On-the-go yield and sugar sensing in grape harvester

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Abstract
This paper summarises the results of a joint R+D project between university and industry. The study was developed at the Alt Penedès region, in Barcelona, during the 2006 and 2007 (on 3, 22, 69 fields respectively). The quality sensors set-up in year 2007, mounted on a New Holland SB55 grape harvester, were: two load cells, one refractometer, an ambient temperature prove and a GPS antenna, while in 2006 only the load cells and the GPS performed properly. The method used for this study is as follows: 1. Data recording from GPS and Logger (the latter is use for according and digitalising the sensor signal); 2. Wireless download of data to a PC; 3. Automatic data integration in a single file; 4. Lane automatic identification based on trajectory angles, machine forward speed determination, effective time calculation, masic flow, kg/m, and total amount harvested, kg/hopper, computation of characteristic soluble solid content and temperature during harvest; 5. Data broadcasting through GPRS to the winery; 6. Comparison of transmitted data with the invoice of the winery containers. After the season was finished, a data post processing was performed in order to a assess the causes of isolated incidences that were registered in 10 fields. Also a recalibration of the sensors for future seasons was performed. At current stage R^2 of 0.9547 is found between winery and in field yield data. Beside georeference data were gathered and compare to the remote photos in “Instituto Cartográfico de Cataluña”. Site-specific yield maps and speed maps have been computed while broad soluble solid information is not available due to slight dysfunctions of the grape juice pumping system towards to the refractometer.

Keywords: precision viticulture, sensors, weight, soluble solid content, site-specific maps

Introduction

Precision viticulture (PV) is a precision agriculture (PA) application where technologies, computing and electronics are used to evaluate vineyard management and variability. Several authors have studied spatial variability of vineyard yield using grids to sampling different points and variables and linking these with optical remote sensing (Ortega *et al.*, 2003; Arnó *et al.*, 2005; Paolit *et al.*, 2005).

This work shows the preliminary results of a joint collaboration between the Polytechnic University of Madrid and Miguel Torres S.A., a large winery situated at the Alt Penedès region, in Barcelona. The work aims at developing a system for grape harvesters which allows gathering the information and data that link field production and corresponding quality, as to improve vineyard management. During harvest season 2006 and 2007 data from some vineyards located at the Alt Penedès region were gathered and analysed. With these data site specific yield maps and speed maps have being computer.

Materials and methods

A New Holland SB55 grape harvester (Figure 1.a) equipped with a DGPS (for data georeferentation), a DataLogger (for recording sensor measurements), two load cells with devoted electronics, one refractometer and a PT100 probe were used to obtain the different data.
The refractometer is an Atago CM-780 in-line brix-monitor (Atago, USA). This instrument measures the refractive index that increases in proportion to the concentration of the solution. The output is an analog current signal (4mA to 20mA) proportional to Soluble Solid Content (SSC, Brix).
In 2006 haverst season, grape juice was ghatered from the bottom of the hopper, but seeds went to block the mechanism. To overcame this problem, in harvest season 2007, grape juice was ghatered from a worm drive situated on the top of the hopper, just where grape grains fall into the hopper.

Data were collected along harvest season 2006 and 2007. In the 2006 vintage, data were collected for 22 vineyards and in the 2007 vintage, data from 69 vineyards were gathered along 6 weeks (25^{th} August – 4^{th} October). Nevertheless, in the first harvest season, only 5 out of these 22 fields could be processed, and in the second harvest season, 31 out of 69 fields could be processed, as full data sets were available.
The data analysis procedure consisted of:
a) on board PC data recording from the GPS and the DataLogger with a 1 Hz frequency. Selected NMEA messages were: GPGGA, GPGSA and GPVTG. GPGGA message was used to determinate antenna position in latitude and longitude, GPGSA message provided the number of available satellites and the signal precision, and GPVTG message was used to know the speed in km/h. The DataLogger recorded data from the two load cells in mV, data from the refractometer in mA and data from PT100 probe in degree Celsius.
b) data download by means of Wi-Fi communications towards a portable PC situated at field. The GPS and the DataLogger were connected to a Wi-Fi.
c) automated time based data linking of GPS-Logger. Data in a portable PC were unified with a Matlab routine in an only file to link each GPS data with each DataLogger data.
d) data processing by means of Matlab routines as to derive: weight (kg), crop yield (kg/m), soluble solids content (ºBrix) and field temperature (ºC). These routines will be further explained in the text.
e) GPRS communication of data towards the winery with devoted application. Once data have been processed, a Matlab routine provides a summary table containing the most important parameters for winery personnel, which is sent to the winery server.
f) comparison of onboard and winery data. Data comparison will explain subsequently.

