Topic 5

“Automation, Remote Control, Robot and Innovative Vehicle”

Oral Presentation

Expert system with cloud database for optimal management of Fruit and Vegetable traceability

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Keywords: cloud, spraying, greenhouses

Objectives

The fresh fruit and vegetable sector is characterized by important number of treatments, whose operational complexity has increased with the release of new regulations and protocols which in fact significantly increases the risk for farmers, to carry out treatments to the outside of the guidelines that characterize each protocol. The paper presents an analysis of the initial work with the traceability requirements and development of a working prototype using the Delphi language, drawing on a database of rules distributed via cloud.

Methods

The requirements of the the application have been discussed by meetings with stakeholders, the chemical laboratory of the Chamber of Commerce of Turin and the Italian Confederation of Farmers. It 's been put in place a system of complex rules to implement the expert system and manage without errors treatments to fruit and vegetable crops in greenhouses and open field. The general rules are implemented for each chemical and are based on the following parameters: Name of commercial product; Adversity; Crop, Phenological stage; Protocol; greenhouse / open field, date of expiry of registration of the chemical.

The combination of the above parameters yield to complex detail rules, based on the following parameters: Maximum dose: L or kg of product per hectare (possibility of treating the entire surface or only the cultivated area); dose per hl: specify the amount of water must be used for the mix; safety time: days after treatment before the FFV can be collected; maximum number of treatments per crop, maximum number of treatments per family of chemicals; maximum number of treatments alternatively within a certain family of chemicals.

Expected Results

The procedure developed will allow for operators to verify, before treatment, which lots could be sprayed without problems (Green), where it can be done the last time (yellow light) and where it can not be carried out (red light). All this taking into account the different protocols of cultivation practiced by the farmer. The ultimate result should be a basis of knowledge of the rules governing the execution of the processing plant crops, which should allow operators to perform the treatments safely, in compliance with the rules and discipline imposed by the large retail chains or by national mandatory rules on the subject.

Automation and robotics for workers health and safety improvements in pot-plant nurseries

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Keywords: robotics, pot-plant nurseries, path control

Objectives

The pot-plants sector is very important in European agriculture, and employees a considerable number of workers. Most operations are still manually performed and many of them are critical for worker health and safety (Belforte et al, 2006). Pots handling is one of the most repetitive and heavy operations forcing workers to hazardous postures for musculoskeletal apparatus, whereas the high number of pesticide applications determines a strong exposition to toxic substances.
Robotic systems and automated machines able to perform repetitive and/or dangerous tasks could significantly facilitate and make safer the work in pot-plants nurseries where millions of pots are grown every year.
This paper discusses operations that can be conducted by automated, specific machines and presents the design of a multipurpose autonomous robot customized for pot-plants nurseries as well as other protected cultivations. Particular attention if focused on the control of the steering and path following systems.

Methods

Pot-plants are usually arranged in plots in greenhouses, walks in tunnels or outdoor. Crop unitary operations have been analysed observing workers in different periods of the crop cycle. The proposed robot has been conceived to operate on crops navigating over plots in autonomous way, by means of a ground reference consisting of a plastic strip laid on floor (for a detailed description of the system see Comba et al., 2012). The basic element is a four driving and independent steering wheels (4WIS) rover able to host different kind of implements. Propulsion and steering system will be implemented by electric motors installed into four wheel-modules and supplied by a generator or, in some specific cases, batteries. In order to change the wheels track, adapting it to the plots and corridors width, wheel modules are connected to the rover chassis by means of a pivot system. A number of 4WIS vehicles has been developed in the last decade (see e.g. Bakker, 2010; Cariou et al, 2009; Oksanen 2012; Simionescu & Talpasanu, 2007). All these vehicles use virtual links, implemented in the control software, to drive the four steering angles of the wheels. In particular most part of them refer to the Ackermann steering kinematic model to avoid the need for tyres to slip sideways when following the path around a curve (Simionescu & Talpasanu, 2007).
However, the narrow spaces in which the robot has to navigate in pot-nurseries make the Ackermann kinematic model (alone) unable to obtain the expected results. A 4WIS system,

with the steering angles of the four wheels really independent, can be able to follow a wider range of paths, allowing also sharp angles (not differentiable points in the path). This geometric driving system can allow to the rover to move in very crowded environment where only very narrow and sharp paths can be design.

