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Application note

Virtual vineyard for grapevine management purposes: A RFID/GPS application

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ABSTRACT

A method for combining data stored in an RFID microchip implanted inside grapevine plants and a GPS system is described. GIS software was used to register geographic coordinates of detected points, and to develop a specific database in which information useful for the positioning phase are stored. The final product is a digital map accessible via mobile or desktop systems that represents the "virtual vineyard". In this digital representation, each grapevine plant marked by RFID can be selected, viewed and edited. Free-to-use software was implemented for use by consumers.

1. Introduction

European Union regulations require that genetic and sanitary characteristics of grapevine are reported on coloured labels: white label for "basic" material, blue label for "certified" material and yellow label for "standard" material. This method is not completely efficient with regards to plant traceability because labels are removable and they are not directly linked to each plant. Passive microchips based on RFID technology can be implanted inside grapevine, providing a useful system for plant identification with no impact on plant vitality (Triolo et al., 2007; Bandinelli et al., 2009), linking stakeholders of production lines. Useful data for traceability purposes (i.e. identity, sanitary status, certification and cultural practices) are collected in an electronic identity card (eID) accessible via internet: the eID is generated from files edited by foundation block of the Associazione Toscana Costitutori Viticoli (Association of Tuscan Grapevine Constitutors, TOS.CO.VIT.) that refer to products – clones and rootstocks – and manufacturers, providing genetic and certification data (Luvisi et al., 2010a). Each eID is linked to the code that identifies the microchip itself.

RFID technology can be integrated with Global Positioning System (GPS) for plant pathology monitoring (Kumagai and Miller, 2006) and hand-harvested fruits (Ampatzidis et al., 2009). With regard to vineyards composed of RFID-marked grapevines, the virtualization of vineyards by combining GPS technology is another interesting possibility: in the urban context, geospatial tools such as GPS and the Geographical Information System (GIS) can provide timely and extensive spatial data to arrive at plant attributes that can be adapted for applications including data fusion, virtual reality, three-dimensional visualization, internet delivery, and modelling (Ward and Johnson, 2007; Wu et al., 2008). This approach to urban green management or forestry monitoring can be extended to vineyards where plants are tagged with RFID: geo-referred data from transplant machines can be matched to RFID labels on individual plants, headland of vineyards or wine bottle (Vieri, 2007). Potentially, subjects containing a microchip will be identified by a code, associated with the microchip itself, and they will be located with GIS on a three-dimensional electronic map, recreating a virtual vineyard (Luvisi et al., 2010a,b). This system can be able to remotely monitor vineyards, archive and manage useful data associated with plants in particular using technical and plant health files, and supply a durable, safe and detailed vineyard information map.

This paper describes a method for combining data stored in a microchip – implanted inside the plant a few cm above ground

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– and a GPS system (receiver/antenna/data recorder/software) appropriate for precision requests. The final product is a digital map that represents the "virtual vineyard".

The aim of this work was to optimize the management of a vineyard composed of RFID-marked plants using professional geographic software (i.e. GIS software) for mobile/desktop applications, and implementing free-to-use software. An additional predictable positive feature is the possibility of modifying the data files from the field, thus making it possible to upgrade and modify associated information of marked plants. Moreover, customer access to production line information can be facilitated.

2. Materials and methods

2.1. Plant marked by RFID TAG

Trials involved 20 grafted cuttings of *Vitis vinifera* cv. Sangiovese (clone I-SS-F9-A5-48) grafted in 2007 on rootstock 1103 Paulsen (*Vitis berlandieri* × *Vitis rupestris*). TAGs were inserted inside pith of rootstocks in 2007, following two different procedures. The first one (A) involves microchip insertion after direct drilling of pith from distal cut of rootstock, just before grafting. The second procedure (B) consists of a "U" cut performed laterally on the rootstock after grafting by a specially designed machine, involving tissues from bark to pith. Following each procedure, the microchip was located inside the pith, 3 cm below the grafting point. Unmarked plants were used as control. Grapevine were transplanted with 0.8 m spacing between the plants and 2.1 m between the rows.

Transponder glass TAG RFID were used (2.11 mm diameter, 12 mm length) working at the frequency of 125 kHz (Glass TAG EM 4100; EM Microelectronic, Marin, Switzerland). TAGs where read electronically 14-length identification number.