Data processing
DGPS data (latitude, altitude, longitude) in degrees are converted to UTM coordinates according to datum ED-50 (European Datum) which is the standard used by the “Instituto Cartográfico de Cataluña” (ICC), the Institution that provides free access to Catalonian orthomaps.
Figures 1.b and 1.c show an example of orthomap and corresponding XUTM-YUTM data.
A dedicated mathematical routine has been programmed for the identification of crop rows using the inverse tangent of the displacement (ΔYUTM/ΔXUTM) as recorded by the GPS (Figures 1.e and 1.f). This algorithm allows to differentiate the periods when the grape harvester stays within crop line (effective time, ET) and those when the grape harvester turns, unloads the hoppers, or stops within the field (accessory times, AT). This information allows computing the so called machine performance (ET/(ET+AT)*100, 0-100, see Table 1).

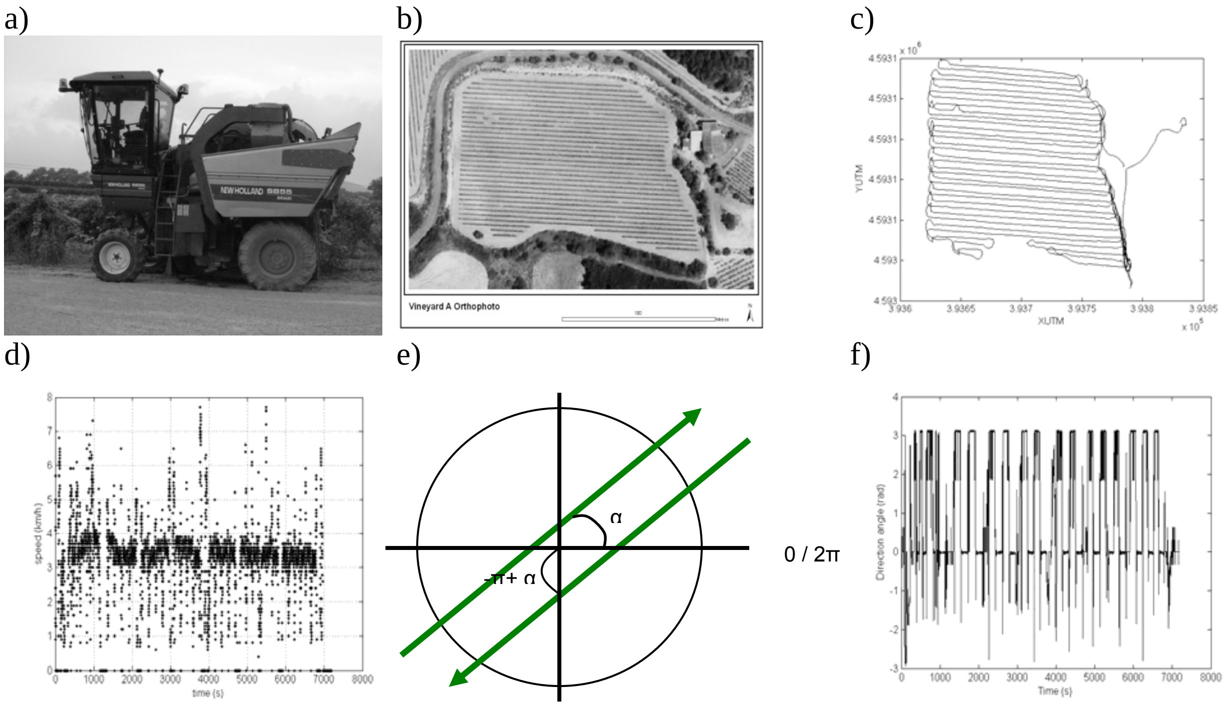

Figure 1: a) Photograph of the grape harvester New Holland SB55; b) Example of an orthomap; c) Example of XUTM and YUTM coordinates; d) Example of the grape harvester speed; e) and f) Identification of row crops.