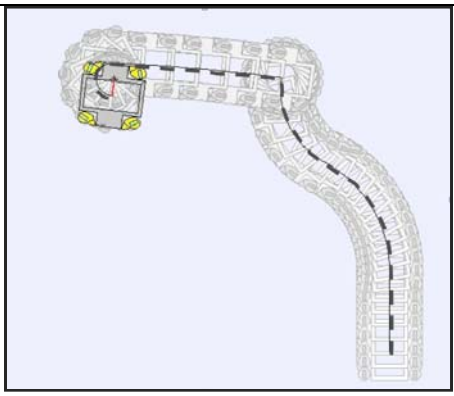

Figure 1: An example of feasible path which involves different kinematics models

Results

The introduction of a multipurpose autonomous robotic platform in the pot-plants farms will lead to significant improvements in terms of work safety as well as reduction of production costs. Pesticide applications will be carried out in automatic way avoiding the exposition of workers to dangerous compounds (Sammons, 2005). A precise distribution will also allow reducing the overall quantities of chemicals as well as the amount of pollutant scattered in the environment. At the same time, a number of highly repetitive tasks, such as pots handling, trimming and granular fertilization could be automatically performed by the robotic platform developing specific implements.

One of the most relevant open problems in the design of such kind of machines, which have been addressed in this work, is the control of the 4WIS module, once a viable path has been designed and assigned. There are some difficulties in solving this optimization problem. The main criticism relies in the definition of a criterion for determining whether a solution (set of steering and driving angles) is feasible or not. Some recent approaches (see e.g. Lun Lam et al., 2008) are based on the minimization of the wheel lateral force and/or of the slipping. The method proposed in this work is based on the adoption of a set of different kinematics (geometric) models that are implicitly feasible and described by a limited number of parameters. The optimization is then performed splitting the whole path in variable-length segments and associating to each of them the best kinematics model (with the respective parameters). An example of a not-smooth trajectory with a sharp edge is reported in Fig.1. As can be seen, the path of the robot is composed by different segments; in each of these segments a different kinematic models and/or parameterization has been choose by the optimization and control algorithm.

References

Bakker, T., Van Asselt, K., Bontsema, J., Muller, J., Van Straten. G. (2010). Systematic design of an autonomous platform for robotic weeding. Journal of Terramechanics, 47, pp. 63-73.

Belforte, G., Deboli, R., Gay, P., Piccarolo, P., Ricauda Aimonino. D. (2006). Robot Design and Testing for Greenhouse Applications, BioSystems Engineering, 95(3), pp. 309-321.

Comba, L., Gay, P., Piccarolo, P., Ricauda Aimonino, D. (2010). Robotics and automation for crop management: trends and perspective, International Conference on "Work Safety and Risk Prevention in Agro-food and Forest Systems", Ragusa, Italy.

Comba L., Finéz Martìnez S., Gay P., Ricauda Aimonino D. (2012). Reliable low cost sensors and systems for the navigation of autonomous robots in pot-crop nurseries. First RHEA International Conference on Robotics and associated High-technologies and Equipment for Agriculture, Pisa, Italy, 19-20-21 September.

Cariou C., Lenain R., Thuilot B., Berducat M. (2009). Automatic Guidance of a Four-Wheel-Steering Mobile Robot for Accurate Field Operations. Journal of Field Robotics, 26(6–7), 504–518

Lun Lam T., Qian H., Xu Y. (2008) Behavior-based steering control for four wheel independent steering vehicle. Robotics and Biomimetics, ROBIO 2008. Proc. of IEEE Int. Conf. on Robotics and Biomimetics, 536-541, Bangkok, Thailand, 22-25 February 2009

Oksanen T., Path following algorithm for four wheel independent steered tractor, CIGR-AgEng 2012 Conference, 8-12 July 2012, Valencia, Spain, con CD.

Sammons, P.J., Furukawa, T., Bulgin, A. (2005). Autonomous pesticide spraying robot for use in a greenhouse. Proceedings of the Australasian Conference on Robotics & Automation, Australia.

Simionescu P.A., Talpasanu I. (2007). Synthesis and analysis of the steering system of an adjustable tread-width four-wheel tractor. Mechanism and Machine Theory, 42, 526–540

Slaughter D, Giles D, Downey D. (2008). Autonomous robotic weed control systems: A review. Computers and electronics in agriculture, 61 (1), pp. 63-78.