2.2. Software

The online database for managing marked plants was developed by InterMedia Sas (Forlì, Italy; www.rfid360.net). The database is classified as a distributed Rich Internet Application (RIA system) and is installed on a remote server, while Flash technology is used for clients. The main software used is Java™ and Adobe® Flex®.

GeoGis software (Geostudio Srl, Milan, Italy; www.geostudiogis.it) was used to record geographic coordinates of detected points, and to develop a specific database in which information useful for the positioning phase are stored (GeoGis eID). The software package is composed by two parts: one for PDA uses, compatible with Microsoft© Windows Mobile® to integrate the system to GPS technology; one for desktop applications, compatible with Microsoft© Windows® environment for downloading data and the post-processing phase.

2.3. RFID/GPS system and mapping

Plant positioning was performed by GPS technology, and positions were recorded as WGS84 geographic coordinates to obtain complete compatibility with widespread software such as Google™ Earth. GeoGis software permits transformation of the reference system selected by users into Cartesian coordinates. In this paper transformation into the Gauss Boaga West Zone using the grid provided by the Italian Military Geographic Institute is reported.

The GPS system was composed of a Trimble GeoExplorer 2008 Series GeoXH (Trimble Navigation Limited, USA) with a Trimble Zephyr external antenna, on which GeoGis PDA software was installed. This system was connected to a palm-PC (Dell Axim X51), provided with a Card Flash reader (EM microelectronic) able to identify the microchip located inside the plant.

2.4. Tests

Working time for plant positioning detection and RFID data matching was recorded following Ampatzidis and Vougioukas (2009) procedure. The correlation between grapevine identity and GPS coordinate was generated automatically using the method described previously. Grapevines with RFID/GPS detection time longer than 180 s were considered undetected. Working time per plant was calculated by dividing the total working time with the number of grapevines. System accuracy and working time were calculated in 3 repetition considering detected plants divided by total plants. Post-process control was performed using GPS and RFID systems separately. Then the collected data were manually matched.

Usability and portability (McCall et al., 1977) of virtualized vineyard was tested by a panel composed by 5 random members (Virzi, 1992) among Tuscan grapevine constitutors, nurseries and farmers. Parameters considered in usability test were performance (mean number of steps required for people to acquire information about a plant), accuracy (mean number of success in retrieving correct information about 30 plants, in percent) and emotional response (recommended software to a colleague) (Nielsen, 1994). Portability of desktop application combined with Google™ Earth was tested on Microsoft© Windows® XP, Vista and 7 or Canonical Ubuntu® 10.0 using Microsoft® Internet Explorer® 6.0–8.0, Mozilla© Firefox© 2.0–3.6 or Google™ Chrome 4.0–6.0.

3. Results and discussion

3.1. RFID/GPS system and mapping

GeoGis eID was designed considering the eID model present on the online database. It is a simplified version, i.e. archives about clones and rootstocks or details about the pre-multiplication center or nursery are not available. This eID focuses on vineyard management, with pages available for storing history of phytoiatric treatments, agronomic procedures, photos and more.

After loading GeoGis eID, GeoGis software acquires data from the RFID reading system and from the GPS system, matching RFID data to the coordinates. Then, the GeoGis PDA version is used to visualize grapevines over a raster map (Fig. 1).

The GeoGis PDA version is used to generate SFF files needed for differential corrections and the GeoGis desktop version for post-processing and exporting RFID/GPS data in formats that are compatible with other software, such as SHP, DXF and XML.

XML format is useful to export the position of experimental plants to widely used software such as Google™ Earth, guarantee online access using PDA or netbook. For this purpose, Google™ Earth placemarks are created for each plant. They can be shared with the stakeholders, and they can be rapidly loaded by the software, indicating the position of each plant on the map (Fig. 2). A link is provided to permit the access to eID of online database within a Google™ Earth window, showing the data relative to the selected plant. The eID reports clone/rootstock identity, certification data, pre-multiplication center, nursery, and production date. Furthermore, the eID can be edited from the field as well, while simply standing in front of the plant.

