Machine to machine connections for integral management of the olive production

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Abstract

Ensuring food safety and guaranteeing appropriate quality require correct management of all the operations involved in the production chain. In the olive sector, most of the advances made in traceability have focused their attention on the arrival of the fruit to industry and internal operations. This work introduces a new machine-to-machine system that allows the sector to integrate all the information generated from the field to the market through a methodology for the real-time management of all operations carried out. The consumer can check the product history, farmers can consult and optimise their resources, and industry can more efficiently control the operations performed. The system developed is composed of an electronic device, iOlivetrack-D, mounted on agricultural machinery, which uses RFID and GPS technology to identify plots and sectors, and sends the information generated in the field to a web application, iOlivetrack-W. The developed system was tested in real working conditions during a table olive grove season obtaining good results in the identification of plots and sectors using RFID and GPS as well as in the registration of information associated in the web application using both technologies. To complete the product chain information, industrial processing operations were simulated by entering the data manually through the application. Finally, a QR code was generated and affixed on the final product packaging to provide consumer access to product traceability information. The work shows the pros and cons of this adaptable system, which not only allows assured traceability of the entire production chain but also efficient management of resources for farmers.

Keywords: traceability, RFID, GPS, QR, field notebook, machinery.

Introduction

Food quality and safety play a fundamental role in our society. Legislation has become more restrictive and consumers demand more confidence (Aung and Chang, 2014), all of which must be addressed through the implementation of a correct traceability system that involves appropriate control and monitoring of the primary product. In order to do this, it is necessary to know the itinerary followed during each phase of the food production chain, identifying both origin and all the inputs the product has received, as well as the procedures and conditions that have intervened throughout its production. The implementation of a reliable traceability system in the agri-food sector can bring many advantages to all levels of the production chain (field, industry, market).

At field level, different farm management software (FMS) are available depending on the needs to be covered (Fountas et al., 2015). The producer can supervise different tasks of the productive cycle such as machinery management and cost control (Paraforos et al., 2017), crop monitoring (López-Riquelme et al., 2017), irrigation management (Bartlett et al., 2015), acquisition of production and yield parameters (Tan et al., 2015) or identification and origin of primary product plantations (Cunha et al., 2010).

At the industry level, there are a wide range of commercial applications based on enterprise resource planning (ERP) software that have the general purpose of controlling resources and ensuring traceability of the product from the time it enters industry until it leaves (Li et al., 2017). However, a good automatic connection for the transfer of data from field to industry is necessary and the largest possible amount of the information generated should be conserved. This would make it easier to classify batches, identify them immediately and, in the event of a risk, identify the causes and scope of the problem (Resende-Filho and Hurley, 2012) thus avoiding serious damage to the brand image.

In general, and more specifically in the olive sector, there are no systems that allow the integration of traceability in all phases of the production chain automatically. Normally, the traceability of olives begins with the arrival of the fruit at industry when, in some cases, the information provided by the producers in their field notebook is recorded. In the case of Spain, the world's leading olive producing country (43% of olive oil and 21% of table olive production) (IOC, 2018), these data are generated by technicians who provide such inputs as the phytosanitary products used (RD 1311/2012, 14th September) and the production plot. This information is linked to the SIGPAC code. The SIGPAC (Geographical Information System of Agricultural Plots) is a SIG application created by Ministry of Agriculture, Food and Environment of Spain and allows the geographical identification of the plots declared by farmers and stockbreeders. Thus, each plot has a SIGPAC Code associated through which you can know the location and use given to the soil. There are some applications that allow these data to be digitised for more exhaustive control (Valencia-García et al., 2018). However, all of them have a high manual component, does not include all the activities and inputs that have taken place in the field and depend on the reliability of the technician. All this translates into incomplete information and hinders the creation of differentiated batches of products with data referring to the whole production chain.