Design of a remotely operable sprayer for precision farming application

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Abstract
The aim of this research activity is to develop a modular, fully customizable and remotely operable sprayer. This kind of device can be installed on-board a standard farm tractor/support machine or to be integrated on-board the U-Go robot that is under development with a joined project between the DiGeSA and the DIEEI and co-founded by MIPAAF. The aim of the U-Go robot is to improve worker safety level during harmful operation inside greenhouses as chemicals distribution. The robot has autonomous navigation capabilities and the on-board computer can send command to the sprayer and receive information from the sprayer sensors. All the sprayer parameter can be accessed and modified during operation. These features are not very common in commercial computer controlled sprayer unit that normally use only a touch screen panel as user interface.
The device is composed by a hydraulic subsystem and an electronic control unit. The hydraulic part of the sprayer is composed by a 130 l tank with 5 l hand-wash separated reservoir, an electrical actuated pump, a manual pressure regulator, an electric flux regulator, a pressure sensor, a flow rate meter and two electric on/off valves. These two valves can supply two vertical bar equipped with anti-drop, high pressure nozzles for spraying operation inside a standard tomato greenhouse. The pump has a nominal maximum pressure of 25 bar and a maximum flow of 20 l/m. The electronic control unit is composed by two digital/analog I/O modules with Ethernet interface that allows to remotely operate the different hydraulic component and read information from sensors and to manage other control unit parameter. The Ethernet interface will allows remote operation from the robot on-board computer as well as any other remote station with an internet connection using a suitable command set. The proposed architecture, being very modular, will allow component (sensor, actuators) to be added in an easy way.
At this stage the sprayer unit is being mounted on-board the U-Go robot. In the meanwhile the electronic control unit is under development at DIEEI laboratory and preliminary functional test has been performed. In order to make totally transparent to a mid-level user all the low-level hardware behaviour, a suitable software server has been developed. In this way, user command can be sent as high-level string and sensor information can be received as numeric text string. As the whole system will be integrated, complete test will be performed.

Keywords: robot, safety, modular sprayer

Objectives
The aim of this research activity is to develop a modular, fully customizable and remotely operable sprayer. This kind of device can be installed on-board a standard farm tractor or on a support machine. One of the most important applications of the device is to be integrated on-board the U-Go robot that is under development with a joined project between DiGeSA and the DIEEI department of University of Catania and co-founded by MIPAAF. The aim of the U-Go robot is to improve worker safety level during harmful operation inside greenhouses as chemicals distribution (Balloni et al. 2009), (Schillaci et al. 2010). The robot has autonomous navigation capabilities and can support the sprayer unit. The robot on-board computer can

send command to the sprayer and receive information from the sprayer sensors; all the sprayer parameter can be accessed and modified during operation.

Materials and methods

The sprayer unit is composed by a hydraulic subsystem and an electronic control unit. The hydraulic part of the sprayer is composed by a 130 l tank with 5 l hand-wash separated reservoir, an electrical (for safe operation inside greenhouse) actuated pump from Bertolini with an 1 kW Seipee DC motor with gearbox, a manual pressure regulator with pressure indicator, an electric flux regulator from Arag, a pressure sensor from Arag, a flow rate meter from Arag and two electric on/off valves from Braglia. These two valves can supply, with the chemical fluid, two vertical stainless steel bar equipped with anti-drop, high pressure nozzles from Braglia for spraying operation inside a standard tomato greenhouse. The pump has a nominal maximum pressure of 25 bar and a maximum flow of 20 l/m. In Figure 1, a drawing that represent the hydraulic subsystem is shown. In that scheme, only the main connections are represented. All the recirculating connections and filters have been omitted for sake of clarity.