3.2. Tests

The proposed RFID/GPS matching system showed an accuracy of 98.3% and a mean working time of 58 s (±4.9, standard deviation) per plant. Plant position detection and RFID data matching

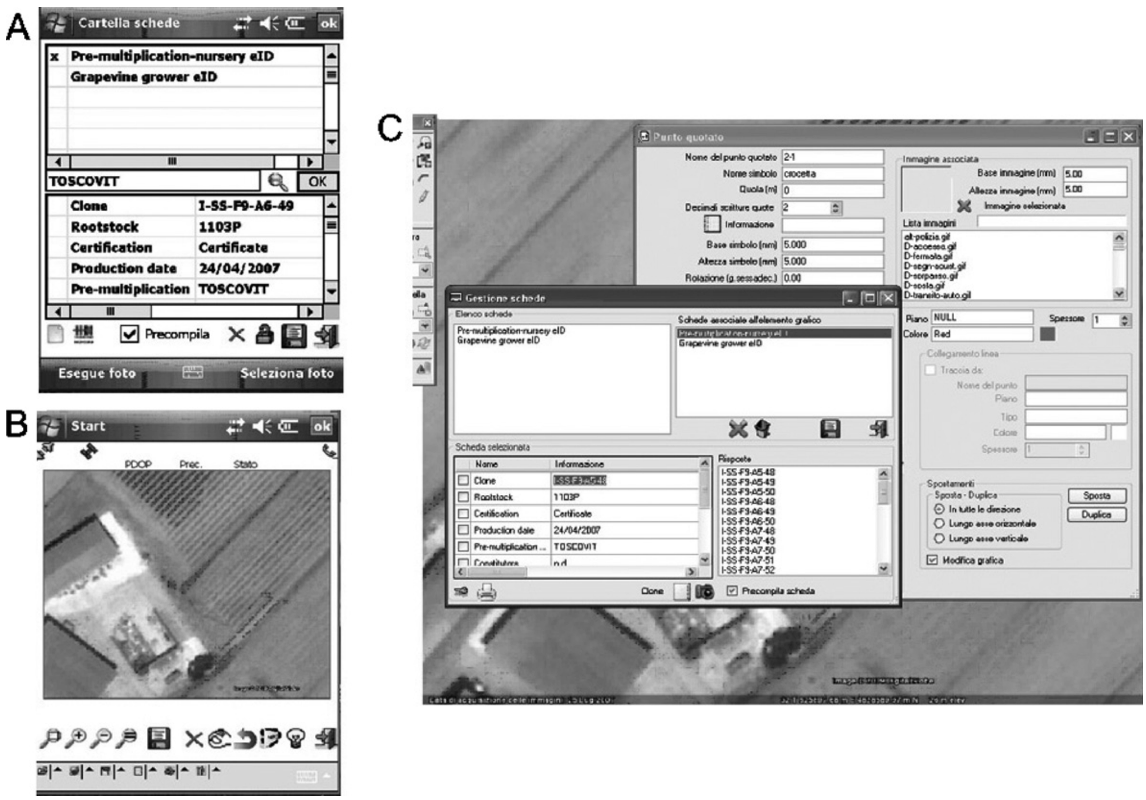

Fig. 1. GeoGIS applications for grapevine plants marked by RFID system. (A) GeoGis eID; (B) plant positions, visualized in PDA; (C) digital map and Geogis eID in desktop environment.

