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Developing and Populating Database Prototype of the Citrus-plant Nursery Chain related to the Italian National Service for Voluntary Certification

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ABSTRACT

In Italy, the establishment of the National Service for Voluntary Certification of plant propagating material has allowed the introduction of certified plants into the market, which were produced by using propagating materials verified in terms of varietal trueness-to-type and phytosanitary condition. The control of productions and activities carried out in the centres established by the National Service for Voluntary Certification could allow the identification of both possible sources of disease risk and the destination of the propagating materials.

In previous studies a methodology was proposed and applied to carry out the requirements analysis and specification for the development of an integrated computer-based information system for certified citrus-plant traceability.

This study proposes a methodology for the implementation of the database prototype required for the execution of the previously designed functionalities of the information system. The use of PostgreSQL, a free and open source object-relational database management system, allowed the implementation of the entity-relation scheme containing the information related to the managed propagating materials and the process activities defined by the certification program.

The proposed methodology was applied to the case study of the Italian citrus-plant nursery chain. Specific information derived from plants and centres of the National Service for Voluntary Certification were included in the database along with the geolocation of both certified citrus plants produced in the nurseries and planted in the field and citrus mother plants. Geographic data acquired by using a GPS system were combined with other information concerning plant health condition and treatments with the aim to find out possible relations between the citrus-plant health status and the territory. The system implemented in this study allows the definition and utilization of 'track and trace' procedures of propagation materials and plants present in the certified Italian citrus-plant nursery chain, as well as the evaluation and prevention of the diffusion of the Citrus Tristeza Virus which causes one of the most damaging diseases in citrus orchards.

Keywords: traceability, citrus plant, CTV, certification, prevention.

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1. INTRODUCTION

Plant diseases could spread from plant propagation during the production of nursery stocks. The risk of plant disease diffusion is also related to the increase of plant exchanges due to trade globalization. Therefore, to protect cultivation from local epidemics or exotic pests and diseases, the production of healthy and high-quality plants and plant propagating materials is of relevance and constitutes the main purpose of certification programs developed in several countries. In this regard, systems able to track and trace plants production have gained importance to improve safety of production and control the diffusion of plant diseases.

As stated by Porto *et al*. (2011a), integrated computer-based information systems (ICBISs), which incorporate data from different production centres and from existing farm information systems, should be designed and implemented to obtain supply-chain traceability of each plant, by including the plant production process and data related to every sub-product. In that study general guidelines were defined for the design of ICBISs to implement supply-chain traceability procedures regarding certified plants for food, fresh fruit production and agro-processing industries. In other study, (Porto *et al.*, 2011b) a methodology was proposed and applied to develop the requirements analysis and specifications (RAS) phase of the ICBIS for the traceability of Italian citrus-plant nursery chain which comply with the National Service of Voluntary Certification (NSVC) established by the Italian Decree of July 24, 2003.

In the development of the RAS, product and process information allowed the implementation of the Entity-Relational (E-R) scheme and definition of the functionalities which the system must provide to the users. This information was gathered through interviews conducted at the Research Centre “Centro di ricerca per l’agrumicoltura e le colture mediterranee (CRA-ACM)” located in the municipality of Acireale (Italy), which includes the conservation and pre-multiplication centre (CCP), at the experimental farm “Palazzelli” located in the municipality of Lentini (Italy), which includes the primary source (PS), the pre-multiplication centre (CP) and a multiplication centre (CM), and at some Sicilian nurseries belonging to the NSVC. To satisfy the requirements of the functionalities defined in the RAS phase it is necessary to develop a database of products and processes and build the software application which uses the database.

The activities described in this paper are part of a wider research aiming at the development of a ICBIS prototype for the traceability of certified plants for food, fresh fruit production, and agro-processing industries. In detail, this article, reports the methodology utilized to build the database prototype of the citrus-plant nursery chain related to the Italian NSVC, the methodology used for the development of the software applications which satisfy the requirements of the traceability functionalities defined in the RAS phase, and the activities related to the building of a geographic information system (GIS) of the citrus-plant nursery chain related to the Italian NSVC.

