Sustainable Precision Agriculture:
Research and Knowledge for Learning
how to be an agri-Entrepreneur

THE FUTURE OF TECHNOLOGY in the field of SUSTAINABLE PRECISION AGRICULTURE

Attachment 2 - Examples of scientific publications

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1. VITICULTURE

1.1 DATA PROCESSING

1.1.1 OBTAINING THE THREE-DIMENSIONAL STRUCTURE OF TREE ORCHARDS FROM REMOTE 2D TERRESTRIAL LIDAR SCANNING

Authors: Rossel J.R., Llorens J, Sanz R., Arnò J., Ribes-Dasi M., Escolà A., Masip J., Camp F., Solanelles F., Gràcia F., Gil E., Val L., Planas S., Palacìn J.

Source title: Agricultural and Forest Meteorology

Affiliations: Department of Agro-forestry Engineering, University of Lleida, Avinguda Rovira Roure 191, 25198 Lleida, Spain; Department of Informatics and Industrial Engineering, University of Lleida, Av. Jaume II 69, 25197 Lleida, Spain; Centre de Mecanització Agrària, Agriculture, Food and Rural Action Department, Generalitat de Catalunya, Av. Rovira Roure 191, 25198 Lleida, Spain; Department of Agri Food Engineering and Biotechnology, Politechnical University of Catalunya, Campus Baix Llobregat, edifici D4, Av. Canal Olimpic, s/n, 08860 Castelldefels, Spain; Department of Mechanization and Agricultural Technology, Politechnical University of Valencia, Camino de Vera, s/n, 46020 Valencia, Spain.

Date: 2009

ABSTRACT:

In recent years, LIDAR (light detection and ranging) sensors have been widely used to measure environmental parameters such as the structural characteristics of trees, crops and forests. Knowledge of the structural characteristics of plants has a high scientific value due to their influence in many biophysical processes including, photosynthesis, growth, CO2-sequestration and evapotranspiration, playing a key role in the exchange of matter and energy between plants and the atmosphere, and affecting terrestrial, above-ground, carbon storage. In this work, we report the use of a 2D LIDAR scanner in agriculture to obtain three-dimensional (3D) structural characteristics of plants. LIDAR allows fast, non-destructive measurement of the 3D structure of vegetation (geometry, size, height, cross-section, etc.). LIDAR provides a 3D cloud of points, which is easily visualized with Computer Aided Design software. Three-dimensional, high density data are uniquely valuable for the qualitative and quantitative study of the geometric parameters of plants. Results are demonstrated in fruit and citrus orchards and vineyards, leading to the conclusion that the LIDAR system is able to measure the geometric characteristics of plants with sufficient precision for most agriculture applications. The developed system made it possible to obtain 3D digitalized images of crops, from which a large amount of plant information - such as height, width, volume, leaf area index and leaf area density - could be obtained. There was a great degree of concordance between the physical dimensions, shape and global appearance of the 3D digital plant structure and the real plants, revealing the coherence of

the 3D tree model obtained from the developed system with respect to the real structure. For some selected trees, the correlation coefficient obtained between manually measured volumes and those obtained from the 3D LIDAR models was as high as 0.976.

1.1.2 YIELD ESTIMATION IN VINEYARDS BY VISUAL GRAPE DETECTION

Authors: Nuske S., Achar S., Bates T., Narasimhan S., Singh S.

Source title: IEEE International Conference on Intelligent Robots and Systems

Affiliations: Robotics Institute, Carnegie Mellon University, Pittsburgh, PA 15213, United States; Cornell University, 6592 West Main Road, Portland, NY 14769, United States

Date: 2011

ABSTRACT:

The harvest yield in vineyards can vary significantly from year to year and also spatially within plots due to variations in climate, soil conditions and pests. Fine grained knowledge of crop yields can allow viticulturists to better manage their vineyards. The current industry practice for yield prediction is destructive, expensive and spatially sparse - during the growing season sparse samples are taken and extrapolated to determine overall yield. We present an automated method that uses computer vision to detect and count grape berries. The method could potentially be deployed across large vineyards taking measurements at every vine in a non-destructive manner. Our berry detection uses both shape and visual texture and we can demonstrate detection of green berries against a green leaf background. Berry detections are counted and the eventual harvest yield is predicted. Results are presented for 224 vines (over 450 meters) of two different grape varieties and compared against the actual harvest yield as groundtruth. We calibrate our berry count to yield and find that we can predict yield of individual vineyard rows to within 9.8% of actual crop weight.

1.2 MEASUREMENT AND DATA DETECTION

1.2.1 COMPARISON OF TWO TEMPERATURE DIFFERENCING METHODS TO ESTIMATE DAILY EVAPOTRANSPIRATION OVER A MEDITERRANEAN VINEYARD WATERSHED FROM ASTER DATA.

Authors: Galleguillos M; Jacob F; Prévot L; French A; Lagacherie P.

Source title: Remote Sensing of Environment

Affiliations: INRA/UMR LISAH, Montpellier, France; IRD/UMR LISAH, Montpellier, France; USDA/ALARC, Maricopa, United States

Date: 2011

ABSTRACT:

Daily evapo-transpiration (ET) was mapped at the regional extent over a Mediterranean vineyard watershed, by using ASTER imagery along with two temperature differencing methods: the Simplified Surface Energy Balance Index (S-SEBI) and the Water Deficit Index (WDI). Validation of remotely sensed estimates was conducted during almost two growth cycles (August 2007-October 2008) over seven sites that differed in soil properties, water status and canopy structure. S-SEBI and WDI were also intercompared at the watershed extent by considering ASTER imagery collected between 2002 and 2008. In order to alleviate the experimental efforts devoted to the validation exercise, ground truthing relied on in situ estimates from the HYDRUS-1D model that simulates water transfers within the vadose zone after calibration against measured soil moisture profiles. For two of the seven validation sites, the consistency of the HYDRUS-1D simulations was beforehand controlled against direct measurements with eddy covariance devices. Thus, it was shown the HYDRUS-1D simulations could be used as ground truthing.Despite the use of simple differencing methods over a complex row-structured landscape, the obtained accuracies (0.8mm.d-1 for S-SEBI and 1.1mm.d-1 for WDI) were similar to those reported in the literature for simpler canopies, and fulfilled requirements for further applications in agronomy and hydrology. WDI performed worse than S-SEBI, in spite of more determinism within the derivation of evaporative extremes used for temperature differencing. This raised the question of compromising between process description and measurement availability. Analyzing validation results suggested that among the possible factors that could affect model performance (spatial variability, soil type and color, row orientation), the first-order influence was row orientation, a property that can be characterized from very high spatial resolution remote sensing data. Finally, intercomparing S-SEBI and WDI at the watershed extent showed estimates from both models agreed within 1mm.d-1, a difference similar to the model accuracies as estimated by the validation exercise. Then, time averaged maps suggested the existence of spatial patterns at the watershed extent, which may be ascribed to combined effects from soil type, soil depth and watertable level.

1.2.2 SPECTRAL DISCRIMINATION OF GRAPE VARIETIES AND A SEARCH FOR TERROIR EFFECTS USING REMOTE SENSING

Authors: Cemin G; Ducati J.R.

Source title: Journal of Wine Research

Affiliations: Instituto de Saneamento Ambiental, Universidade de Caxias do Sul, Caxias do Sul, Brazil; Centro Estadual de Pesquisas em Sensoriamento Remoto e Meteorologia, Departmento de Astronomia; Instituto de Física, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Date: 2011

ABSTRACT:

Satellite images are used to determine the reflectance dependency on wavelength in different grape varieties (cabernet sauvignon, merlot, pinot noir, and chardonnay). The terroir influence is investigated through a study of vineyards in France, Brazil and Chile. Statistical techniques (ANOVA, cluster and discriminant analysis) are applied. Results indicate that there are consistent spectral features, mainly in the near infrared, which can lead to variety identification. Discriminant functions were derived; these separate grape varieties for the regions studied. Spectral features are affected by terroir effects, since the reflectance spectra showed similarities between regions, specially for cabernet sauvignon; phenological factors, expressed by the NDVI, further contribute to variety differentiation. It is concluded that remote sensing data are effective for terroir and grapevariety studies.

1.3 DATA TRANSFER

1.3.1 A WIRELESS SENSOR NETWORK FOR PRECISION VITICULTURE: THE NAV SYSTEM

Authors: Matese A.; Di Gennaro S.F.; Zaldei A.; Genesio L.; Vaccari F. P.

Source title: Computer and electronics in Agriculture

Affiliations: Istituto di Biometeorologia (IBIMET - CNR), Consiglio Nazionale delle Ricerche, via Caproni 8, 50145 Firenze, Italy

Date: 2009

ABSTRACT:

In the last decade, wireless technologies have been increasingly applied in precision agriculture. Wireless monitoring systems in particular have been used in precision viticulture in order to understand vineyard variability, and therefore suggest appropriate management practices for improving the quality of the wines. The NAV (Network Avanzato per il Vigneto - Advanced Vineyard Network) system is a wireless sensor network designed and developed with the aim of remote real-time monitoring and collecting of micro-meteorological parameters in a vineyard. The system includes a base agrometeorological station (Master Unit) and a series of peripheral wireless nodes (Slave Units) located in the vineyard. The Master Unit is a typical single point monitoring station placed outside the vineyard in a representative site to collect agrometeorological data. It utilizes a wireless technology for data communication and transmission with the Slave Units and remote central server. The Slave Units are multiple stations placed in the vineyard and equipped with agrometeorological sensors for site-specific environmental monitoring, which store and transmit data to the Master Unit. Software was developed for setup and configuration functionality. A graphical user interface operating on the remote central server was implemented to collect and process data and provide real-time control. The devices were tested in a three-step process: hardware functionality and data acquisition, energy consumption and communication. The NAV system is a complete monitoring system that gave flexibility for planning and installation, which fully responded to the objectives of the work in terms of energy efficiency and performance.

1.3.2 WIRELESS MESH NETWORK FOR IRRIGATION CONTROL AND SENSING

Authors: Coates R. W.; Delwiche M. J.

Source title: Transaction of the ASABE

Affiliations: Department of Biological and Agricultural Engineering, University of California, Davis, One Shields Ave, Davis, CA 95616, United States

Date: 2009

ABSTRACT:

Variations in plant water and nutrient demand and environmental regulations to protect water quality provide significant justification for site-specific irrigation and fertigation systems. We have developed wireless valve controllers that self-assemble into a mesh network. Mesh networking means that controllers pass messages to extend the effective communication range without using high-power radios. Solar energy is collected with a 200 mW panel to operate each controller node without yearly battery replacement. Nine nodes were tested in a mesh network, and each properly responded to commands. Measurements of battery voltage, solar panel voltage, enclosure temperature, and external sensors were transmitted every 10 min. Irrigation schedules were stored locally on each node and executed automatically. Schedules for each node were unique, based on the needs of the particular area being irrigated. Internal clock drift was an average 6.3 s per day. Clock offset was removed using daily time stamps. One-hop transmission range using 916 MHz radios varied from 20.9 m with a whip antenna at ground level to 241.1 m with a dipole antenna at 3 m. Node commands were acknowledged after an average of 2.7 s per hop. Charge consumption was approximately 7.03 mA-h per day for the node circuit and 1 mA-h per day for battery self-discharge. The solar panel produced 26.0 to 81.3 mA-h in direct sunlight and 6.5 to 13.7 mA-h in shade. Node operation is expected to be continuous with occasional sunlight exposure. Soil moisture, pressure, temperature, and other environmental sensors will be used for feedback control and detection of problems. Such a network of intelligent valve controllers will allow growers in orchards, vineyards, nurseries, greenhouses, and landscapes to develop management practices that improve water- and fertilizer-use efficiency.