This work proposes a methodology for the automated acquisition of data related to batches of fruit throughout the whole field cycle and the interconnection of this data with the industry level. To this end, an electronic device (iOlivetrack-D) was which uses different technologies based on radio-frequency identification (RFID) and the Global Positioning System (GPS) in order to identify the origin of the inputs and manage the machinery. On the other hand, a web application based on cloud computing technology (iOlivetrack-W) was developed to manage all of the data.

As RFID systems use tags, they offer high versatility for information management (Costa et al., 2013) and have shown significant advantages over other identification technologies such as 2D codes (Qian et al., 2012). The technology has been successfully employed in numerous applications (Ruiz-Garcia and Lunadei, 2011) and is valid for both product batch identification and information recording. In the proposed system, RFID technology is used to identify the plots where all field operations are carried out and to associate the inputs generated in them, as well as the data transfer to industry.

The use of GPS technology for tasks such as navigation or machinery location has spread worldwide. It is already used in combination with geographic information systems (GIS) for applications such as the variable dosage of phytosanitary products (Pérez-Ruiz et al., 2011), irrigation adapted to soil conditions (Privette et al., 2011), performance monitors (Magalhães and Cerri, 2007) or automatic guidance of machinery (Perez-Ruiz et al., 2012). To control traceability, and as an alternative to the RFID system previously outlined, this work proposes the use of GPS technology for a real-time identification of plots that links machinery input with the plot.

Cloud computing systems have proven capable of adaption to the agricultural sector for many tasks (Choudhary et al., 2016) and they bring numerous advantages such as efficiency, cost reduction, quality and food safety (Bo and Wang, 2011). Applications developed on a web server make it possible to optimise the management of resources from any location and at any time (Channe et al., 2015). The proposed application uses this technology to record and automatically classify all of the information generated at field and industry levels, as well as allowing its consultation.

Finally, QR codes have proved very useful to provide a link to the information associated with a product for the consumer (Tarjan et al., 2014) by means of an open-source 2D identification system that allows fast, omnidirectional readability and storage of up to 7089 characters. The high capacity of these codes to restore reading data with a damaged area of up to 30% makes them ideal for product identification and traceability applications under various environmental conditions (Suresh et al., 2014). This type of code has been used in the proposed application to serve as a gateway for consumers of the product at market level to obtain information about its production history (field and industry).

The information incorporated into the traceability process can be very diverse, and its scope depends directly on the methods employed and the processes performed. The following sections set out a methodology that allows data from the field and industry levels to be recorded, and the data processed by the different role users (farmer - producer - consumer) (Figure 1) to be consulted. Therefore, the objective of this work is to introduce a new system for the integral management of olive production by machine-to-machine interconnections and to enhance the traceability of the products generated in this, or other similar, sectors. For this purpose, one electronic device "iOlivetrack-D" and one web application "iOlivetrack-W" were developed and tested.

Materials and Methods

Electronic Device "iOlivetrack-D"

The iOlivetrack-D is a flexible device that allows identification of the plots on a farm, the acquisition and uploading of data to a web application (iOlivetrack-W) and the labelling of product batches. This device will normally be mounted on the tractor that controls the machinery used during the different field operations. The components of the device are shown in Figure 2 and described below.

A. HMI display (CR1200, IFM, Essen, Germany). 12" display with function keys and several communication interfaces such as a CAN bus, USB and Ethernet. Storage capacity of 1 GB for datalogger, and a real-time clock (RTC).
B. RFID UHF reader/writer (ISC.LRU1002, FEIG Electronic, Hessen, Germany). This device has up to 2 W configurable output power and allows the multiplexing of up to 4 antennas. In addition, it provides USB, Ethernet and RS232 communication interfaces and IP64.
C. RFID antenna. It allows an adjustable 8-meter range and a 65º emission cone on the x and y axes in combination with the reader/writer. Size 270x270 mm.
D. UHF RFID tags (Higgs 3, Alien Technology, California, USA). Passive PVC tag with a 512-bit memory. Tags can operate over metallic elements.
E. 3G modem (MTX-3G-JAVA-GPS, Matrix, Barcelona, Spain). The modem provides RS232 communication. Communication between the HMI display and modem is established through a CAN-RS232 converter. An internal buffer has been programmed to record information in the memory whenever there is no mobile coverage and to forward the information when coverage resumes. The GPS receiver has an accuracy of 2.5 m and supports NMEA protocol.
F. Sensors deployed for measuring the variables on board the machinery used in field operations. Example of a configuration with one encoder and one inductive sensor.