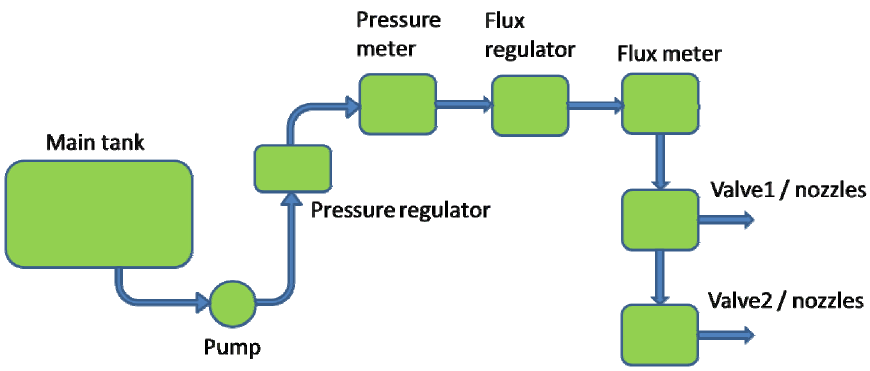

Figure 1. Schematic representation of the hydraulic subsystem

The electronic control unit is composed by two digital I/O and analog I/O modules with Ethernet interface that allows to remote operate the different hydraulic component (valves, flow regulator, pump) and read information from pressure sensor, flow rate sensor and other control unit parameter (main breaker status, pump current, flux regulator valve status and so on). The Ethernet interface allows remote operation from the robot on-board computer as well as any other remote station with an internet connection using a suitable command set described in next paragraph. In Figure 2 the electric scheme is shown.

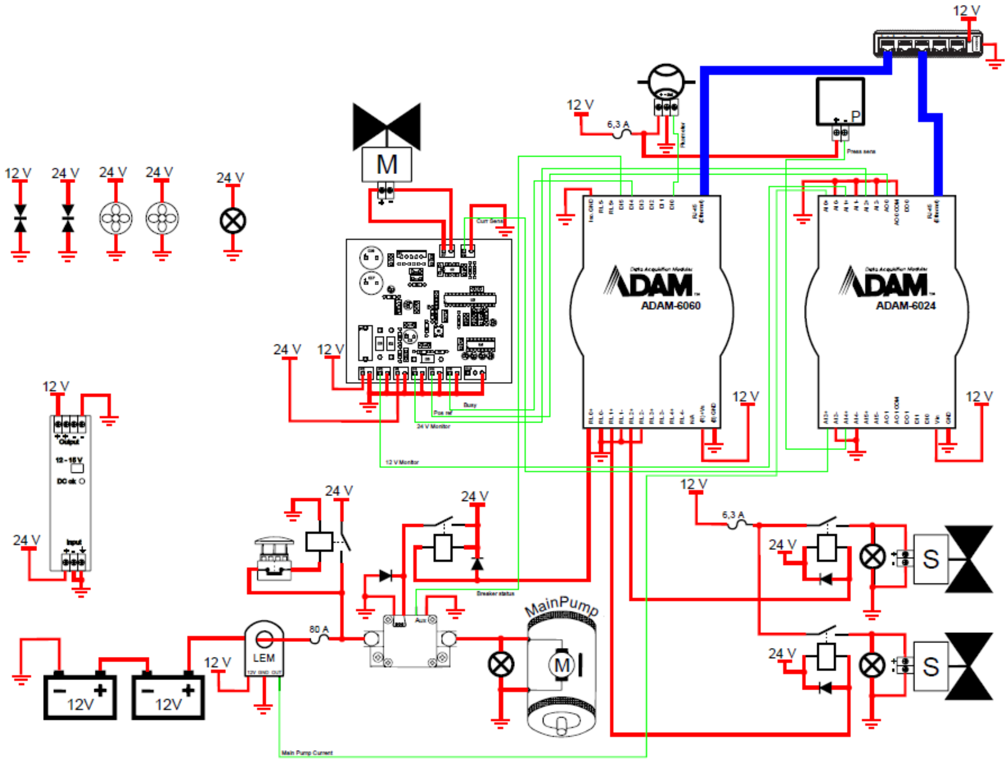

Figure 2. Electric connection for the sprayer control unit subsystem

As can be seen in Figure 2, the two On/Off valves are controlled by two different relè. In the same way, the main pump is controlled by a power relè that provide also an auxiliary contact for monitoring relè status. Using an Hall Effect current sensor, the pump current can be monitored. Pressure sensor and flux meter are directly connected to the two Adam modules. In more details, pressure sensor has a 4-20 mA output type while the flux meter has a pulsed output in which the pulse rate is related to the corresponding flow. In order to control the flow regulator valve, a custom electronic board, based on a low cost 8-bit microcontroller, has been designed and realised. The valve relies on a DC motor that move a butterfly valve. The specific firmware developed for that electronic board, allows to control the absolute butterfly valve position starting from an analog signal in the range [0..10 V], controlling the relative motion of the DC motor of the valve. The sprayer control unit contains also a DC-DC converter that provide a +12 V supply rail for the different valves and sensors and a mushroom security switch that allows to stop sprayer operation in emergency situation. An Ethernet switch is also provided in order to realise all the Ethernet connection of the two Adam modules to the robot network.