Table 1 shows different data for 10 vineyards harvested in 2006 vintage. To compute the parameters, the GPS information is necessary. The most important fact observed in the table is the large differences in machine performance for the different vineyards. For example, in the vineyard number 8, machine performance is 39.59%, through in the vineyard 1, machine performance is 77.93%. The reason for this is the effect of field shape and line length on corresponding AT and ET.

Vineyard	Rows (nº)	Accessory time (s) AT	Effective time (s) ET	Mean Speed (km/h)	Yield (kg/m)	Theoretical Work Capacity (ha/h)	Machine performance (%) ET/(ET+AT)
1	108	4050	14299	3.68	3.22	0.81	77.93
2	32	1557	3342	3.02	2.29	0.66	68.22
3	34	2263	3601	3.16	4.09	0.69	61.41
4	36	1396	4104	3.01	2.82	0.66	74.62
5	30	775	2055	3.11	2.42	0.68	72.61
6	29	2051	2499	3.33	2.94	0.74	54.92
7	24	3387	2811	3.36	2.51	0.74	45.35
8	72	12249	8027	3.08	2.57	0.65	39.59

9	7	500	833	3.02	2.69	0.66	62.49
10	34	1760	2384	2.59	3.21	0.57	57.53

Table 1: Theoretical Work Capacity (ha/h) and Machine performance (%) for processed vineyards in 2006

Weight signal (kg) is filtered as to remove the noise caused by vibrations due to the movement of the grape harvester. A one-dimensional digital filter that eliminates high frequencies related noise is used (see Figure 2). This filter finds a running average without using a for loop. Instantaneous mass flow (kg/s) is computed by means of linear regression of the weight-time signal using a user defined window, which in our case was fixed to 5 points. The instantaneous yield (kg/m) is computed as the ratio between instantaneous flow (kg/s) and instantaneous filtered speed (m/s). Taking into account that inter-vine distance is standardised to 1 meter, the yield (kg/m) is also referring to a single plant yield. The total weight of the hoppers (kg) was assessed as the integral of the instantaneous mass flows for inter unload periods.

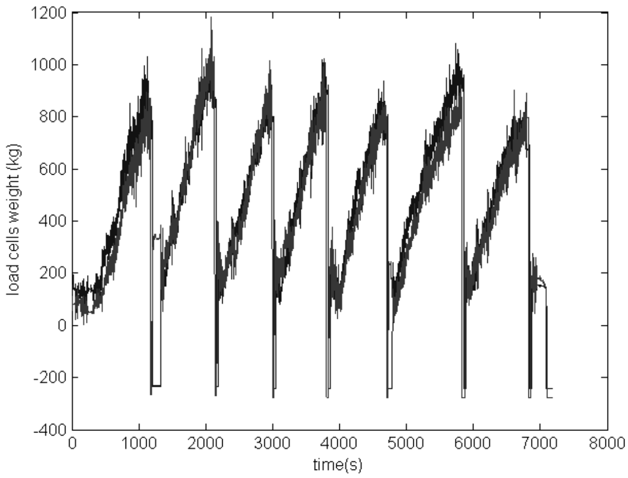

Figure 2: Load cells weight (kg)

Site-specific maps
Once data have been processed and UTM coordinates have been computed, the process to develop yield maps is the following. The first step is to include these UTM coordinates into a web site of the ICC with the aim of addressing the proper orthophoto. The second step consisted of including the orthophotos into ArcGis, creating layers on top of them referring to yield (kg/m) and machine speed (km/h).

Results and discussion
Weight data analysis
In harvest season 2006 only 5 fields' data were processed; however in harvest season 2007, data were gathered from 69 vineyards, although only 31 vineyards of these 69 could be processed correctly.

When onboard weight and winery weight data (from 31 vineyard data of harvest season 2007) are compared by means of linear regression, a random error of 4.53% is found with an slope of 1.0979 (9.79% above the unit value).
Figure 3 shows the weight comparison between harvest season 2006 (squares) and 2007 (stars). Both sensors follow the same linear function.