G. Power supply. iOlivetrack-D needs a 9-32 VDC supply range. It can be connected to a 12 VDC tractor battery since a tractor is a machine commonly used for field operations.
H. Connection box to interconnect all elements of the iOlivetrack-D.

Although, this application uses a modem that incorporates GPS, the iOlivetrack-D system could dispense with GPS and perform sector identification using only RFID. However, as will be discussed below, both technologies (RFID and GPS) have their pros and cons and using both together can increase the system's reliability and give it the flexibility to adapt to different needs.

Web application "iOlivetrack-W"

Web application works over a database implemented in MariaDB. This is a database management system with General Public License (GPL) resulting from MySQL database system therefore there is high compatibility. The web services implemented to transferring information between server and database have been programmed in ASP.NET, an environment for Microsoft web application. The web application developed, iOlivetrack-W, allows to create an IDs system for registration of plots and sectors, operations, sensors, parameters and product such as additional information associated. Its main function is to receive field and industry level information from the iOlivetrack-D, host them in the database and show them to the user when requested. A user demo has been created to show the application's utility (Supplementary material: iOlivetrack-W tutorial). Figure 3 shows the structure of web application user interface. As can be seen there are five clearly differentiated sections. Field (A), industry (B), administrator (C), query filters (D) and results (E). Field and Industry sections have two respective subsections, edition menu (A1,B1) and selection menu (A2,B2).

At Field section (Figure 3. Section A), the farmer can create the plot or sector that is to be managed according to criteria of size, orography, varieties, layout, adaptation to certain machinery and/or harvesting logistics. A plot is the land either declared by the farmer or identified geographically according to a SIGPAC code, which is legally recognised and used for many applications such as the management of economic aid under the Common Agricultural Policy. A sector is a virtual, independent area that the farmer delimits within the plot to associate with traceability management.

Both the parcel and the sector the web application automatically assigns an id (PLOT ID and SECTOR ID) and are linked to its corresponding SIGPAC code if farmer has insert it. The combination of the PLOT ID and the SECTOR ID forms the ROOT ID code that serves to classify the information in the server according to its origin. In addition, farmer can create the operations performed during olive growing (pruning, phytosanitary treatments, fertiliser treatments, clearing, ploughing, irrigation, harvesting...), sensors employed to measure parameters (pressure switch, flowmeter…), parameters (flow, pressure, temperature, humidity, dose…) and products applied (glyphosate, dimetoato, oxyfluorfen…) with the official registration number (Law 43/2002), the safety period (if necessary), or its category (herbicide, insecticide, etc.). Operations, sensors, parameters and products have their respective OPERATION ID, SENSOR ID, PARAMETER ID and PRODUCT ID. All IDs will be available to the farmer on the iOlivetrack-D display on board the machinery to configure them and to let a correct registering in combination with the ROOT ID.

Field section has a specific operation separately, HARVESTING. This operation has special relevance because it is the link with industry. In this section, it is possible to consult the batches harvested in one sector, with an identification code associated with each batch that includes the date, time and weight of each batch. The machinery employed here can be very diverse, using anything from harvesters to manually aided systems, but each of these options can be indicated in the HARVESTING operation edition section, as is explained iOlivetrack-W Tutorial.

