Harvesting olive tree using accurate vibrations generated by a robotic system

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Abstract. The paper presents the results of the study regarding the olive harvesting trees systems and the concept of an olive tree robot. Important is the result, namely the harvesting speed and accuracy. Mechanical and automatic harvesting methods collect more olives than the traditional methods but may damage the olive trees. The necessity of an olive tree robot is based that the agricultural industry is very complex and need a lot of attention and qualified employments but is an activity only seasonal and are hands work. The same think is in grove-olive, where necessary many workers with experience to collect olives with their hands. In this case take a lot of time to collect the entire olive grove. Our study shows that the best system to increase the production of olives is to harvest the olives trees mechanics with robots.

1. Introduction
Since ancient times up to modern days, olive harvesting methods have remained approximately the same, without much investment in the harvesting technology. The majority of olive harvesting is still done in the traditional way.

The technological development is slower in this field due to the fact that agriculture is a seasonal job. The harvesting of olives, in Greece, begins at the end of September and lasts about 20 days, being dependent on the season and the weather conditions.

However, in recent years, thanks to the technological development, mechanical dispositive and tools which improve the harvesting of olives have been introduced.

When it comes to manual harvesting, 2 to 5 people are needed per olive tree. This process consists of setting down a piece of cloth on the ground, followed by the shaking of the tree’s branches, and finally the gathering of the olives off the piece of cloth. The use of certain rakes to shake the tree could deteriorate the branches in time. Sometimes olives are gathered by hand, one by one [1, 2].

Recently, especially in countries with a strong economical presence, mechanical systems for gathering olives have been introduced. Some of the best known and used systems are trunk shakers and self-propelled harvesters. These mechanical systems are used in harvesting olive cultures grown specifically for this purpose.

It is difficult to use these systems for traditional “natural” cultures due to the fact that the olive sizes can vary, as well as due to the fact that the trees are not grown in rows and columns.
Some of the advantages of mechanical systems is that they can harvest much faster than traditional methods. What is more, they can be used for other fruit trees which can be harvested through vibration.

The main disadvantages are the harvesting accuracy, in this case both the ripe and unripe olives are collected, as well as the deterioration of the olive tree. Usually vibration-based systems deteriorate the trunk of the tree, whereas the self-propelled harvester system deteriorates the tree even more than the vibration based systems, due to the breaking of the branches [3].

In our laboratory we intend to create a robot which can harvest with or without human assistance based on GPS coordinates with the use of a shaker.

2. Methods and materials

In the first phase of our study we collected the experimental data for that we travelled to Greece in the region of Halkidiki at an olive farm (Olea europaea), during harvest season, October 2017, when is olives are at their ripest, Figure 1. The dimensions of this olive farm are about 9.500 square meters with about 350 olive trees. The farm was composed by density olive orchards adapted for mechanical harvesting. The mechanical harvesting is released with self-propelled shaker by Pellenk with adjustable vibration frequency from 0 to 31 Hertz and adjustable amplitude from 0.01 to 0.10 m, Figure 2 [4].

Figure 1. Olive farm in Halkidiki, Greece.

Figure 2. Olive self-propelled shaker.

Using a pulse generator on several olive trees, each of them containing olive fruits with different degrees of ripeness we observed different reactions to the vibrating, depending on the stage of ripeness of the olive fruits. We know that the acceleration is amplified to all olive tree structure [2]. The olive wood mechanical properties describe the olive wood as a polymeric material which is defined in terms of elastic solids and viscous liquids [5].
The vibration frequency was between 23Hz and 32Hz and acceleration was between 160.1 ms$^{-2}$ and 212.1 ms$^{-2}$ in the tree trunk knowing this value from theory and other experiments [6, 7, 8, 9].

3. **Experimental work**

The main challenge was to determine the necessary vibration to detach green and black olives. Olive wood modulus of elasticity is 2200N/cm$^2$, dynamic stiffness about 0.00731 N/cm corresponding to natural frequency from 20-22Hz and the density 1.1 g/cm$^3$. According this data we estimate the necessary frequency for detached olive is from 20Hz to 32Hz and the displacement from 0.1 to 10 cm [5]. The majority of the olive trees, in farm, had the same dimensions. We took for our study the average dimensions. A height of 3.5 meters, the trunk diameter of 22 cm, the trunk height of 143 cm and the gripe shaker was fixed at 45cm above the ground level. We began our experiments with a high frequency, knowing that at this level the black olives would detach and continuing with various amplitude levels, not more than 5 second for each test [10, 11]. Following we repeated the test with lowered frequency values, Table 1.

