous Vehicle for Saffron Harvesting

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Abstract

The objective of this paper is the design and development of an autonomous vehicle which would be able to harvest saffron flowers unsupervised. This vehicle will be able to collect the flowers of the saffron unharmed. The time for the harvest isn't more than the time needed by a human to accomplish the same task. Moreover, this procedure must be more cost effective compared to the same task accomplished by a human. We also take under consideration that the plant appears to be very sensitive to the fluctuation of pH and can be chemically destroyed in the presence of oxidizing factors and in an ionized environment. It is also very sensitive to the atmosphere's humidity (due to its trichoid stamen) however it seems to be resistant to heat. Generally, the vehicle will be able to accomplish all the operations without the need of human supervision.

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Keywords: autonomous vehicle; saffron; harvest; gripper

1. Introduction

Nowadays, the technology of mechanical harvesting is focused on harvesting plants of large crops (e.g. wheat, corn) using special mowers of large size and cost. On the other hand, in spite of the great technological advances, the harvesting of vegetables, fruits and other corps (e.g. saffron) depends primarily on human labour. This affects mainly the cost of production, the product's quality, as well as the safety of workers in crops that have been sprayed

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with pesticides (e.g. greenhouses). The main reasons for the shortage of automated solutions are the difficulty in tracking the corps and the difficulty in simultaneously cutting and collecting the corps without damaging them.

Saffron (Crocus sativus L) is one of the most expensive edible flowers of the world. Iran, Spain, Italy and Greece are producers of dried saffron. A farm of saffron needs daily and manually harvesting because every plant of saffron produces only three flowers in different height and days. There are 2170 flowers in each Kg of harvested fresh flower, and processing every 78 Kg of fresh flowers results in one kg of dried saffron-spice [1].

This final product is actually the stigma part of flower. The stigma, as the only economic part of flower has eatable and medicinal applications. One stigma of saffron weighs about 2 mg, each flower has three stigmas and 150,000 flowers are required to produce 1 kg spice. Harvesting the flowers and separation of stigmas from the flower is a most difficult operation. It is time consuming, laborious and makes saffron the expensive spice of the world. Picking of 1000 flowers requires 45–55 min, and another 100–130 min is required for removing the stigmas for drying. Thus, 370–470 h is required to produce 1 kg of dried saffron. The flowers are picked exactly when they are fully bloomed and the saffron strand or stigma is at its reddest. The harvesting must begin shortly after dawn. If left exposed to the sun, saffron quickly loses its colour and flavour and withers under the sun light. The task includes picking the flowers and separating the stigmas from the petals and stamens (Fig. 1). Flowers are picked at the base of the segments, and put into basket in thin layers to avoid excess pressure and deformation of flowers organs, particularly of the stigmas [2].

Many researchers are engaged on the automatic harvesting of fruits or vegetables but there is always the need for the introduction harvest methods for saffron. Automation of harvest and post-harvest of saffron flower increases harvest efficiency and consequently reduce the final cost of the product. Dimitriadis and al designed a conceptual machine which operates by separating the petals, the stigmas and stamens from the plant individually in the field using a combination of pneumatic and mechanical processes [3], Bertetto described and discussed a robotized system with the aim to harvest and separate the saffron flower spice [4], Ruggiu et al developed a prototype for harvesting the saffron [5], Javari developed a suitable algorithm for recognition and locating saffron flower using machine vision [6], Gracia et al presented a new machine for automated cutting of saffron flowers in order to obtain their stigmas [7], Emadi et al designed a vertical wind tunnel for separation of stigma from the other parts of saffron flower using its aerodynamic properties [1].

This paper explores the feasibility of mechanization of the harvest procedure. It focuses in the design and development of an autonomous vehicle which will be able to collect saffron flowers unsupervised.

The main elements that consist the structure of the vehicle are described as well as their combined operation (sensors, motors, collision avoidance), the sequence followed in order to ensure that the right flowers are harvested, the sequence followed in order for the vehicle to avoid colliding with any obstacles during its course and the operation of the robotic arm and the gripper, which must operate according to strict specifications, regarding the harvesting, the transportation and the storage of the flowers.