At Industry section (Figure 3. Section B), the editing of the INDUSTRIES is analogous to PLOTS, and serves to identify the processing industries with the corresponding INDUSTRY ID where the batches of fruit arrive for their processing to olive oil or table olives. In addition, the producer can create all the operations carried out in industry (cleaning, cooking, milling...), the sensors used for their control, the parameters to be measured (temperature, fruit bruising, concentration…) and the products applied. Operations, sensors, parameters and products have their respective OPERATION ID, SENSOR ID, PARAMETER ID and PRODUCT ID to let a correct registering in combination with the INDUSTRY ID.

As Field section, Industry section has a specific operation separately, LOTS GENERATION. Lots are generated by adding the weight of different batches of fruit and are assigned a LOT ID. For each lot, processing operations are performed and recorded with their corresponding values and ID codes. The procedure of creating operations for this is similar to that explained in FIELD OPERATIONS, as well as uploading frames of IDs to the server. Finally, the last operation is packaging, where a QR code will be generated in iOlivetrack-W which will be printed on the product packaging. The QR code is generated through the GPL-licensed library called QRCoder, which allows translation the URL of the batch history into a 2D code.

Both the Field and the Industry sections have a filter query section (Figure 3. Section D). This makes easier searching in the database filtering by plot, sector, operation, date and time, sensor or product. In addition, if iOlivetrack-D has GPS, it is possible to consult the track followed by the machinery within the plot on a map. All data can be displayed or downloaded in '.csv' format. Once configured the desired filters the information is displayed through the results section (Figure 3. Section E).

Lastly, at Administrator section (Figure 3. Section C), the administrator user can assign different permissions regarding the field plots or the industries created in the database. More detailed information about the web application can be found in the tutorial attached to the publication.

Communication management between “iOlivetrack-D” and “iOlivetrack-W”

Firstly, communication takes place between the HMI display and the modem. The information configured on the display by the user is transmitted to the modem via a frames sequence. Each frame sent follows a well-defined 8-byte message structure and a message ID in the message header. The first message (ID 201) contains the date and time, the second and third messages (ID 202 and 203) contain the location, altitude and speed if iOlivetrack-D has GPS but is completed by zeros. The fourth message (ID 400) contains the IDs of the plot, sector, operation, sensor and product. The fifth message (ID 401) contains the variable ID and its value. This message can be repeated as many times as desired if more than one variable needs to be recorded. The last message (ID 499) is completed with zeros and indicates the closing of the frames sequence. In order to register the information correctly it is necessary that the frame sequence always includes the origin plot ID or its GPS coordinates in its defect and the operation ID. Otherwise the information will be stored in the error log of the web application. The rest of the IDs (sector, sensor, product, variables and value) can be completed with zeros as they are optional. iOLivetrack-D has a led that indicates the communication status between iOlivetrack-D and iOlivetrack-W. The green led indicates that the communication is opened, and the information is being sent correctly. The red led indicates that the transmission is interrupted.

Then, the modem receives the sequence of frames and through the ID of each message decodes the information and transforms it into XML format to send it as a string to the server. The server decodes the information again thanks to the XML format labels and records it in the corresponding table of the database. If any frame sent by iOlivetrack-D contains an error, iOlivetrack-W store it in an error log where you can query its structure and verify the reason for the error. These errors can be due to the fact that the plot and sector in the post has not been read by RFID reader, it has not been possible to link the GPS information to a valid plot and sector by means of the Ray-casting algorithm or some ID of the operation fields, sensor, product or variable configured in iOlivetrack-D do not exist in the database.

Working methodology

When starting an operation in the field plot, the user indicates and configures the items involved in the operation to be performed (Figure 4). The data generated during execution of the operation will be uploaded by iOlivetrack-D to iOlivetrack-W associated with the ROOT ID where it is being applied. Every time an operation is carried out in the sector throughout the olive growing season this whole process is repeated.

To generate an orderly classification of data, it is necessary to communicate the sectors where the information is being generated to iOlivetrack-W, and in order to do so there are two alternative proposals using either RFID or GPS technology. Both options can be used jointly and complementarily.