1.4 HARVESTING AND PRUNING

1.4.1 GRAPE QUALITY MAPPING FOR VINEYARD DIFFERENTIAL HARVESTING

Authors: Antonio Odair Santos; Robert L. Wample; Sivakumar Sachidhanantham; Oren Kaye

Source title: Brazilian Archives of Biology and Technology

Affiliations: Instituto Agronômico; Rodovia Dom Gabriel Paulino Bueno Couto, Km 65, CEP 13212-240; Jundiaí - SP – Brasil; Viticulture and Enology Research Center; California State University; 2360 East Barstow Avenue, Fresno - CA – USA; Constellation Wines, 12667 Road 24, Madera - CA - USA

Date: 2012

ABSTRACT:

An experiment was carried out from 2005 to 2008, to calibrated NIR-based instrumentation and explore within field grape quality variability and map potential grape quality descriptors along vineyards, as a subsidy for differential harvesting. The quality indicators (anthocyanin content, pH, titratable acidity and soluble solids) were subject to geo-spatial modeling. Subsequently, the data set was utilized to delineate "within-field" grape quality zone and to determine the timing of the harvest. Differential machine harvesting was implemented, and segregation of wine grapes was done "on-the-go". The approach for field prediction of grape quality parameters and zone delineation allowed for separated fermentation for at least two wine styles.

1.4.2 MECHANIZATION IN AUSTRALIAN VINEYARDS

Authors: Clingeleffer P.R.

Source title: Acta Horticulturae

Affiliations: CSIRO Plant Industry, Waite Campus Urrbrae, SA, Australia

Date: 2013

ABSTRACT:

The adoption of low-input management systems, based on mechanization of harvest and pruning, has been a key factor leading to the development of efficient, internationally competitive wine and raisin industries in Australia. This has been achieved with substantial savings in the cost of production without compromising quality. For table grapes, which are hand harvested, pruning inputs are reduced by mechanized pre-pruning of spur pruned cultivars and removal of spent fruiting canes from cane pruned cultivars. For wine grape production, the introduction and rapid adoption of mechanical harvesting in the 1970s provided a catalyst for the adoption of low-input mechanical pruning systems ranging from tight mechanical hedging, aiming to retain similar bud numbers to hand pruning, lighter forms of mechanical hedging and minimal pruning. Post-set mechanical thinning is also routinely used for crop control. For dried grapes, highly productive mechanized systems have been developed for in-situ, trellis drying first introduced in the 1960s. These systems use bi-lateral cordons established on tall trellises and hanging, fruit bearing canes. They provide a large canopy surface to optimize photosynthetic capacity of high vigour, grafted vines with separation of fruiting and renewal zones to optimize fruitfulness and facilitate mechanization of the drying and pruning processes. It is now estimated that more than 80% of the Australian dried grape crop is mechanically harvested based on the concept of trellis drying. This overview will provide an update on the adoption of mechanization in Australian vineyards, the development of improved trellis systems to facilitate these processes and the role of mechanization in the future 'total integrated systems approaches' to vineyard management.

1.5 VINEYARD CARE

1.5.1 IRRIGATION SCHEDULING FROM STEM DIAMETER VARIATIONS: A REVIEW

Authors: Fernández J.E., Cuevas M.V.

Source title: Agricultural and Forest Meteorology
Affiliations: Instituto de Recursos Naturales y Agrobiología (IRNAS-CSIC), Avenida de Reina Mercedes, No. 10, 41012 Seville, Spain.

Date: 2010

ABSTRACT:

Precise irrigation is essential in arid and semi-arid areas where water is scarce. This has impelled the scientific community to develop new technologies for scheduling irrigation. Of these, the ones relying on plant-based water-stress indicators have been found to have the greatest potential. Thus, measurements of stem water content, canopy temperature, sap flow, and stem diameter variation (SDV), among other variables, have proved useful not only for research purposes, but also for precise irrigation scheduling in commercial orchards. In this work we focus on the use of SDV records for irrigation scheduling. Of those mentioned above, this is the water-stress indicator that has received most attention from the scientific community, in terms of its potential for irrigating commercial orchards. Apart from being capable of an early detection of water stress, even if this is mild, SDV can be continuously and automatically recorded. This is a clear advantage over conventional indicators such as stem water potential (Ψstem). Among the SDV-derived indices that are useful for scheduling irrigation, the maximum daily shrinkage (MDS) and stem growth rate (SGR) are the most widely used. For young trees, and in periods of rapid stem growth, SGR could be a better indicator than MDS. In periods of negligible growth, however, SGR cannot be used as an indicator of plant water stress. Considerable differences in both MDS and SGR as a function of crop load have been reported for some species. It has been found, that SDV outputs are affected by seasonal growth patterns, crop load, plant age and size, and other factors, apart from water stress. Thus, expert interpretation of SDV records is required before using them for scheduling irrigation, which limits their potential for automating the calculation of the irrigation dose. For some species, the MDS vs Ψstem relationships show diurnal hysteresis and seasonal changes. Some relationships also shown an increase of MDS as the plant water potential fell to a certain value, after which MDS decreases as the plant water potential became more negative. This has been reported for peach, lemon, grapevine and olive, among other species. Although SDV-derived indices show a high plant-to-plant variability, in most cases the signal intensity is high enough to achieve an acceptable sensitivity, which, for peach, lemon and pepper has been found to greater than that of Ψstem and leaf conductance (gl). In plum, apple and grapevine, however, Ψstem is more sensitive than MDS and SGR. In any case, the usefulness of an SDV-derived index for irrigation scheduling must be evaluated for the orchard conditions. In this work we describe the qualities that must be considered in such evaluation. One of them, the signal intensity, is being successfully used to schedule low-frequency irrigation in orchards

of a variety of species, for both full- and deficit-irrigation treatments. When combined with aerial or satellite imaging, SDV measurements are useful for scheduling irrigation in large orchards with high crop-water-stress variability.