2. MATERIALS AND METHODS

The building of the database prototype and the software applications required the use of a number of different software tools which serve the following functions: a) to build and manage a database which is able to store all the information represented in the relational data model (Codd, 1990); b) to provide an Integrated Development Environment (IDE) which facilitates software development to computer programmers; c) to build and manage a GIS which makes it possible to create static or dynamic maps, view the geographic maps through a desktop program or a web page, perform query and analyze geospatial data.
The software tools used in this research are open-source software solutions with their source code made available and licensed with an open-source license. In general, these solutions are used for research activities, yet the commercial purpose may be authorized according to the license or by purchasing commercial licenses.
The software tools utilized in this study were the following: PostgreSQL, PostGIS, Java Virtual Machine (JVM), Eclipse, and Quantum GIS (QGIS). These software tools, though they are free of charge, provide efficient solutions for the execution of their functionalities and are supported by worldwide organizations of developers.

2.1 Database design

To create the database by using the PostgreSQL database management system (DBMS), it was necessary to derive the relational model, i.e., the logical data structure suitable to represent the data within the DBMS. The relational model was obtained from the E-R scheme by applying the following 5 conversion rules (Codd, 1990): rule for entities, rule for attributes, rule for relations ‘one to many’, rule for relations ‘many to many’, rule for identification dependency.
The relational model was then given as input to the application PgAdmin, an open source administration tool for PostgreSQL, which executed the building of the database and the tables by using the physical structures of the data that were present within the PostgreSQL DBMS.

2.2 Applications design

The applications that implement the system functionalities were developed on the basis of the client-server paradigm. According to this paradigm, the ‘back-end’ logical level, i.e., the management functions and query of the data contained in the database were separated and independent from the ‘front-end’ logical level, i.e., the user interfaces. These interfaces provided the user with the following services: show and make available, in a graphical way, the functionalities; activate the back-end functions in order to receive data; elaborate data deriving from back-end functions; and show the elaborated data. The subdivision of the functionalities into two logical levels simplified the development, optimization and maintenance of the applications. Furthermore, the functionalities of the back-end can be utilized by different types of front-ends, e.g., stand-alone front-end and web-based front-end.

The back-end functionalities of the system were built within PostgreSQL through the implementation of stored-procedures by using the structured language PL/pgSQL. The use of this language made it possible to perform complex elaborations on data of the database tables, which could not be carried out by uniquely using SQL queries.

Front-end functionalities were implemented in a stand-alone application by using the java language within the IDE 'Eclipse for Java Developers'. The connection among the functions of the front-end and those of the back-end was obtained by using the driver Java Database Connectivity (JDBC).

The GIS functionality was implemented by using the QGIS application. QGIS was connected to the PostgreSQL/PostGIS database and, as a consequence, the GIS is automatically refreshed when any data of the database are modified. To implement GIS functionality, the Regional Technical Map (scale 1:10000), provided in DWG format by the Sicilian Region, was utilized as base cartography. From this map, the feature classes related to the buildings, the administrative boundaries, the road system and hydrography were obtained and exported in SHP format. The building of the NSVC centres and the nurseries where the registered plants were bred, were selected from the building feature class to constitute a thematic layer. Each feature attribute was stored into PostgreSQL tables.

Furthermore, another thematic layer was built from the information acquired by means of the GPS (Global Positioning System) described in the following section. This information allowed the localization of citrus mother plants and certified citrus plants present in other citrus orchards. Also in this case, the attribute data regarding the plants were stored in PostgreSQL tables.

2.3 Data geolocation

The GPS technology makes it possible to obtain the localization of an object in space with a precision related to the technological level of the acquisition device, the device data elaboration method, e.g., GPS, Differential GPS, and Real-time DGPS, and the survey method, i.e., static method or cinematic method.