In order to control the sprayer control unit, different software modules have been developed using a client/server paradigm. In Figure 3, the used software architecture is represented.

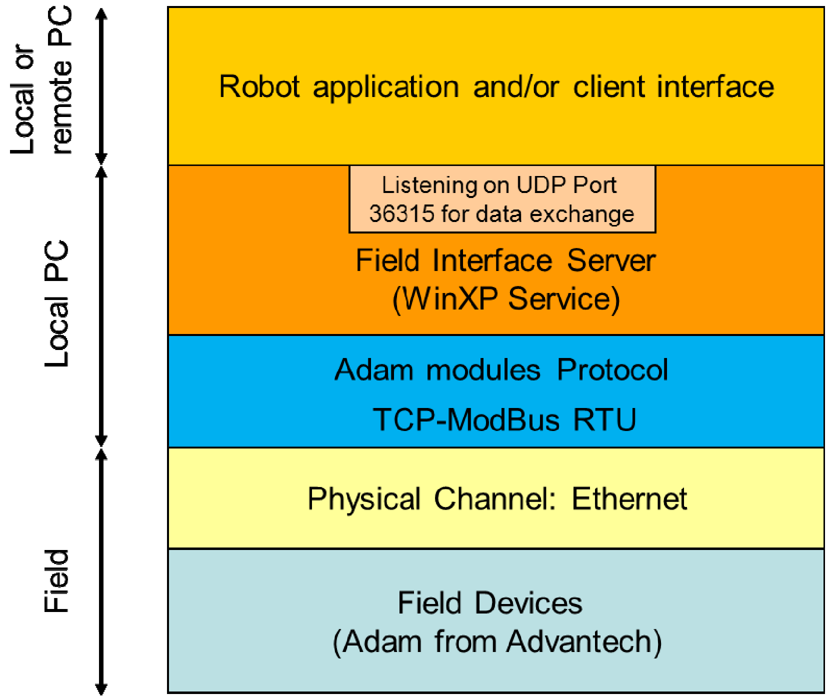

Figure 3. Graphical representation of the used software architecture

The two Adam modules used to realise all the interfaces with the field devices and sensors, relies on an Ethernet connection using a TCP/IP based ModBus RTU protocol. This communication is based on a specific DLL library available from Advantech. In order to hide to the user all the register configuration and addressed of the two Adam modules, a Field Interface Server has been developed. Because the robot on-board PC operating system is Windows XP, this server has been implemented as a system service. At the top of the used software architecture, there is an UDP connection between the server and the robot control software (for example the navigation and obstacles avoidance software). For testing and debug purpose, a standard UDP client able to send ASCII strings can be used. For the communication between the client side application and the server side, a suitable command set has been defined. In Figure 4 the used command dictionary is reported. Here is also possible to see the physical channel used for a specific signal to/from the sprayer unit and the related register address in the Adam module register file.