The plant appears to be very sensitive to the fluctuation of pH and can be chemically destroyed in the presence of oxidizing factors and in an ionized environment. It is also very sensitive to the atmosphere's humidity (e.g. fog, frost net and wind currents due to its trichoid stamen) however it seems to be resistant to heat. Therefore, it is essential that the harvesting vehicle and gripper must handle the flowers very gently. Due to the plant's sensitivity, the harvest procedure should be completed within a time period of one day, or two at the maximum, from the moment that the flower blooms (so that its flavour and fragrance could be sealed off), the vehicle is designed to complete this procedure within the time period of one day. In addition, as the harvest of the saffron must take place early in the morning or late in the afternoon, when the concentration of the plant's oil is higher, the vehicle has four working hours in the morning and four working hours in the afternoon.

Fig. 1. The saffron flower with six petals (violet), three stamens (yellow) and three stigmas (red)

2. Description and Operation of the Vehicle

The following assumptions are made, concerning the surface of the field on which the vehicle is collecting the saffron (Fig. 2):

- The movement of the vehicle must follow specific restricted paths within the plant lines, and collect the flowers from them.
- The plants are ordered in rows, and the distance between them is approximately 60 cm.
- The flowers are situated at a distance of 10 – 30cm (depending on the farmer).

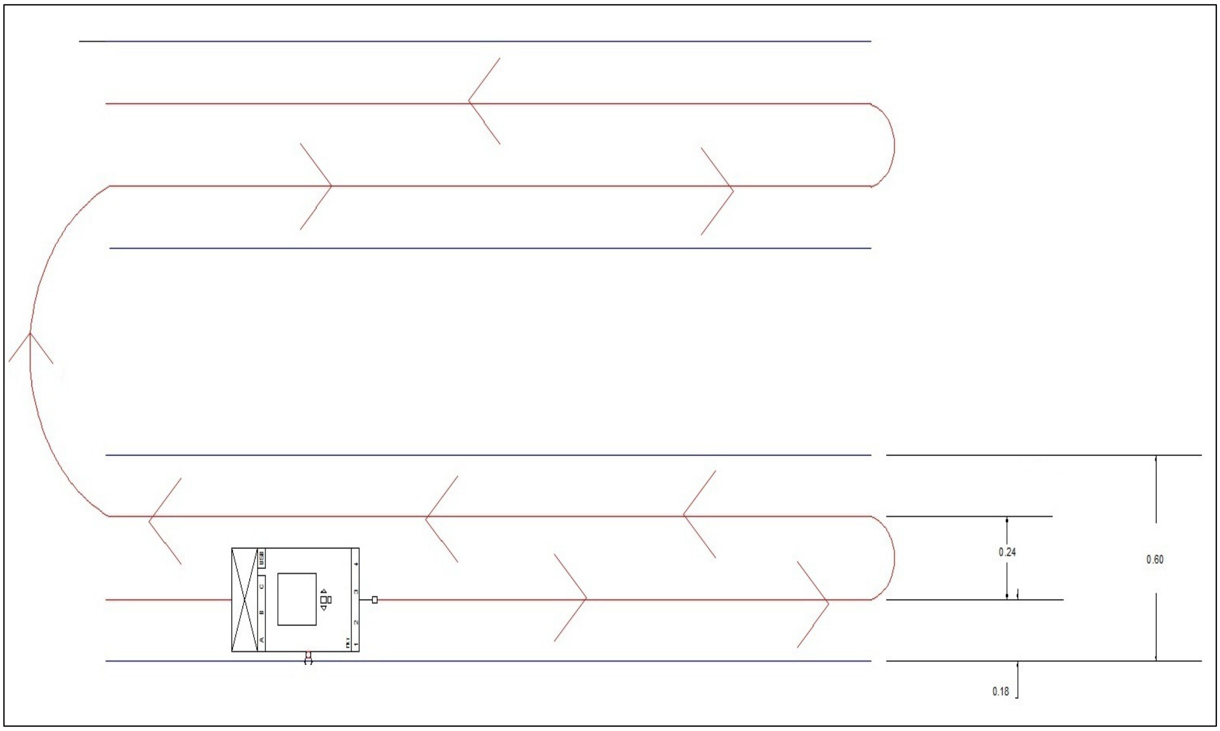

Fig. 2. View of the route that the vehicle follows in a field.