1.5.2 SIMULATION OF THE DYNAMIC BEHAVIOR OF A TRACTOR – OSCILLATING SUBSOILER SYSTEM

Authors: Shahgoli G., Fielke J., Saunders C-. Desbiolles J.

Source title: Biosystem Engineering

Affiliations: Agricultural Faculty 1, University of Mohaghegh Ardabili, Ardabil, Iran; Institute for Sustainable Systems and Technologies, School of Advanced Manufacturing and Mechanical Engineering, University of South Australia, Mawson Lakes, SA 5095, Australia

Date: 2010

ABSTRACT:

A two-tine oscillatory subsoiler was developed at the University of South Australia for fracturing the compacted soil layers between grapevines using small tractors. As the soil forces exerted on the tines were unbalanced, the tillage forces, torque peaks through the power-take-off and the inertia of the tines transferred vibrations to the tractor and its driver. These vibrations currently prevent the commercial use of soil loosening settings that require the lowest engine power to be used. A simulation model is presented that calculates the dynamic behaviour of the tractor-oscillating subsoiler system with the focus being on the vibrations at the tractor driver's seat. The model considers the three oscillatory tillage phases of soil cutting, backing-off and catching-up, with positive and negative oscillation angles; tine inertia and the various tyre stiffness and damping parameters. The results of the simulation were compared to field measurements and a good correlation of both the magnitude of root mean square (RMS) acceleration and the response to change in the oscillatory tillage parameters of amplitude, frequency and oscillation angle were obtained.

2 ARABLE CROPS

2.1 DATA PROCESSING

2.1.1 VISION-BASED OBSTACLE DETECTION AND NAVIGATION FOR AN AGRICULTURAL ROBOT

Authors: Ball D., Upcroft B., Wyeth G., Corke P., English A., Ross P., Pattern T., Fitch R., Sukkarieh S., Bate A.

Source title: Journal of Field Robotic

Affiliations: School of Electrical Engineering and Computer Science, Queensland University of Technology, Brisbane, QLD 4001, Australia; ARC Centre of Excellence for Robotic Vision, Australia; Australian Centre for Field Robotics, The University of Sydney, Sydney, NSW 2006, Australia

Date: 2016

ABSTRACT:

This paper describes a vision-based obstacle detection and navigation system for use as part of a robotic solution for the sustainable intensification of broad-acre agriculture. To be cost-effective, the robotics solution must be competitive with current human-driven farm machinery. Significant costs are in high-end localization and obstacle detection sensors. Our system demonstrates a combination of an inexpensive global positioning system and inertial navigation system with vision for localization and a single stereo vision system for obstacle detection. The paper describes the design of the robot, including detailed descriptions of three key parts of the system: novelty-based obstacle detection, visually-aided guidance, and a navigation system that generates collision-free kinematically feasible paths. The robot has seen extensive testing over numerous weeks of field trials during the day and night. The results in this paper pertain to one particular 3 h nighttime experiment in which the robot performed a coverage task and avoided obstacles. Additional results during the day demonstrate that the robot is able to continue operating during 5 min GPS outages by visually following crop rows.

2.1.2 A REAL-TIME WIRELESS SMART SENSOR ARRAY FOR SCHEDULING IRRIGATION

Authors: Vellidis G., Tucker M., Perry C., Kvien C., Bednarz C.

Source title: Computer and electronics in Agriculture

Affiliations: National Environmentally Sound Production Agriculture (NESPAL), University of Georgia, Tifton, GA; United States.

Date: 2008

ABSTRACT:

A prototype real-time, smart sensor array for measuring soil moisture and soil temperature that uses off-the-shelf components was developed and evaluated for scheduling irrigation in cotton. The array consists of a centrally located receiver connected to a laptop computer and multiple sensor nodes installed in the field. The sensor nodes consist of sensors (up to three Watermark soil moisture sensors and up to four thermocouples), a specially designed circuit board, and a Radio Frequency IDentification (RFID) tag which transmits data to the receiver. The smart sensor array described here offers real potential for reliably monitoring spatially variable soil water status in crop fields. The relatively low cost of the system (~USD 2400 for a 20-sensor node system) allows for installation of a dense population of soil moisture sensors that can adequately represent the inherent soil variability present in fields. This paper describes the smart sensor array and testing in a cotton crop. Integration of the sensors with precision irrigation technologies will provide a closed loop irrigation system where inputs from the smart sensor array will determine timing and amounts for real-time site-specific irrigation applications.

2.2 MEASUREMENT AND DATA DETECTION

2.2.1 A CONCEPTUAL FRAMEWORK TO DEFINE THE SPATIAL RESOLUTION REQUIREMENTS FOR AGRICULTURAL MONITORING USING REMOTE SENSING

Authors: Duveiller G., Defourny P.

Source title: Remote Sensing of Environment

Affiliations: Earth and Life Institute, Université catholique de Louvain, 2/16 Croix du Sud, B-1348 Louvain-la-Neuve, Belgium

Date: 2010

ABSTRACT:

Satellite remote sensing is an invaluable tool to monitor agricultural resources. However, spatial patterns in agricultural landscapes vary significantly across the Earth resulting in different imagery requirements depending on what part of the globe is observed. Furthermore, there is an increasing diversity of Earth observation instruments providing imagery with various configurations of spatial, temporal, spectral and angular resolutions. In terms of spatial resolution, the choice of imagery should be conditioned by knowing the appropriate spatial frequency at which the landscape must be sampled with the imaging instrument in order to provide the required information from the targeted fields. This paper presents a conceptual framework to define quantitatively such requirements for both crop area estimation and crop growth monitoring based on user-defined constraints. The methodological development is based on simulating how agricultural landscapes, and more specifically the fields covered by a crop of interest, are seen by instruments with increasingly coarser resolving power. The results are provided not only in terms of acceptable pixel size but also of pixel purity which is the degree of homogeneity with respect to the target crop. This trade-off between size and purity can be adjusted according to the end-user's requirements. The method is implemented over various agricultural landscapes with contrasting spatial patterns, demonstrating its operational applicability. This diagnostic approach can be used: (i) to guide users in choosing the most appropriate imagery for their application, (ii) to evaluate the adequacy of existing remote sensing systems for monitoring agriculture in different regions of the world and (iii) to provide guidelines for space agencies to design future instruments dedicated to agriculture monitoring.