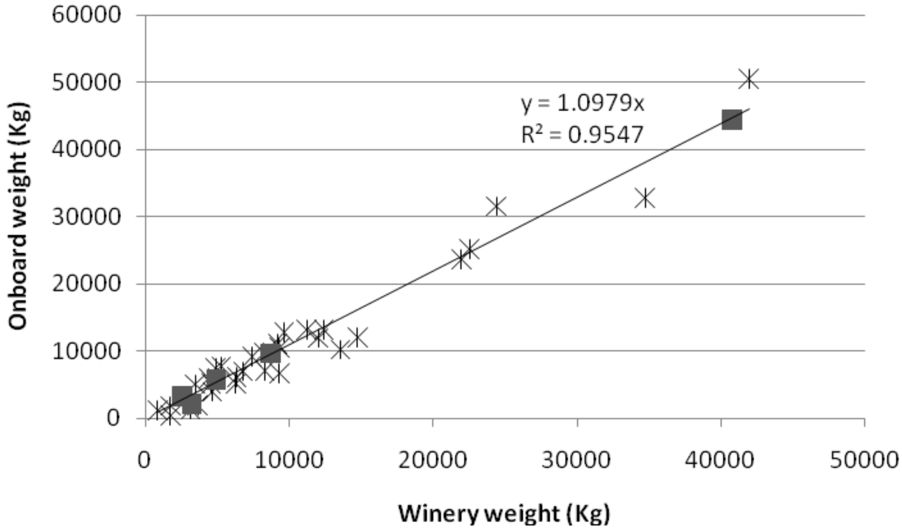

Figure 3: Weight comparison between harvest season 2006 (squares) and 2007 (stars)

Yield data analysis

Figure 4 shows the site-specific yield map for vineyard A. Data were divided into eleven ranks to difference the yield along the vineyard with STD/x*100, % variation along the field.

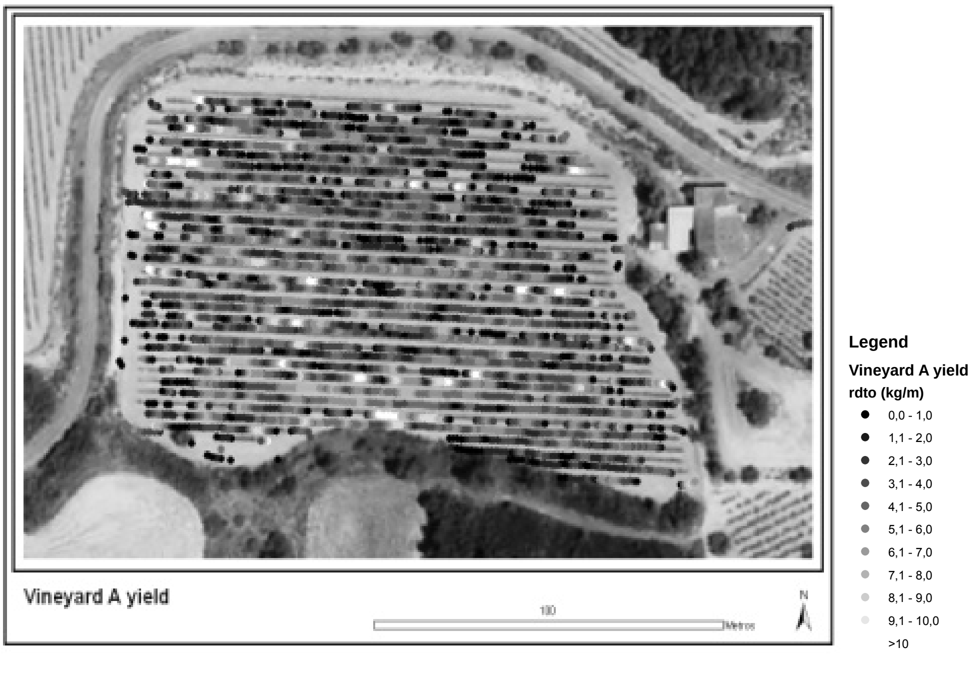

Figure 4: Site-specific yield map for vineyard A

Sugar data analysis

During the two harvest seasons, the grape juice flow system showed strong incidences: pump feeding, mechanical problems related to the DC motor and worm drive system, thus most of the vineyards haven't got solible solid data. However, the procedure used in harvest season 2007, previosly explained, would be more solid for mapping compared to the former.