The maximum surface that this particular vehicle can serve is up to 1,200 squared meters (i.e. 60m x 20m). The surface of the field is considered to be not smooth with a mean height fluctuation d= ±5cm. The height of the plants is from 5 to 10cm.

The vehicle should start from one side of the field and after collecting all the flowers it terminates at the other side of the field. The vehicle should drive across a row and collect its flowers. Marks can be positioned along the rows in order for the vehicle to be properly oriented but also to define the start and the end of the process.

The vehicle should be also able to store the products from the half the field (four hour period) in a special designed container, on its undercarriage, making sure that all the special conditions of light, humidity, pressure and the other factors have being considered. The vehicle should also have the ability to check the flower in order to determine whether it is appropriate to be harvested otherwise it would proceed to the next flower. Moreover, the vehicle should be able to move along the roughness of the surface ±5cm but also it should have the ability to overcome various physical obstacles e.g. stones during its movement, without affecting the harvest procedure.

2.1. General description of the Vehicle

The vehicle must accomplish the following operations:

- Begin its operation with voice message.
- Follow a specified route determined by coloured marks which are detected by a colour sensor.
- Detect the next flower using distance sensors.
- Evaluate the quality of the flower with the use of colour sensors.
- Harvest the flower with a use of the gripper.
- Complete its operation when detecting the end of the field.

The vehicle consists of the following equipments (all the necessary calculations have been made for the selection of devices-components listed in parenthesis):

- 2 colour sensors (IFM Electronics 05-C500)
- Distance sensor (Sharp 2D120X)
- Voice sensor (BOB-099.24)
- Gripper
- Worm gear, worm wheel system
- Movement motor (Transmotec 750 series)
- Gearbox (Tamiya 4-Speed Crank-Axle Gearbox)
- Servomotors for the movement of the robotic arm – gripper system (Hightec HS-485HB Deluxe Servo)
- Servomotor controller (Phidget AdvancedServo 4)
- Wheels
- Motherboard to control the operations (GRoboduino)
- Electrical Supply-Battery (BQY 11,1V LiPo 3S 5200 mAh)

In Fig. 3 are shown the top, the front and the side views along with the vehicle’s dimensions.

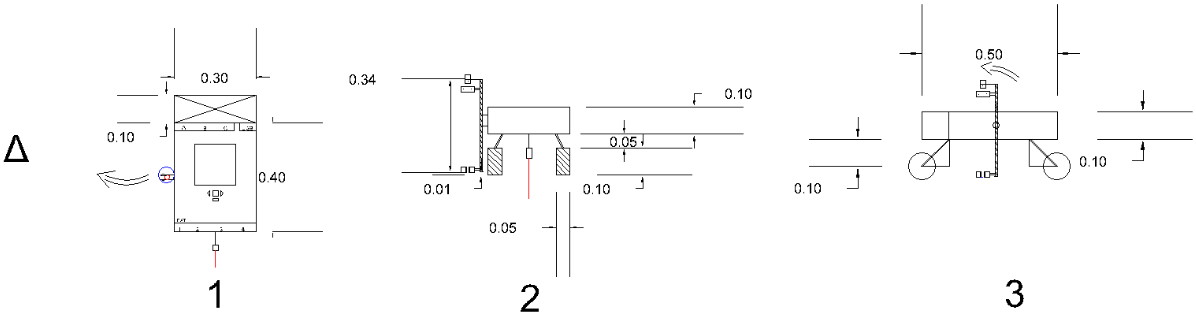

Fig. 3. Vehicle's (1) ground (2) front (3) side views

2.2. Operation of the Robotic Vehicle

The operation of the vehicle begins when the voice sensor detects a voice signal "BEGIN". The vehicle is guided by coloured marks situated along the plant rows of the field.

A colour sensor is situated on the front centre of the vehicle. It is situated there because of its low accuracy. This sensor is responsible to maintain the vehicle on its route along the red mark.