2.2.2 MAPPING DAILY EVAPOTRANSPIRATION AT FIELD SCALES OVER RAINFED AND IRRIGATED AGRICULTURAL AREAS USING REMOTE SENSING DATA FUSION

Authors: Cammalleri C., Anderson M-C., Gao F., Hain C.R:, Kustas W.P.

Source title: Agricultural and Forest Meteorology

Affiliations: U.S. Department of Agriculture, Agricultural Research Service, Hydrology and Remote Sensing Laboratory, Beltsville, MD, United States. Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD, United States

Date: 2014

ABSTRACT:

Continuous monitoring of daily evapotranspiration (ET) at field scale can be achieved by combining thermal infrared remote sensing data information from multiple satellite platforms, given that no single sensor currently exists today with the required spatiotemporal resolution. Here, an integrated approach to field-scale ET mapping is described, combining multi-scale surface energy balance evaluations and a data fusion methodology, namely the Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM), to optimally exploit spatiotemporal characteristics of image datasets collected by the Landsat and Moderate resolution Imaging Spectroradiometer (MODIS) sensors, as well as geostationary platforms. Performance of this methodology is evaluated over adjacent irrigated and rainfed fields, since mixed conditions are the most challenging for data fusion procedures, and in two different climatic regions: a semi-arid site in Bushland, TX and a temperate site in Mead, NE. Daytime-total ET estimates obtained for the Landsat overpass dates suggest that the intrinsic model accuracy is consistent across the different test sites (and on the order of 0.5mmd-1) when contemporaneous Landsat imagery at 30-m resolution is available. Comparisons between tower observations and daily ET datastreams, reconstructed between overpasses by fusing Landsat and MODIS estimates, provide a means for assessing the strengths and limitations of the fused product. At the Mead site, the model performed similarly for both irrigated and rainfed fields, with an accuracy of about 0.9mmd-1. This similarity in performance is likely due to the relatively large size of the fields (≈50ha), suggesting that the soil moisture dynamics of the irrigated fields are reasonably well captured at the 1-km MODIS thermal pixel scale. On the other hand, the accuracy of daily retrievals for irrigated fields at the Bushland site was lower than that for the rainfed field (errors of 1.5 and 1.0mmd-1, respectively), likely due to the inability of the model to capture ET spikes right after irrigation events for fields substantially smaller than MODIS data resolution. At this site, the irrigated fields were small (≈5ha) compared to the MODIS pixel size, and sparsely distributed over the landscape, so sporadic contributions to ET from soil evaporation due to irrigation were not captured by the 1-km MODIS ET retrievals. However, due the semiarid environment at Bushland, these irrigation-induced spikes in soil evaporation are not long-lived and these underestimations generally affect the irrigation dates only and they do not seem to influence negatively the estimates at the seasonal scale. ET data fusion is expected to perform better over agricultural areas where irrigation

is more spatially continuous, resulting in moisture fluxes that are more uniform at the MODIS pixel scale. Overall, the model accurately reproduces the ET temporal dynamics for all the experimental sites, and is able to capture the main differences that were observed between irrigated and rainfed fields at both daily and seasonal time scales.

2.3 DATA TRANSFER

2.3.1 THE REALIZATION OF PRECISION AGRICULTURE MONITORING SYSTEM BASED ON WIRELESS SENSOR NETWORK

Authors: Xiao L., Guo L.

Source title: CCTAE 2010 - 2010 International Conference on Computer and Communication Technologies in Agriculture Engineering

Affiliations: Department of Early Warning Surveillance Intelligence, Air Force Radar Academy, Wuhan, 4300194, China

Date: 2010

ABSTRACT:

Based on the analysis of the development of agricultural mechanization, the trend of agricultural service system reform, agricultural environment protection and the development of information technology, it is possible to realize the precision agriculture. This paper designs the agricultural environmental monitoring system based on the wireless sensor network (WSN). The system can real-timely monitor agriculture environmental information, such as the temperature, humidity, and light intensity. This paper introduces the theory of the monitoring system, and discusses the aspect of hardware and software design of the composed modules, network topology, network communication protocol and the present challenges. Experiments show that the node can achieve agricultural environmental information collection and transmission. The system has the feature of compact in frame, light in weight, steady in performance and facilitated in operation. It greatly improves the agricultural production efficiency and automatic level drastically.

2.3.2 AGRICULTURAL ENVIRONMENT MONITOR SYSTEM BASED ON UAV AND WIRELESS SENSOR NETWORKS

Authors: Zhang B., Luo X., Lan Y., Huang Z., Zeng M., Li J.