Azione	Nome comando	Parametro	Risposta server	Tipo	Range	Protocol	Com Port	Indirizzo IP	Channel	Register	Device
Corrente assorbita dalla pompa principale	MainCurr?	**	"Current"	Sensor	[0-50] A	ModBus-TCP	**	10.0.0.240	AI0	1	ADAM-6024
Stato 12 V	AuxPS?	**	"Voltage"	Sensor	[0-12] V	ModBus-TCP	**	10.0.0.240	AI1	2	ADAM-6024
Stato 24 V	MainPS?	**	"Voltage"	Sensor	[0-24] V	ModBus-TCP	**	10.0.0.240	AI2	3	ADAM-6024
Corrente assorbita dal regolatore di flusso	FluxRegCurr?	**	"Current"	Sensor	[0-3] A	ModBus-TCP	**	10.0.0.240	AI3	4	ADAM-6024
Misura pressione agli ugelli	SprayerPress?	**	"Press"	Sensor	[0-20] bar	ModBus-TCP	**	10.0.0.240	AI4	5	ADAM-6024
Regolazione flusso	FluxReg!	Flux [l/m]	Done!/Err!	Actuator	[0-20] l/m	ModBus-TCP	**	10.0.0.240	AO0	11	ADAM-6024
Misura flusso verso gli ugelli	SprayerFlux?	**	"Flux"	Sensor	[0-20] l/m	ModBus-TCP	**	10.0.0.250	DI0		ADAM-6060
Stato del regolatore di flusso	FluxRegBusy?	**	0/1	Sensor	0/1	ModBus-TCP	**	10.0.0.250	DI4	5	ADAM-6060
Breaker status	BreakStat?	**	0/1	Sensor	0/1	ModBus-TCP	**	10.0.0.250	DI5	6	ADAM-6060
Accensione spegnimento pompa principale	PumpContr!	0/1	Done!/Err!	Actuator	0/1	ModBus-TCP	**	10.0.0.250	RL0	17	ADAM-6060
Comando apertura chiusura valvola 1	Valve1!	0/1	Done!/Err!	Actuator	0/1	ModBus-TCP	**	10.0.0.250	RL1	18	ADAM-6060
Comando apertura chiusura valvola 2	Valve2!	0/1	Done!/Err!	Actuator	0/1	ModBus-TCP	**	10.0.0.250	RL2	19	ADAM-6060
Inizio richiesta dati	Hi!	**	Welcome!								
Fine richiesta dati	Bye!	**	See you..								
nop	comando sconosciuto	**	Err!								

Figure 4. Command reference for the client side application

For example, sending the text string "MainCurr?" to the server (using any kind of UDP client or the robot control application), the server will report the current drained from the batteries by the main pump. If the command "Valve1!1" is issued to the server, the On/Off valve 1 will switch on while the command "Valve1!0" will switch off the same valve.

Conclusion

In this work the design of a fully customizable, remotely operable sprayer unit is described. These features are not very common in commercial computer controlled sprayer unit that normally use only a touch screen panel as user interface and a speed sensor to be mounted on a tractor wheel, but are very important in the context of a research project.

All the hydraulic subsystem has been designed in order to meet all specification for spraying chemicals inside tomatoes greenhouses taking into account that the sprayer has no fan. Suitable sensors and actuators have been included in order to gain full control over the spraying process. In order to allows automatic control of the sprayer unit, an electronic control unit has been developed. Also this subsystem has been endowed with different sensors to monitor unit behaviour.

In order to make totally transparent to a mid-level user all the low-level hardware behaviour of the control unit, a suitable software server has been developed. In this way, user command can be sent as high-level string and sensor information can be received as numeric text string.

The proposed architecture, being very modular and Ethernet based, will allow component (sensor, actuators) to be added in an easy way.

Acknowledgment

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References

Balloni S., Caruso L., Conti A., Schillaci G., Longo D., Muscato G., "Development of an electrical multifunctional autonomous vehicle able to cultivate covered crops and to safe distribute agricultural chemicals inside greenhouses", Proceedings of the XXXIII CIOSTA - CIGR V Conference 2009, pp 355-359, Vol 1, June 17-19 2009, Reggio Calabria, Italy. ISBN 978-88-7583-031-2

Schillaci G., Bonsignore R., Pennisi A., Longo D., Muscato G., "A multifunctional remote controlled and/or autonomous electrical vehicle able to operate in slope vineyard", Proceedings of the Third International Congress on Mountain Steep Slope Viticulture, Castiglione di Sicilia (CT), Italy, 12-14 May 2010.

Designing and testing a new small tractor prototype for the mechanisation of terraced-vineyard farming systems in South-Tyrol

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Abstract
A new tractor prototype suitable to be used in extreme slope conditions of hilly and mountain areas is here proposed and described. It was primarily designed to address the problem of working in vineyards trained with the so-called "*pergola*" system, that has a long tradition in South Tyrol and it is still very common in the mountain sides of this Province, being the most suitable training system required by the typical vine varieties here cultivated (*Lagrein* and "*uva schiava*"). "*Pergola*" is even well suited to the terrains cultivated through terracing methods, that permit to extend farming practices until 130% of slopes. Anyhow, its use involves many mechanization problems mainly due to need to face with limited transit widths and heights (<1,10 m and <1,70 m, respectively) available below the *pergola* itself and to the presence of steep and very narrow-angle curves in the row heads, with great difficulties of manoeuvre. The prototype here presented was designed and constructed by a local machine constructor under the suggestions of a team of farmers wishing to find viable solutions to overcome the above problems. This is based on an unconventional design concept: it looks like a tool-carrier 20 kW power rated tractor formed by an articulated body and fully driven by hydraulic transmissions. It was tested both on laboratory, for a general characterization of its features according to official OCSE measures, and in field for a comparative evaluation of its performances with the traditional equipment commonly applied in the same environmental conditions.