- The identification of sectors through RFID technology involves the installation of an RFID pole and the previous creation of the ROOT ID code of each sector. The RFID pole is oriented towards the service path, according to the optimal route to follow when starting a field operation, so that the iOlivetrack-D onboard the tractor will instantaneously detect the RFID tag to associate the field operation information with the proper sector and then upload the data to the server (Figure 5). Specifically, when the operator passes near the RFID pole and clicks the PLAY button on the HMI interface (Figure 4), the device reads the ROOT ID from the RFID UHF. Then, it begins to send the operation data in real time, generating a historical record. Once the ROOT ID has been read, the RFID remains inactive to prevent the detection of RFID poles from adjacent sectors.
- The identification of sectors using GPS technology involves setting a GPS system on board the tractor, connected to iOlivetrack-D, which continuously sends the GPS coordinates of the machinery with the operation data. If the machinery location is within one of the defined sectors, the data received is associated with the ROOT ID from the detected sector and the detected sector is shown on the HMI display; otherwise it is sent to the error log (Figure 6). A ray-casting algorithm has been used for this purpose, which consists of counting the number of times that a given point crosses the boundaries of a polygon in a given direction, placing it within the same if it is odd, or outside if it is even. At this moment, the operator clicks the PLAY button (Figure 4) to start uploading the operation data and the GPS coordinates of the path followed by the machinery.

In both options, the uploading of data ends when the operator clicks STOP if the operation has finished or PAUSE if a pause in operation is required (breakdowns, refill, rests...). Clicking PLAY again resumes the unfinished operation in the sector. Clicking STOP resets the sector identification to null.

The last field operation is the harvesting that involves two stages, fruit detachment-collection and management of the harvested fruit. In general, the procedure is similar to use with other field operations, but there is a button on the HMI interface (Figure 4) that opens a new interface (Figure 7) where some options for PARAMETER (pressures, flow, speed...) and SENSOR can be recorded according to the machine used. Identification of the sector where the harvesting is being performed is carried out via the previously explained options. For the second stage, there is a STORAGE button to select the system used (boxes, bags...).

Once the sector has been identified and the options set, the harvested fruit is loaded into the storage device. In the case of an incorporated weighing system, it will be possible to monitor the progress to maximum capacity by displaying the filling level. Then, the storage system must be labelled. For this purpose, iOlivetrack-D may incorporate an HF RFID in the case of a storage system located in a fixed position, such as a hopper, or a UHF RFID in the case of several independent units, such as boxes, which will be labelled simultaneously (Figure 8). When the operator considers it appropriate LABEL BATCH (Figure 7) is clicked and the RFID will write a BATCH ID code composed of the ROOT ID + DATE and TIME of labelling on each storage unit tag. At this moment, iOlivetrack-D sends iOlivetrack-W the batch information with a frame of BATCH ID + BATCH WEIGHT. Afterwards, batches are transported to industry for processing and a new storage system is put in place to continue harvesting. Once the harvesting operation in the sector finishes and the last labelling is complete, the operator clicks STOP and all the batch information is recorded in iOlivetrack-W.

The batches harvested in the field reach industry and are identified by the ROOT ID set in their tags by a RFID reader. The industry creates LOTS (Figure 9), according to characteristics and demands, formed of different batches, and a code (PACKAGE ID) is assigned to each one. In this way, a lot can be formed of batches from a single or several sectors, but the information concerning each of them is already recorded in the server. For each of these lots, the OPERATIONS that are required in the industry are applied, as previously predefined in iOlivetrack-W. These operations can be different depending on the intended target industry: oil or table olive. The uploading of these data is carried out by iOlivetrack-D in an analogous manner to that explained in the field phase. Finally, at market level, consumers can access the product history via smartphone or another electronic device with an application for scanning the QR code printed on the packaging. They will then be connected to a website with an area to consult the whole traceability backwards from the production cycle (Figure 9). Due to the enormous amount of information that can be registered, a summary of operations performed is generated where it is possible to consult the sector and plot of origin, a history of the operations carried out, the products applied, and other parameters measured in each operation with their average values.