Source title: Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering

Affiliations: Engineering Research Center for Agricultural Aviation Application, Guangzhou, Guangdong 510642, China; Modern Education and Technology Center, South China Agricultural University, Guangzhou, 510642, China

Date: 2015

ABSTRACT:

The wireless sensor network (WSN) technology has been evolving very quickly in recent years. Sensors are constantly improved in their sensing, processing, storage, and communication capabilities. In a larger scale hilly land agricultural environment monitor WSN, a pure multi-hop approach to route the data all the way along the network, which can extend for hundreds or even thousands of kilometers, can be very costly from an energy dissipation point of view. In order to significantly reduce the energy consumption used in data transmission and extend the network lifetime, we presented a three-tier framework for monitoring agricultural environment using TUFSN (Three-tire Unmanned aerial vehicle Farmland Sensor Network) where data collection and transmission were done using Unmanned Aerial Vehicles (UAVs) in South China. In the system, we defined three types of nodes, which included: sensor nodes, relay nodes, UAVs. In the sensor nodes, a classic WSN one-hop or multi-hop routing approach to transmit their data to the nearest RN was used, which acted as a cluster head for its surrounding sensor nodes. Then, an UAV was moved along the pre-defined route or optimizing route that transported the data collected by the RNs to the data center. The TUFSN was divided into three layers, which included: the lower layer for acquisition data based on relay node and sensor node, the middle layer of relay transmission based on sensor node and UAV, and the upper layer for moving aggregation based on UAV and data center. This architecture led to considerable savings in node energy consumption, due to a significant reduction of the transmission ranges by use of a one-hop or the least hop between sensor node and relay nodes and the transmission to communicate the data by use of a one-hop from the relay nodes to the UAV. Furthermore, the strategy provided reduced interference between the relay nodes that can be caused by hidden terminal and collision problems, which would be expected if a pure multi-hop approach was used at the relay node level. We evaluated the performance of the architecture by some simulation. Our simulation of investigating the impacts on some parameters included: flying speed, flying height, flying time, relay node buffer size, UAV buffer size and relay node communication radius. Simulation and test results showed that, 1) when flying at the speed of 1 m/s, UAV should fly much lower to get enough time for communication with relay node; 2) when the communication radius of relay node was higher than 30 m, UAV could have more than 45s for communication; 3)

when the buffer size of each relay node increased, UAV needed to fly more slow or fly more lower; 4) when relay node communication radius increased, UAV could fly more high or fly more quickly; and 5) when the transition ratio was 2000 bps, the range of relay node's cache was 3-13kB. We hoped that our simulation provided some guidelines on large scale hilly country farmland data collecting systems. A set of experiments were carried out in the Teaching and Research Farm of South China Agricultural University in April 2015, with the purpose of demonstrating the effectiveness of the proposed system. The experiments were limited to eight relay nodes which were separated from each other at a distance of 150 m. There were two or three sensor nodes surround every relay node. It should be highlighted that sensor nodes can only communicate with the closest relay node. The eight rotors of the UAV attached mobile node flied at a speed of 1 m/s and 15 meters altitude in the experiment. Statistical results indicated that the average communication time for UAV and each relay nodes were 26 seconds.

2.4 HARVESTING AND MANIPULATING

2.4.1 COMPARATION ON RAPE COMBINE HARVESTING AND TWO-STAGE HARVESTING

Authors: Wu C., Xiao S., Jin M.

Source title: Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering

Affiliations: Nanjing Research Institute for Agricultural Mechanization Ministry of Agriculture, Nanjing, 210014, China; Hefei Academy of Agricultural Sciences, Hefei, 238014, China.

Date: 2014

ABSTRACT:

In order to find out the differences between two methods of rape harvest, i.e. combine harvesting and two-stage harvesting and to provide a reasoning basis for choosing mechanized harvesting method, the simulation contrast experiments of the two harvesting methods were carried out in this paper, and the economic coefficient, grain water content, stalk moisture content, loss rate and seed quality were tested at different harvesting times. Artificial simulation of combine harvesting means artificial direct harvesting (ADH). First, the rape was cut down from a randomized plot of 5 square meters in the field, moved to a threshing ground, and then threshed and separated by manual labor immediately. The total loss was the sum of those occurred in oilseed rape due to natural shedding, crop disturbance by human being, and threshing and separation losses. The artificial two-stage harvesting (ATH) means cutting down the rapes and picking up them in different periods. The rape should be aired for 4~5 days after cutting down, then threshed and cleaned by manual labor. The artificial simulation experiments showed that the seed loss of ADH got to 3.2%, 50.8% lower than that of ATH, 6.51%, and the oilseed qualities of the two harvesting methods had no obvious difference, however the oil content of ADH was slightly higher than ATH, while its protein content was slightly lower. Besides, the two kinds of mechanized harvesting experiments were carried out. Fifteen types of combine harvesters produced by 12 enterprises were put in use in the two-stage harvesting. The loss rate, broken rate, impurity rate and operation efficiency were measured. Except the impurity rate, the measurements of mechanized two-stage harvesting (MTH) were better than mechanized combine harvesting (MCH). Further more, economic efficiencies of the two harvesting modes were analyzed. The fuel cost, labor cost, workload in life period, depreciation cost, income of yield increase and comprehensive benefit in the lifetime were compared. The results indicated that the economic benefit of MTH was 361 yuan/hm2 higher than that of MCH. In addition, the two harvesting methods were comparatively analyzed based on the machinery performance, adaptability and some other aspects. The time of vacating field for the next crop could be about 4.8 days earlier in MTH. And it had widespread adaptability to various rapes and different harvest conditions, also had superiority in seeds storage and straw chopping because of the lower moisture content. However, finishing the swathing and picking up in two operations was one of the imperfections, and another was its relatively poor

ability of adapting to cloudy day or continuous rain. MCH was relatively more convenient and had higher efficiency for it could finish harvesting in shorter time, but it didn't well adapt to different crop morphologies, and had high loss rate if the rape of improper breed was not gathered in time. The analyses indicate that the two harvesting methods have their own advantages and disadvantages and adapt to different regions and conditions, so the two methods will have further development in China, and should be chosen and used in accordance with local conditions.

2.4.2 DESIGN AND EXPERIMENT OF 4LZG-3.0 MILLET COMBINE HARVESTER

Authors: Liang S., Jin C., Zhang F., Kang D., Hu M.

Source title: Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering

Affiliations: Nanjing Institute of Agricultural Mechanization, Ministry of Agriculture, Nanjing, 210014, China; Xingguang Agricultural Limited by Share Ltd, Huzhou, 313017, China.