The distance sensor, the colour sensor and the gripper are placed at the right side of the vehicle on a system of worm gear-butterfly system (an axis with internal thread). The sensors are fixed on the axis shell and the gripper is moving mechanically and automatically along this axis (robotic arm).

The distance sensor calculates the distance of the next flower by sending active signals and reading the reflected signal. It is situated near the ground, at the bottom-end of the axis, in order to detect the smallest flowers taking into account that the height of the plant is between 5cm and 10cm and the fluctuation of the field is ±5cm.

When the colour sensor, which is situated exactly above the open gripper (and the flower), determines that the flower is suitable for harvesting the gripper closes and moves upwards 1 cm, cutting the flower with a motion similar to that of the human hand. Then the axis rotates 90^o and the gripper turns towards the inner side of the vehicle and drops gently the flower in the properly developed container. The container is at the back of the vehicle and has dimensions 30x10x10cm and capacity 3 litres.

If the flower is considered to be inappropriate for harvesting, the axis along with the gripper rotates 90^o and the vehicle moves on without hurting the plant. This process is repeated until the vehicle reaches the end of the field.

3. Analytical Description of the Process

In this section are described in detail the steps of the vehicle's movements and gripper operations.

3.1. Harvesting Procedure

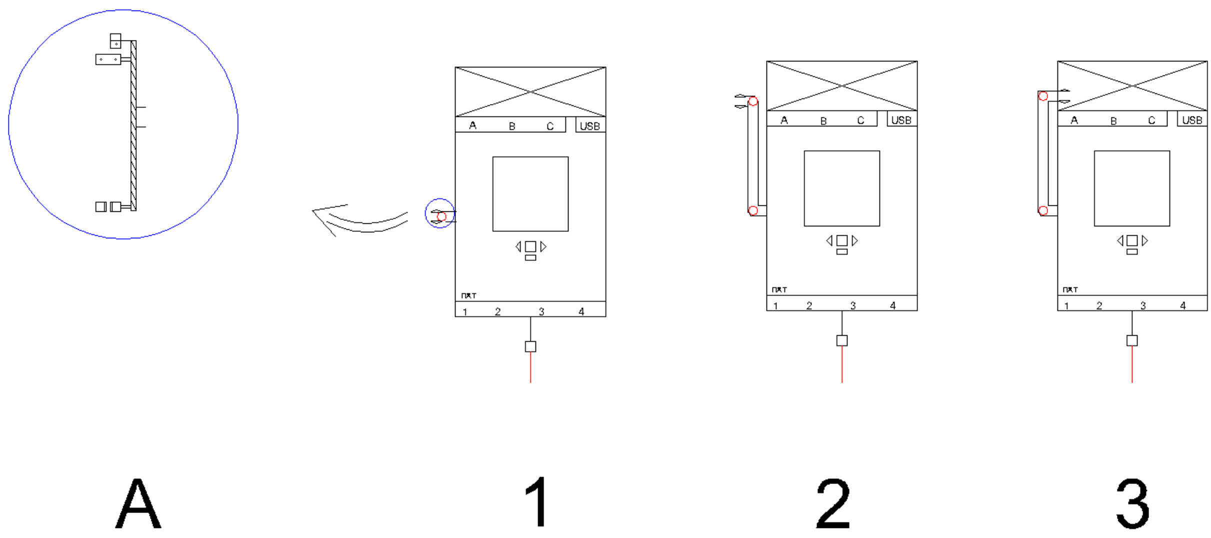

Fig. 4. Detailed view of the gripper's movement

Fig. 4A shows the positions of the sensors on the axis-robotic arm; Fig. 4.1 shows the position of the sensor which is responsible for maintaining the course of the vehicle on a preset route defined by the colored mark, and the axis at the vertical position at the side of the vehicle. Fig. 4.2 shows the position of the gripper, after the rotation of the robotic arm to the back of the vehicle and Fig. 4.3 shows the gripper rotated inwards to drop the flower in the container.