Field test

A field test was carried out using the methodology described and the iOlivetrack-D and iOlivetrack-W systems developed. The next section describes the steps followed.

First, a plot of an intensive olive orchard of table olives located in Almodóvar del Río (Córdoba, Spain) (37.828244, -4.994502) was selected. The orchard had a row spacing of 6 m and tree spacing of 4 m. The plot was bounded at iOlivetrack-W and three sectors were created (Figure 10). The PLOT ID of the plot was 10 and the SECTOR IDs were 30, 35 and 36. The sector 30 with the largest area (1.68 ha) was used to perform field operations. Once they had been defined in iOlivetrack-W, the RFID pole with the proper ROOT ID was located on a service path according to the best operation logistics. The tags were placed within a range that would give a minimum reading error threshold, at a height of 1.50 metres from the ground, with a spacing between 3 to 4 metres, and oriented to the service path along which the machinery would drive.

To evaluate the feasibility of the identification systems proposed, different tests were carried out using the methodology (Figure 11):

- The RFID device was tested by mounting the reader on a tractor and placing the pole with the RFID tag at a fixed site. Then the maximum reading distance, the reading zone and incidence of machine ground speed in the reading were evaluated.
    - The reading range defined by the manufacturer is up to 8 m, but during the tests, the appropriate range to make a reading with 100% accuracy was 0-4 m, with the antenna placed orthogonally to the tag. This range is adequate to allow the transit of machinery near the

RFID pole without the need for accuracy in the approach to it. At larger distances the RFID tag was not detected or was detected with difficulties. If a higher reading range is needed, the manufacturer proposes changing the antenna for one with higher coverage and using other tags.

    - The reading zone did not correspond to a constant cone that opens 65º along the x,y axis according to the manufacturer. At 2 m, the reading zone obtained with 100% success was 116.5º gradually narrowing until one of 8.6º was obtained at 4 m.
    - The speed tests carried out in the range 1-14 km/h were totally satisfactory, achieving 100% success in reading the tags at different speeds.
- The GPS device was tested by mounting the device on a tractor and driving along the path of a plot of land. The accuracy obtained was below the maximum error of 2.5 m that can be obtained according to the manufacturer. An average error of 0.71±0.32 m was obtained, and a maximum point of 1.75 m. These values must be considered when creating contiguous sectors, attempting to ensure that the distance between the limits of both sectors is around a minimum of 2 m. This will avoid problems when associating the information to the real sector worked.

Secondly, the farmer created the usual operations carried out in the orchard, the parameters to be controlled and the sensors available to measure some of these parameters. The values of the sensors registered in iOlivetrack during the operations were entered manually, although in field tests the feasibility of connecting them to iOlivetrack-D through the communication buses necessary to perform the reading has been verified. The buffer implemented in the modem allows data to be acquired at speeds of less than 1 second and stored in the memory so that, in the case of loss of coverage or any other communication problem, there is no loss of information. The data uploaded in the buffer are FIFO type (First Input First Output) but in order to carry out an increase in real time and so as not to slow down the system, it has been verified that the optimal speed for the modem used is a data send every 2 seconds.

In harvesting, a trunk shaker mounted on a tractor equipped with iOlivetrack-D was used to detach fruit, which fell onto nets placed under the trees, and the operation parameters were saved. After that, other operators loaded the fruit harvested into 20 kg capacity boxes (Figure 12).

The fruit in the boxes was transferred to larger, 500 kg capacity boxes with RFID tags attached that were located on a trailer instrumented with iOlivetrack-D (Figure 13). Previously, the tractor had identified the sector by passing close to the RFID pole located on the logistics path. When the big boxes were full, an operator tagged the five batches simultaneously by clicking the display, as previously explained, assigning the respective BATCH ID to each. Then the tractor drove the batches to industry. This action was repeated about seven times until the plot was totally harvested, producing 34 batches of approximately 19,400 kg of olives.