| Frequency ($Hz$) | Amplitude ($m$) | Green olive (unripe) (kg) | Brown olive (semi ripe) (kg) | Black olive (ripe) (kg) |
|-----------------|----------------|---------------------------|----------------------------|-------------------------|
| 32              | -0.01          | 0.01                      | 0.01                       | 14                      |
|                 | -0.05          | 0.01                      | 0.03                       | 1                       |
|                 | -0.10          | 0.02                      | 0.01                       | 0                       |
| 29              | -0.01          | 0.01                      | 0.1                        | 30                      |
|                 | -0.05          | 0.02                      | 0.5                        | 4                       |
|                 | -0.10          | 0.02                      | 0.1                        | 1                       |
| 28              | -0.01          | 0.01                      | 0.8                        | 10                      |
|                 | -0.05          | 0.03                      | 1                          | 2                       |
|                 | -0.10          | 0.05                      | 0.7                        | 0.7                     |
| 27              | -0.01          | 0.01                      | 1.1                        | 2                       |
|                 | -0.05          | 0.1                       | 3                          | 0.9                     |
|                 | -0.10          | 0.9                       | 1.2                        | 0.1                     |
| 26              | -0.01          | 0.02                      | 2.5                        | 0.7                     |
|                 | -0.05          | 0.2                       | 7                          | 0.09                    |
|                 | -0.10          | 3                        | 2                          | 0.04                    |
| 25              | -0.01          | 0.35                      | 1.2                        | 0.1                     |
|                 | -0.05          | 1                        | 3                          | 0.02                    |
|                 | -0.10          | 6                        | 1.1                        | 0.01                    |
| 24              | -0.01          | 0.4                       | 0.9                        | 0.01                    |
|                 | -0.05          | 3                        | 1                          | 0.01                    |
|                 | -0.10          | 24                       | 0.8                        | 0                       |
| 23              | -0.01          | 0                        | 0.01                       | 0                       |
|                 | -0.05          | 0                        | 0.02                       | 0                       |
|                 | -0.10          | 0                        | 0.00                       | 0                       |

The vibration frequency and the amplitude vary for ripe and unripe olives. Fruit detached varied from 0 to 30kg and depending on different parameters of frequency and amplitude.

4. **Results and discussions**

To determine the accuracy of the detached moment we tested under different conditions, such as frequency and amplitude. As a brief result of this experiment for olives detached moment we can derive the information shown in Table 2.
Table 2. Synoptically table with olive detached moment.

| Type olive fruits | Green olive (unripe) | Brown olive (semi ripe) | Black olive (ripe) |
|-------------------|----------------------|-------------------------|-------------------|
| Frequency (Hz)    | 24                   | 26                      | 29                |
| Amplitude (m)     | 0.10                 | 0.05                    | 0.01              |

In the development of the solution we created a prototype for the shaker system based on experimental data. This shaker system has rubber grips and a digital optical sensor for recognizing the olive tree trunk based on colour and a proximity sensor for grabbing [12, 13], Figure 3.

![Grip system with optical and proximity sensor.](image)

Figure 3. Grip system with optical and proximity sensor.

We have included a digital optical sensor which recognizes the colour of the trunk and a proximity sensor which acts in the process of grabbing the trunk of the olive tree [14]. There are many methods of generating mechanical vibration, such as rotating ones, with eccentric, Scotch yoke type or using multiple eccentric. When the digital optical sensor recognizes the olive tree, the robot arm rotates, and the trunk is grabbed, and the shaking process begins, this prototype is programmable, Figure 4.

![Programming of the robot arm.](image)

Figure 4. Programming of the robot arm.

For this test we have include also a mini eccentric vibrating controller for selecting the frequency and the amplitude and a mini vibrating sensor that are fixed on olive branch measurements the forces [15, 16], Figure 5.
Figure 5. Grip system with optical and proximity sensor.

The concept of an olive harvesting robot is based on the constraint to use minimal manpower. Our concept is based on a trunk AGVS system with a trunk shaker system and trailer for collected olives [12], Figure 6.

Figure 6. Olive robot shaker.

5. Conclusions
This trunk works based on GPS coordinates and a wireless ad hoc system for positioning for increased accuracy system [12, 16], to receive and to send information, such as images of the olive trees and olives, weather and soil conditions or temperatures. This subject will be further analysed in a future paper.

The present experiment demonstrates a connection between frequency and amplitude in harvesting process. It has been found also that green olives are detached on low frequency and high amplitude and black olives are detached on higher frequency and lowest amplitude, Figure 7. We can concluded that the robotic harvesting system must be concept to apply various frequencies, from lowest to highest and must have the ability to change the shaking amplitude from very low values.
Figure 7. Olive detached moment.

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