The steps of detecting a flower, evaluating its ripeness and cutting it are as follow. Initially the distance sensor as is down detects a flower. When the plant is reached, the colour sensor compares the flower's characteristics with internal data. If the ripeness criteria are met the flower is suitable to harvesting and gripper closes and moves 1cm from the ground (in order to cut the flower).When closing, the cutting of the flower, is much alike that accomplished by a human hand.

After the gripper cuts the flower it moves by 90^o horizontally and then goes up to the higher point of the axis. Afterwards, the robotic arm rotates 90^o (so it's parallel to the frame of the vehicle) then the gripper's arm rotates by 180^o and the wrist rotates by 90^o leaving the flower in the container.

After that, the gripper returns to its initial position while the vehicle moves to the next plant.

3.2. Procedure of Bypassing a Flower

The steps of detecting and bypassing a flower that does not meet the harvesting criteria are as follow. Again the gripper is located at its original position. The distance sensor detects a flower and the color sensor evaluates the ripeness of the flower. If the flower is not suitable to harvesting the axis along with all its components, including the gripper, rotates by 90^o and gets in parallel with the vehicle's frame, in order to avoid the flower without injuring it. After that, the gripper returns to its initial position and the procedure continues.

3.3. Avoiding Obstacles during the Harvesting Procedure

If the vehicle meets an obstacle (e.g. stone) which will be detected by the distance sensor, the colour sensor checks if the image is consistent with a plant. If the characteristics of the object do not much then the vehicle's microprocessor rotates the axis by 90^o and gets it in parallel with the vehicle's frame. When the vehicle overcomes the obstacle and it travels about 30 cm which is the minimum distance between plants and it continues seeking for new plants.

4. Operation of the Gripper's Arm

4.1. Operation of Gripper's Fingers

The movement for opening and closing gripper's fingers is being achieved by using a system of a gear and a worm gear. This way we can achieve the transformation of rotational movement to linear. The force is carried from the gear, which is attached on the servomotor, to the worm gear which is attached to it.

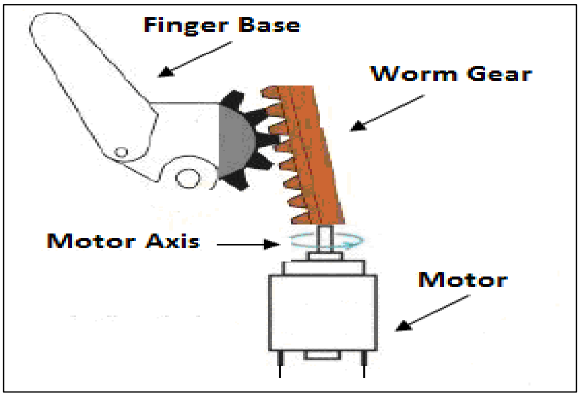

Fig. 5. Gripper's mechanism

The motor produces rotational motion which is transmitted to the worm gear and then to two gears that rotate the gripper's fingers. So the rotational movement is converted to a mutual movement for the opening and closing of the gripper's fingers. In the following scheme (Fig. 6) we can see the details of the gripper's mechanisms and the fingertips containing the cutting arrangement and the net retaining the flower before it is released in the container.

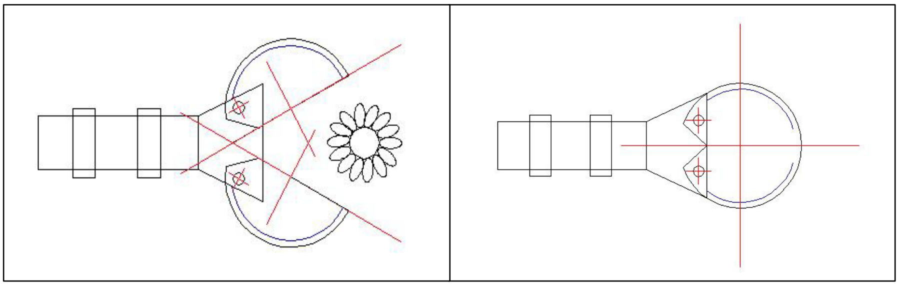

Fig. 6. View of the gripper with its cutters (opened and closed)

By the time the gripper is about to leave the flowers its arm executes a rotation of 180^{o} and its wrist a turn of 90^{o}, so that the spoon-like gripper's fingers can release the flower towards the inner side of the vehicle, at the container.