Date: 2015

ABSTRACT:

4LZG-3.0 millet combine harvester is developed to cope with the inadequacy in mechanized harvesting in millet. The major design is given in details. The header, conveyer, threshing system and cleaning system are designed, and their key parameters are calculated. The header dedicated for millet has a length of 580 mm. The crop dividers have their top points more than 1300 mm above the ground, and foremost point over 700 mm from the knife bar. Inner and outer divider bars are added to the left crop divider, which are located at a distance of 100-120 mm from the side of the crop divider. The height of the center of the reel is over 1100 mm, and has an adjustable region of 500-600 mm. The rotary speed of the reel is 30-34 r/min. The diameter of the feeder auger is 330 mm and the rotary speed 170 r/min. The original problems of crop stacking on the side of the header, ear dropping off and crop clinging to the reel are thus solved, and the header loss is significantly reduced. The threshing system has the structure of double transverse axial flow with D-type rasp bar. The entry clearance is 15-20 mm and the exit clearance is 2-4 mm. The concave is a grating one. The front conclave has a bar distance of 9 mm and the rear one 12 mm. The rotor speed is 850-970 r/min. By modifying the parameters mentioned above, the carry-on loss is reduced compared to other millet threshing systems while maintaining the grain breaking during the threshing procedure at a low level. Centrifugal fan with 3 kinds of available speeds and double-wire sieve is used in the cleaning system. The pore of the upper sieve is 14 mm × 14 mm and that of the lower sieve is 6 mm × 6 mm. The newly designed cleaning system has a drop in cleaning loss. A broken spike recycling device is developed to recollect capes and heavier broken stalk from the residual. This recycling device can be added to the machine as an attachment when required, as in some regions such materials are

demanded as forage. Major parameters of the millet harvester are as follows. The engine power is 55 kW, the cutting width 2.0 m, the capacity ≥3.0 kg/s, the productivity 0.23-0.45 hm2/h, the rubber track 400 × 90 × 48 (mm × mm × segment), and the wheelbase 1080 mm. The field experiment and performance test results show that this harvesting machine has achieved a stable performance. The main indices tested in the standard working condition are as follows. The feeding amount is 3.30 kg/s, the total loss rate 6.89%, the impurity rate 1.8%, the broken rate 1.4%, the productivity 0.4 hm2/h, and the equipment reliability coefficient 95%. Each of the indices has reached or exceeded the designed technical specification. It is concluded that the millet combine harvester is suitable for harvesting small-grain crops like millet, with superiorities such as large capacity, low header and threshing loss rate and little impurity for the grain. It can save operation time by over 90% while reducing labor intensity, promoting efficiency and cutting cost compared to manual harvesting. This study has provided a reference for millet mechanical harvesting.

2.5 PLANTING AND SOIL WORKING

2.5.1 STRIP-TILLAGE USING ROTATING STRAIGHT BLADES: EFFECT OF CUTTING EDGE GEOMETRY ON FURROW PARAMETERS

Authors: Matin M.A., Desbiolles J.M.A., Fielke J.M.

Source title: Soil and Tillage Research.

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Date: 2016

ABSTRACT:

Efforts to develop strip-tillage drills for two-wheeled tractors have often used conventional bent rotary blades designed for full disturbance soil tillage which have resulted in poor furrow backfill and smeared furrows. This soil bin study examined the use of rotating straight blades with a range of cutting edge geometries for cutting a 50. mm wide strip-till furrow. Results showed that a set of rotating straight blades can only create a furrow if the blade set exerts sufficient strain onto the soil volume between the blades. The furrow formation was aided when using either inside chamfered or square edged blades. For the same thickness of blades, double-side chamfered blades, due to applying a reduced strain, resulted in an uneven furrow of shallower depth at its centre along with a coarser soil tilth, and additionally produced smeared furrow walls. For the inside chamfered and the square edged cutting edge geometries the furrow backfill was the highest with only 20-26% of loosened soil ending outside the furrow. The outside chamfered blades applied a soil strain outward from the blade set which was not able to produce a furrow and only created two smeared slots in the soil. The study recommends inside chamfered blades be used for strip-tillage, with their optimum thickness related to the targeted furrow width, in order to apply the minimum strain required for achieving a targeted loosening result.

2.5.2 DEVELOPMENT OF SEEDER FOR MIXED PLANTING OF CORN AND SOYBEANS

Authors: Woo S.M., Uyeh D.D., Sagong M.S., Ha Y.S.

Source title: International Journal of Agricultural and Biological Engineering.

Affiliations: Department of Bio Industrial Machinery Engineering, Kyungpook National University, Daegu, 41566, South Korea.

Date: 2017

ABSTRACT:

Corn and soybeans should be sown between 5 cm and 10 cm apart in mixed cultivation to increase protein content and improve productivity of the forage. However, existing sowers cannot plant at intervals of less than 20 cm. Consequently, mixed cultivation of corn and soybeans is currently performed by first sowing corn seeds with a tractor and then manually planting soybean seeds. This method results in irregular intervals between the seeds, it is laborious and time consuming. This study aimed at developing a seeder that can simultaneously, precisely and efficiently plant corn and soybean. The geometrical and rheological properties of corn and soybeans were initially measured. The seed conveying equipment were designed using the EDEM software. The sowing interval between seeds, depth of soil over planted seed, and sowing performance were analyzed. The EDEM simulation results indicated that a 6-mm-wide and 3-mm-deep grooved seed-delivering roller had the highest particle mobility of the designs considered, with a 2.5% misplanting rate. A performance test showed that no misplanting occurred in the sections sowed with soybean seeds at a seeding interval that averaged 32 mm (321 seeds sown in 10 m) and that misplanting occurred in one section sowed with corn at a seeding interval that averaged 247 mm (40 seeds sown over 10 m). The sowing efficiency for both corn and soybeans was found to be 0.42 h/hm2. The average depth of soil over seed was 32.7 mm for soybean and 39.7 mm for corn. These average depths are within the stipulated range for the depth of soil over seed, which is 5 to 10 times the seed size. This study developed an efficient seeding machine that can simultaneously plant soybean and corn precisely, consequently improving forage yield and saving man-hours.