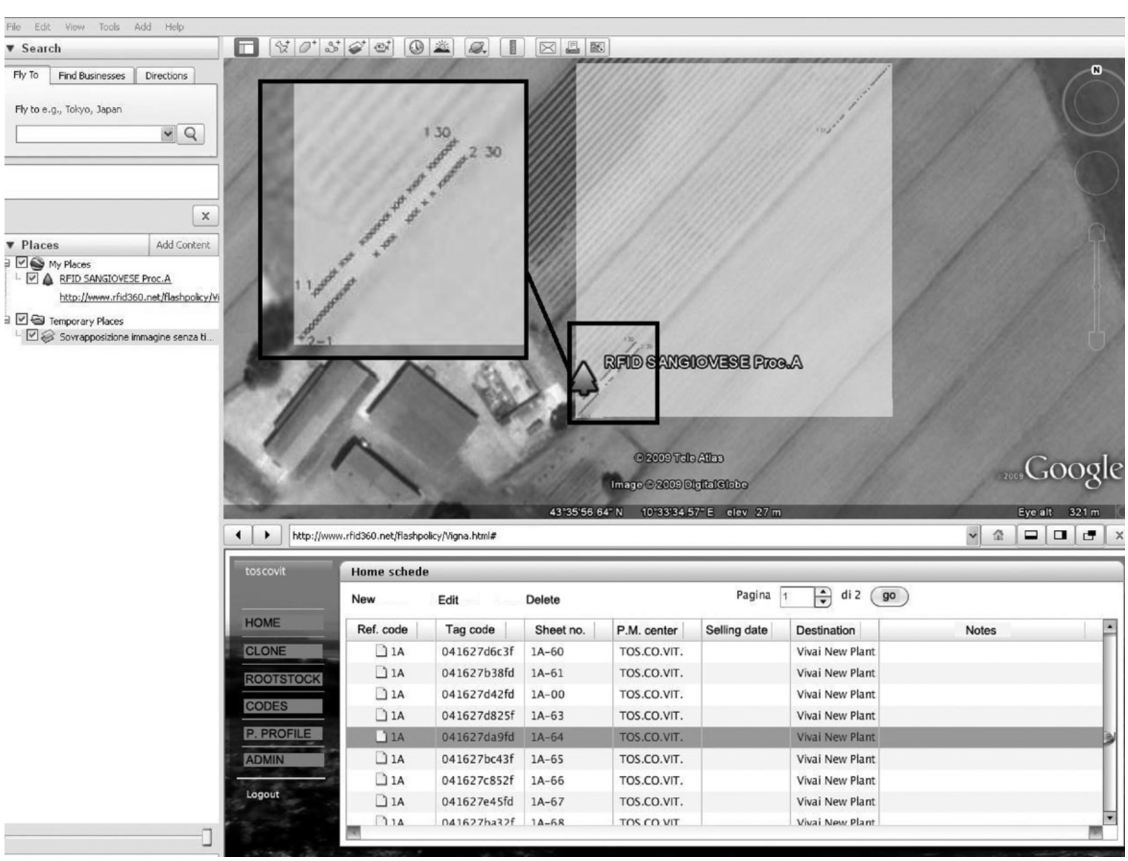

Fig. 2. Google Earth^{TM} application for grapevine plants marked by RFID system. A grapevine cv. Sangiovese plant marked using Procedure A is selected (main window), and the eID is visualized (lower window). A magnification of s portion of the vineyard is included in the figure, showing the mapped plants.

showed no erroneous records comparing automatic and manual data matching.

Virtualized vineyard desktop application performance was set at 5.6 (minimum steps for retrieving information was 5) and accuracy at 97.3% by stakeholder panel. All users recommended software to a colleague, while 20.0% of users have indicated high loading time on old hardware (i.e. Intel Pentium III series or AMD K6 series). Portability was evaluated at 100.0% considering selected software.

4. Conclusions

In recent years various methods were proposed for matching items or data with corresponding tree using RFID (Bowman, 2005; Ampatzidis and Vougioukas, 2009; Luvisi et al., 2010b) and among possible implementations of the component-based model of farm information management system, sensor readings from process activities involving RFID and Global Positioning System (GPS)-based technologies such as wireless systems for data transfer have been suggested (Sørensen et al., 2010).

Vineyard virtualization using GeoGis or other software offers support to management, especially with regard to grapevine plants in which a RFID microchip is implanted. In fact, the combination of identification system by RFID and satellite positioning provide a complete tool for traceability purposes and farm management. The history of vineyard management can be easily recorded, with plant-focused attention, and safe and durable traceability can be achieved. Professional geographic software permits great precision in the visualization of position data and a complete system for consulting and editing from the field. In future applications, a unique RFID/GPS system can be designed, using the same principles as presented in this paper, with a radio-modem for data transmission to a data center for post-processing where data can be registered and evaluated using GIS analysis software.

Common and free-to-use software can be implemented for vineyard virtualization, providing rapid access to the online database where plants marked by RFID TAGs are registered. Moreover the Web browser interface can provide most of the functionality achievable with a local user interface (Nikkilä et al., 2010). In particular, this method can be useful for marketing purposes, considering the potential interest by final consumers of wine productions and those without access to commercial GIS software.

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