When the different big boxes arrived at industry, an RFID reader recorded the batches in iOlivetrack-W. Because the available capacity of the fermenter was 10,000 kg, two lots composed of different batches were created. Then, several processing operations were carried out on the fruit of each lot, and the data were simulated by entering the data manually, according to the industry history, using iOlivetrack-W database. In the last stage of packaging, a corresponding QR code was generated by iOlivetrack-W (Figure 14). By scanning the QR code, the consumer will be able to consult the history that contains full traceability of the product purchased.

Discussion

After the test carry out, the exchanges of information between iOlivetrack-D and iOlivetrack-W through the different identification codes (IDs) has been successfully performed. Each input capable of intervening at a level (plot, sector, operation, sensor, product, variables) has been registered by its corresponding ID. This reduces the size of the messages sent between iOlivetrack-D and iOlivetrack-W and allows recording intervals in real time of around 2 seconds. The great editing possibilities enable an automatic record with a adjustable degree of detail to control traceability and manage the resources avoiding handwritten or paper records what it would facilitate the transfer of reliable information between the different levels of the value chain (Ruiz-Garcia et al., 2010).

The system would constitute a powerful tool for the farmer to complete the compulsory farm logbook (Royal Decree 1311/2012) and manage the data by filtering and exporting to other systems. By using identification based on official databases such as the SIGPAC code, the recorded information can be used for operations and dealings related with public administration. The more variables introduced in the fruit lifecycle, the greater the added value the final product, which enables improved product quality through control of important variables, such as monitoring of the cold chain (Abad et al., 2009), among others.

iOlivetrack-D with a GPS incorporated allows more accurate tracking operations that may provide other interesting results, such as production or product application maps, machinery performance, and so on, as is habitually used in other areas such as livestock tracking (Muminov et al., 2016). However, it is known that GPS may cause some discomfort for the operators driving the machinery, and other technical problems may exist. On the one hand, the time required for initial positioning of the GPS normally increases in the field due to limited mobile coverage. On the other hand, GPS accuracy can be a critical aspect when identifying contiguous sectors because some data may be recorded as either associated with one sector or with the adjacent one in cases where the distance between the two is small and GPS accuracy is low. In order to avoid this problem, it would be necessary to resort to another, more accurate type of GPS such as the RTK, although the cost of the proposed system would be considerably higher. Other positioning errors due to the leaf density of trees must be studied (Zheng et al., 2005).

The alternative option proposed with RFID identification has reported satisfactory results with the geolocation of RFID poles (Ning et al., 2013). Nonetheless, this method involves previously establishing a proper work route to identify the plot at the beginning of the field operation. The use of both technology systems, as is proposed in this work, can be complementary (Prinsloo and Malekian, 2016) to obtain better results in cases where, used individually, they would not provide optimal guarantees. One aspect to consider when contemplating implementation of the proposed methodology is the problem that changing working operations represents. Farmers or operators would have to modify their procedures and be more methodological insofar as they would have to prepare a proper work plan before starting work. This change could be a problem in the early stages of training, although developing a user-friendly and comfortable interface both for iOlivetrack-D and iOlivetrack-W, would make this change less challenging. The farmer would have a far-reaching control of the inputs (products applied, fuel, water…) and outputs (fruit per area cultivated) of each defined plot. This would enable forecasts of profits, or detection of the possible causes of plant disease or pests. Moreover, the information associated with the farm might be expanded by adding other parameters to record at field level, such as climatic variables (Hamrita and Hoffacker, 2005). All of this constitutes the origin of the generation of knowledge and patterns required for the application of precision agriculture techniques (Suprem et al., 2013).