2.6 AGRICULTURAL VEHICLE

2.6.1 ACQUISITION OF NIR-GREEN-BLUE PHOTOGRAPHS FROM UNMANNED AIRCRAFT FOR CROP MONITORING.

Authors: Hunt Jr E.R., Dean Hively W., Fujikawa S.J., Linden D.S., Daughtry C.S.T., McCarty G.W.

Source title: Remote Sensing.

Affiliations: USDA-Agricultural Research Service, Hydrology and Remote Sensing Laboratory, BARC-West, 10300 Baltimore Avenue, Beltsville, MD 20705, United States; IntelliTech Microsystems, Inc., 2138 Priest Bridge Court, Suite 3, Crofton, MD 21114, United States; DSL Consulting, Inc., 7611 Kingfisher Court, Dexter, MI 48130, United States.

Date: 2010

ABSTRACT:

Payload size and weight are critical factors for small Unmanned Aerial Vehicles (UAVs). Digital color-infrared photographs were acquired from a single 12-megapixel camera that did not have an internal hot-mirror filter and had a red-light-blocking filter in front of the lens, resulting in near-infrared (NIR), green and blue images. We tested the UAV-camera system over two variably-fertilized fields of winter wheat and found a good correlation between leaf area index and the green normalized difference vegetation index (GNDVI). The low cost and very-high spatial resolution associated with the camera-UAV system may provide important information for site-specific agriculture.

2.6.2 REVIEW OF RESEARCH ON AGRICULTURAL VEHICLE AUTONOMOUS GUIDANCE

Authors: Zhang B., Luo X., Lan Y., Huang Z., Zeng M., Li J.

Source title: International Journal of Agricultural and Biological Engineering.

Affiliations: Graduate School of Agricultural and Life Sciences, The University of Tokyo, Japan.

Date: 2009

ABSTRACT:

A brief review of research in agricultural vehicle guidance technologies is presented. The authors propose the conceptual framework of an agricultural vehicle autonomous guidance system, and then analyze its device characteristics. This paper introduces navigation sensors, computational methods, navigation planners and steering controllers. Sensors include global positioning systems (GPS), machine vision, dead-reckoning sensors, laser-based sensors, inertial sensors and geomagnetic direction sensors. Computational methods for sensor information are used to extract features and fuse data. Planners generate movement information to supply control algorithms. Actuators transform guidance information into changes in position and direction. A number of prototype guidance systems have been developed but have not yet proceeded to commercialization. GPS and machine vision fused together or one fused with another auxiliary technology is becoming the trend development for agricultural vehicle guidance systems. Application of new popular robotic technologies will augment the realization of agricultural vehicle automation in the future.

2.7 IRRIGATION AND FERTIGATION

2.7.1 A WIRELESS SENSORS ARCHITECTURE FOR EFFICIENT IRRIGATION WATER

Authors: Navarro-Hellin H., Torres-Sanchez R., Soto-Valles F., Albaladejo-Pérez C., López-Riquelme J.A., Domingo-Miguel R.

Source title: Agricultural Water Management

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Date: 2015

ABSTRACT:

Water is an essential resource for the development of agriculture. In several locations like the south-east of Spain water is scarce and its cost is high, so optimal management of this important resource is essential. Therefore, the application of irrigation strategies to improve the watering process, affects the profitability of crops quite significantly. It is necessary to carry out the instrumentation of the variables that affect the growing process of the crop (soil, water and plant) and use the techniques associated with this instrumentation to take actions to optimize the production. The system proposed in this paper uses information and communication technologies, allowing the user to consult and analyze the information obtained by different sensors from any device (computer, mobile phone or tablet) in an easy and comfortable way. The proposed architecture is based on different wireless nodes equipped with GPRS connectivity. Each wireless node is completely autonomous and makes use of solar energy, giving it virtually unlimited autonomy. Different commercial sensors for measuring the wide range of parameters of the soil, plant and atmosphere can be connected to the nodes. The data is sent and processed on a remote server, which stores the information of the sensors in a database, allowing further consultation and analysis of data in a simple and versatile way.

2.7.2 AUTONOMOUS PRECISION AGRICULTURE THROUGH INTEGRATION OF WIRELESS UNDERGROUND SENSOR NETWORKS WITH CENTER PIVOT IRRIGATION SYSTEMS

Authors: Dong X., Vuran M.C., Irmak S.

Source title: Ad Hoc Networks

Affiliations: Cyber-Physical Networking Lab, Department of Computer Science and Engineering, University of Nebraska-Lincoln, Lincoln, NE 68588, United States; Biological Systems Engineering Department, University of Nebraska-Lincoln, Lincoln, NE 68588, United States.

Date: 2013

ABSTRACT:

Precision agriculture (PA) refers to a series of practices and tools necessary to correctly evaluate farming needs. The accuracy and effectiveness of PA solutions are highly dependent on accurate and timely analysis of the soil conditions. In this paper, a proof-of-concept towards an autonomous precision irrigation system is provided through the integration of a center pivot (CP) irrigation system with wireless underground sensor networks (WUSNs). This Wireless Underground Sensor-Aided Center Pivot (WUSA-CP) system will provide autonomous irrigation management capabilities by monitoring the soil conditions in real time using wireless underground sensors. To this end, field experiments with a hydraulic drive and continuous-move center pivot irrigation system are conducted. The results are used to evaluate empirical channel models for soil-air communications. The experiment results show that the concept of WUSA-CP is feasible. Through the design of an underground antenna, communication ranges can be improved by up to 400% compared to conventional antenna designs. The results also highlight that the wireless communication channel between soil and air is significantly affected by many spatio-temporal aspects, such as the location and burial depth of the sensors, soil texture and physical properties, soil moisture, and the vegetation canopy height. To the best of our knowledge, this is the first work on the development of an autonomous precision irrigation system with WUSNs.

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