4.2. Wrist's Operation

The rotation of the wrist is caused by the wheel that is placed on the edge of the axis of the relative motor (M2). The movement of this wheel is directly relevant to the wrist's rotation. In order to protect the wiring of the motor responsible for the movement of the gripper's fingers (M1), the wheel stops the rotation at some point with a stopper (rotor stopper). This happens after a properly specified number of turns. But even if the wrist would stop, the motor wouldn't. It would continue to rotate exerting an excessive force. This force would be catastrophic for the motor so we put a small plastic flange (Fig. 7) that stops the crown gear which is attached to the motor.

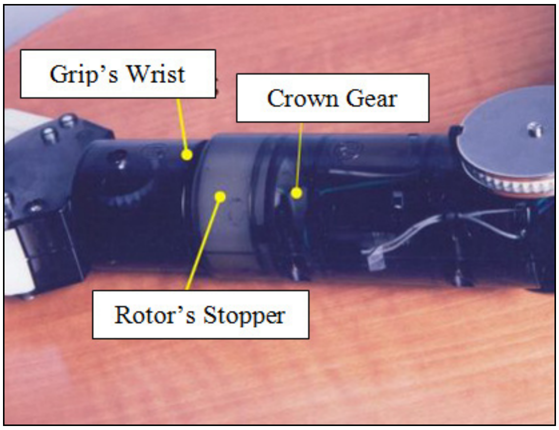

Fig. 7. View of the gripper's wrist

When the wrist is rotating normally the small plastic flange transports energy from the motor to the wrist. When the wrist stops its reciprocation due to the stopper or the wrist continues reciprocating due to other forces, this flange gets pushed automatically forward towards the wrist because of the reciprocating force caused by the crown gear of the motor. This action has as a result that the flange won't be attached to the motor's crown gear any more thus the wheel of the motor will continue to rotate without transporting its movement to anything.

5. Conclusions

This paper contains the feasibility study, initial design, and development of an autonomous harvesting vehicle. The design was based on some assumptions regarding the saffron plants locations and dimensions and the sensitivity requirements due to the delicate nature of the flower. The vehicle is designed to operate at a speed comparable to that of a human and it can run approximately four hours without recharging. It is based on commonly available electrical and mechanical parts and common communication and control devices. Its implementation and testing in real fields is the goal of future research efforts.

References

[1] Emadi, B., Yarlagadda, P.K.D.V. (2008) Design of a Wind Tunnel for Separating Flower Parts of Saffron, Journal of Achievements in Materials and Manufacturing Engineering, Vol. 31 (2), p.635-638.

[2] Rakesh Kumar, Virendra Singh, Kiran Devi, Madhu, M.K. Singh & P.S.Ahuja (2008) State of Art of Saffron (Crocus sativus L.) Agronomy: A Comprehensive Review, Food Reviews International, 25:1, p.44-85.

[3] Dimidriadis, C.I., Brighton, J.L (2002) The Design of a Mechanical System for the Harvest of Saffron Plants Greece, Acta Hort. (ISHS) 850, p. 205-208.

[4] Bertetto, A.M. (2012) Service Robots for Agriculture: A Case Study for Saffron Harvesting, Service Robots and Robotics: Design and Application, 26 pages.

[5] Ruggiu, M., Bertetto, A.M. (2006) A Mechanical Device for Harvesting Crocus Sativus (Saffron) Flowers, Applied Engineering in Agriculture, 22 (4), p.491-498.

[6] Javari , A., Bakhshipour, A. (2010) Development of Suitable Algorithm for Recognition and Locating Saffron Flower Using Machine Vision, International Conference on Agricultural Engineering- AgEng 2010, Clemont-Ferrand, France, p.101.

[7] Gracia, L., Perez-Vidal, C. and Gracia-Lopez, C. (2009) Automated Cutting System to Obtain the Stigmas of the Saffron Flower, Biosystems Engineering, 104, p.8-17.