The implementation of the system at a commercial level would not imply a significant economic outlay when compared to the advantages that could be obtained by generating added value (Alfaro and Rábade, 2009). In many cases, the consumer might be willing to pay more for a product accompanied by a reliable traceability system (Zhang et al., 2012). For this purpose, the integration of QR codes is a feasible option to offer broad, accessible information on the traceability of the product in a reduced space on packaging. The possibility of consulting any data related to the product being consumed can increase consumer confidence (Chen and Huang, 2013) through transparency, thus increasing the value of the brand.

The economic viability of the system will depend directly on the costs imposed on its distribution, maintenance and sale. The technology implemented in the proposed devices could be adapted according to client-demanded configurations, and according to hardware and programming requirements. One issue that must be considered for study is the time spent by the farmer managing the information generated from the machinery and the orchard.

At field/industry exchange level, the proposed procedure has strong potential for optimisation of the resources involved in logistics, with the automatic sorting of batches and creation of lots. The information transferred to the industry from the field will improve in terms of reliability and accuracy.

Batches processed in industry may be resized and formed of batches from the same origin, to allow closer control and reduce food safety problems.

Distribution also represents an important phase in the supply chain of any product. Thus, in the event of any problem, it will be possible to quickly identify the history of the product and other lots involved by following traceability backwards. The historical record of activities represents a guarantee of quality and food safety in any traceability system, even more so for consumer products that use products of a toxic nature that can be harmful to health if they are not properly handled or controlled, as is the case with phytosanitary products (Martínez Nieto et al., 2009). The use of a reliable traceability system will give the sector more confidence and efficacy in managing incidents.

Conclusions

The iOlivetrack system developed, hardware and software together with the methodology have allowed the automatic recording of all the operations carried out along the production chain in real time. iOlivetrack-D allows data collection in the field and sending to the web application. The iOlivetrack-W provides storage and management of all generated data. Relevant information is offered to the consumer via through QR code. Likewise, the traceability system gives the producer versatility to adapt to the needs of each farm or industry.

The traceability system developed here could be considered as a starting point for the implementation of blockchain technology. This helps to prevent risks and provide solutions to problems that may arise (Tian, 2017), ensuring the veracity and incorruptibility of information from the field to the consumer. This premise is possible because this approach has one of the basic principles of the blockchain: the existence of a common platform shared by all actors in the supply chain. Both farmers and industry have their own databases so the traceability system could be adapted to blockchain technology by modifying the architecture of the system to a decentralised database (Lu and Xu, 2017) and the blockchain structure for data, typical of this technology. Thus, a wide diversity of options opens up for the implementation of the developed system. Finally, although the inconveniences of using the system may mean that it is not generally implanted, foreseeable, more stringent food quality or safety measures could be the catalyst for its general acceptance and adoption.

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Figure captions

Figure 1. Information flow set for controlling olive traceability

Figure 2. Electronic device iOlivetrack-D and their components

Figure 3. Interface of the web application iOlivetrack-W for administrator user. A: Field area, B: Industry area, C: User management area, D: Filters options, E: Data representation, 1: Query options, 2: Editing options.

Figure 4. HMI Interface used for setting the configuration to be applied in the field, and an example of the choice of options (right).

Figure 5. Sector identification using RFID technology and uploading data to the server.

Figure 6. Sector identification using GPS technology and uploading data to the server.

Figure 7.HMI interface, harvesting section, used in harvesting, storage and batch labelling.

Figure 8. Labelling batches of the fruit harvested and data uploading data.

Figure 9. Uploading of data at Industry level and access of lot information by the consumer.

Figure 10. Plot, sectors and RFID pole tested by the integral management data of an olive farm.

Figure 11. Test performed with iOlivetrack-D on board the machinery to upload the field data to iOlivetrack-W. Example of sector identification using the RFID option.

Figure 12. Recording a harvesting operation using GPS.

Figure 13. Fruit batch labelling and transporting operation.

Figure 14. QR code generated in industry.