Figure 5 shows Soluble Solid Content (SSC) from two different vineyards harvested in 2006 vintage. One of this (black) corresponds to Muscat variety (more sweet), while the other vineyard (grey) corresponds to Parellada variety (less sweet than the Muscat). The first vineyard presents one SSC mode of 26.6 ºBrix and the second presents two modes whose values are 12.1 and 16.2 ºBrix, the second one due to juice mixture between fields.

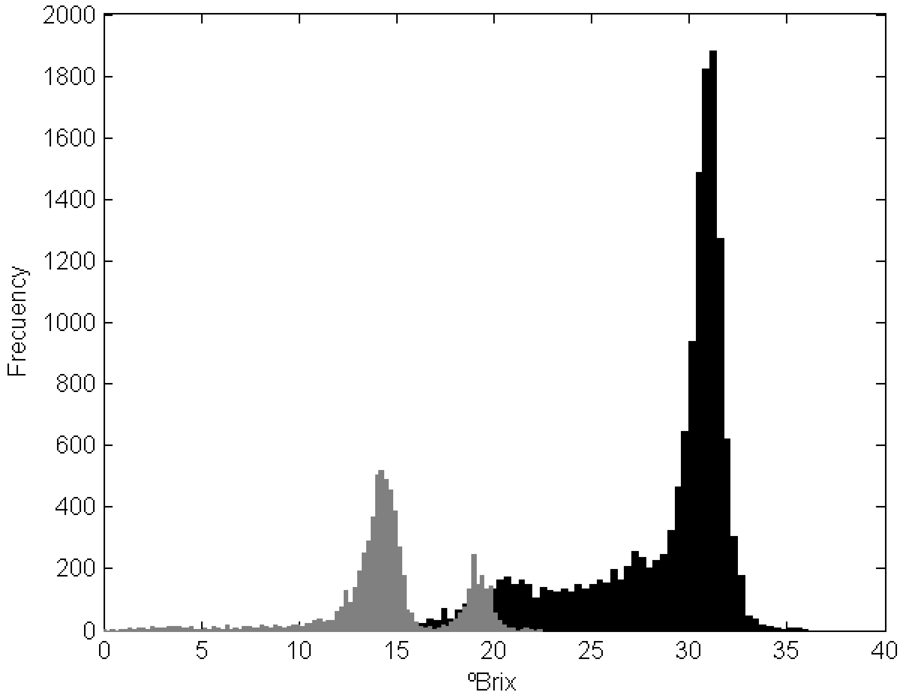

Figure 5: Brix histograms for two different vineyards harvested in 2006

Conclusions

GPS data allow a very representative estimation of machine performance. Weight system underneath the hoppers of the grape harvester is very robust, however, in future works, weight data could be processed computing in more robust ways as to adjust better the weights compared to winery values. Soluble Solid Content estimation depends on the proper flow of liquid, so the system should be revised to come to a better adjustment.

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References

Arnó, J., Bordes, X., Ribes-Dasi,M., Blanco, R., Rosell. J.R. and Esteve, J., 2005. Obtaining grape yield maps and analysis of within-field variability in Raimat (Spain). In: Proceeding of the 5th European Conference on Precision Agriculture, Eds. J.V. Stafford, Wageningen Academics Publishers, The Netherlands, pp. 899-906.

Domsch, H., Heisig, M. and Witzke, K., 2007. Estimation of yield maps using yield and data from a few tracks of a combine harvester and aerial images. In: Proceeding of the 6th European Conference on Precision Agriculture, Eds. J.V. Stafford, Wageningen Academics Publishers, The Netherlands, pp. 289-296.

Hall, A., Louis, J. and Lamb, D., 2003. Characterising and mapping vineyard canopy using high-spatial-resolution aerial multispectral images. Computers & Geosciences 29: 813-822.

Johnson, L.F., Roczen, D.E., Youkhana, S.K., Nemani, R.R. and Bosch D.F., 2003. Mapping vineyard leaf with multisprectral satellite imagery. Computer and Electronics in Agriculture 38: 33-44.