A Leica GPS 1200 (Leica Geosystems, USA) was the system utilized for the acquisition of the geographic coordinates of the citrus mother plants and the certified citrus plants present in other citrus orchards. The instrument, which is composed of a fixed base and a rover that communicate between them by means of two radio modems, makes use of a differential GPS. This system allowed the acquisition of plants' positions with an accuracy of about 10 cm.

By using the software Leica Geo Office the acquired data was exported in a vector format and then imported in the GIS.

3. RESULTS

3.1 Database implementation

The relational logical model obtained by the application of the 5 conversion rules to the E-R scheme was constituted by 22 tables. In Figure 1 the relational model of the table

‘Plant’ that contains the data of the citrus plants is reported. Figure 2 shows some records of the tables ‘Plant’ and ‘Multiplication_Centre’ which were obtained by the application of the conversion rules. The attribute ‘Multiplication_centre_code’ (external key) of the ‘Plant’ table is used to define a logical link between the two tables. One or more records of the ‘Plant’ table are logically connected to one record of the ‘Multiplication_Centre’ table if the value of the external key is the same of the value of the primary key of the ‘Multiplication_Centre” table, i.e., the attribute ‘code’.

Attribute name	Type	Primary key	NOT NULL	Constraints	Foreign key
code	CHAR(30)	YES	YES		
region	CHAR(255)		YES		
province	CHAR(255)		YES		
vendor_code	CHAR(30)		YES		
protection_service	CHAR(255)		YES		
botanical_name	CHAR(30)		YES		
rootstocks_variety_name	CHAR(30)		YES		
category	CHAR(30)		YES	values in ("FP", "prebase", "base", "certified")	
tipology	CHAR(30)		YES	values in ("Orange", "Limon", "Mandarin", ...)	
health_status	CHAR(30)		YES	values in ("virus-free - VF", "virus checked - VT")	
card_certificate_code	CHAR(30)		YES		REFERENCES Card_certificate(code)
national_register_accession_code	CHAR(30)		YES		REFERENCES National_register_accession(code)
multiplication_centre_code	CHAR(30)		YES		REFERENCES Multiplication_centre(code)
nursery_code	CHAR(30)		YES		REFERENCES nursery(code)
species_code	CHAR(30)		YES		REFERENCES species(code)
gis_position	geometry(Point,4326)		NO		

Figure 1. Relational model of the table ‘Plant’.

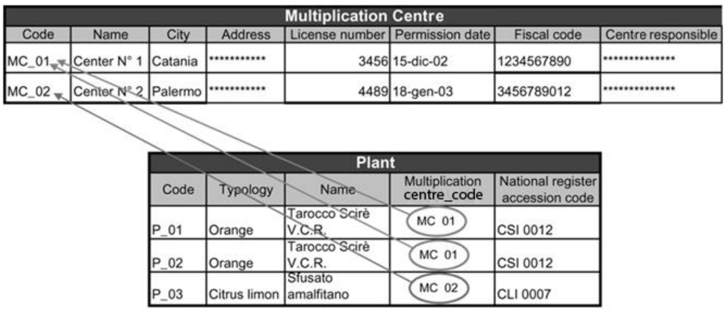

Figure 2. Logical link ‘one to many’ between the records of ‘Multiplication_Centre’ and ‘Plant’ tables

Since the PostgreSQL database has been extended to manage geographic objects by installing the PostGIS spatial database extender, in the tables it was possible to define also geometry attributes which are spatial representation of geographic features.

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3.2 Applications implementation

The system back-end provided the system front-end applications with a number of functionalities among which the following figure prominently: to provide the characteristics of a plant; to provide the list of the plants located in a centre or a nursery of the NSCV; to provide the list of the infected plants; to identify the plants that provided the propagation material for the production of a considered plant; in relation to a possible contamination occurrence, to identify the plants and the propagating materials involved; to store and provide the flow of plants and propagation materials.
The system front-end is a stand-alone application with a menu interface which provides the user with the following functionalities: the input of attribute values required in order to execute each of the functions available in the back-end; the execution of a function of the back-end; the visualization of the results, in table format.
The GIS functionality allowed a number of operations among which: the visualization of the centres, nurseries and geolocated plants on a geographic map and the use of the information contained in the thematic layers to carry out queries aiming at highlighting the relation between the plants and the territory. For instance, the query "Plant_traceability", for each certified citrus plant placed in the field or citrus plant in the mother plant field, made it possibile to display on a map the localization of all the plants that provided propagation materials for its production within the nursery chain.

3.3 Plants and NSVC centres for database population

The population of the database required the census of the plants located in the involved centres and nurseries belonging to the NSVC. Each registered plant belongs to a species or accession among those defined in the national register of the varieties of citrus plant stored and updated at CRA-ACM. The number of accessions was equal to 91.
The structures present in the NSVC centres and the typologies of plants allocated in these centres are the following:

1. one screen-house, used to conserve the PS, located in the experimental farm "Palazzelli". Within the screen-house one plant for each accession is bred;
2. two screen-houses, used as CCP, located in the CRA-ACM. In the screen-houses two plants for each accession are bred;
3. one screen-house used as CP located in the experimental farm "Palazzelli". In the screen-house two plants for each accession are bred.
4. five CMs located at: "Palazzelli"; "Center Gea", in the municipality of Lamezia Terme (Italy); "COVIP", in the municipality of Massafra (Italy); "COVIL", in the municipality of Metaponto (Italy); and "Mediterranea Vivai", in the municipality of Mazara del Vallo (Italy).

4. DISCUSSION

The method adopted to develop the RAS phase of the ICBIS for the traceability of the citrus-plant nursery chain related to the Italian NSVC, which was developed in a previous study (Porto *et al.*, 2011b), yielded a number of important technical documents for exchanges of information among operators of the citrus plant nursery chain and the ICBIS developers. In fact, the E-R scheme and the system functionalities defined in the RAS phase were crucial to build the database and the applications and, as a consequence, system implementation was facilitated.

The choice of using the client-server paradigm for the design of the applications that implement the system functionalities defined in the RAS phase made it possible to obtain a flexible ICBIS. In fact, since the database is independent from the software implementation, it is possible, for instance, to add new functions to the actual applications or to develop a web-based front-end which would require to the final user only the use of a web browser, without modifying the structure of the database.

Furthermore, since the considered open-source software is available on different platforms (i.e., Linux, Microsoft Windows, Apple Mac OS X), it was possible to obtain a multi-platform ICBIS. As a consequence of these choices, system versatility and costs are well balanced.

At present the prototype system architecture is characterized by a centralized database used by centralized applications, whereas the system must be completed with a local database for every NSVC centre that contains a replica of the centralised database regarding activities, plants and materials of the considered NSVC centre, and local applications to manage local data, as described in the system architecture design reported in a previous study (Porto *et al.*, 2011a). Moreover, the population of the database at the local level would require an active collaboration of the farmers in keeping updated the information contained in the farm database.

5. CONCLUSIONS

In this paper, the implementation and population of the database prototype of the citrus-plant nursery chain as well as the software applications which implement the ‘track and trace’ procedures of propagation materials and plants related to the Italian NSVC were carried out by designing specific methodologies which made use of open-source software solutions and technologies for data geolocation. The application of these ‘track and trace’ procedures could allow knowledge of severe plant diseases diffusion, like CTV virus, in the territory.

In this work the GPS technology was utilized to get the localization of citrus mother plants and the certified citrus plants present in other citrus orchards.

However, when a targeted intervention by the operator in field controls is needed, it is useful to identify each certified plant directly in field. Therefore, it is necessary to use plant identification devices which assure data security, robustness, and data storage capacity (Luvisi *et al*., 2010).To this aim, further research already in progress involves the identification of the nursery plants through the use of RFid (Radio Frequency Identification) tags.

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