Keywords: articulated tractor, small mechanization, tractor stability, mountain mechanization

Introduction
The Faculty of Science and Technology of the Free University of Bolzano (FUB) has recently completed the works of a research project entitled "*Tractor 360° - A new tractor concept for use in extreme conditions*". The project, funded by the Innovation Department of the Autonomous Province of Bolzano, was managed under the responsibility of a local SME (*WM Ltd, Prato all'Isarco, BZ*), that is a European leader of machines for the maintenance of ice rinks and recently interested in diversification and technology transfer activities focused on the development of proper mechanization solutions for the mountain agricultural environments of South Tyrol.

The initiative arose from the needs of a group of farmers dealing with mechanization problems in the St.Magdalen production district, i.e. a typical wine-growing area located in the mountain slopes surrounding the town of Bolzano and characterized by a predominant presence of vineyards cultivated with the classical training system named "*pergola*". This system is nowadays tending to decline in favor of vertical trellis systems (such as *guyot*) where the mechanization is more easily feasible. Nevertheless, many farmers still consider the pergola system as essential for particular vine varieties grown here (such as *Schiava* and

Lagrein), owing to the most favorable dynamics of grape maturation it provides despite its major problems of mechanization. In short, the latter are mainly due to: *i)* the presence of terraces with very narrow transit widths (<1,10 m), *ii)* the need of having to make turning movements and maneuvers in narrow headlands, often featured by slopes greater than 60%, and *iii)* presence of a small workspace directly beneath the *pergola* (<1,70 m), usually not even enough to accommodate a man standing at work.

In the case of the terraces, as is known (Cost-Folch et al., 2006; Ramos et al., 2007), the higher the slope, the more restricted is the transit width available in the space below the *pergola*. Generally speaking, the tractors of conventional mechanization systems can be hardly adapted to terraced mountain environments featured by slopes greater than 40%. In addition, the relevant lack of space beneath the *pergola* usually doesn't allow tractors to work with their devices ROPS properly positioned (they are usually rotated in a horizontal position). The need to find alternative solutions to ensure an efficient and safe use of machinery in these contexts is therefore particularly felt.

State of the art and requirements for new mechanization systems

The aforesaid "*extreme environments*" does not constitute contexts of niche. Indeed, these situations are widely distributed at national and international level in relation to both intensive (e.g., viticulture areas in France or Germany, such as Mosel) or extensive (e.g., cultivation of olive trees in many marginal Mediterranean regions) farming systems. Consequently, a correct analysis of requirements for more adequate mechanization systems cannot ignore issues related to the *multi-functionality of the machines* that are going to be considered.

The technical requirements on which the entire project was developed were intended to focus on the need to build a new power unit for use primarily in hilly and mountain farming systems and able to meet the following operational objectives:

- ability to operate in the agricultural context featured by very narrow spaces, in terms of transit width and height (which is the case of the aforementioned *pergola* training system),
- ability to operate in high sloped environments (with peaks up to 65-70%), both during *actual* (i.e. *effective*) work, and *auxiliary* works (maneuvers, turns, journeys for movements or transports etc.),
- ability to allow quick and safe maneuvers in very confined spaces, often characterized by sudden changes in steepness, possibly without the need to make arrests and reverse speeds during maneuvers themselves,
- ensure performance as much as possible similar to the crawlers, without, however, suffer their typical operating limitations (low ergonomics, inability to pass on asphalted roads, adaptability to the ground etc.), in particular, avoiding the danger of erosion phenomena facilitated by the formation of deep furrows in the ground at the points of maneuvering or when reversing the direction of work,
- ensure adequate safety standards for the stability of the machine, especially with reference to the risks of lateral and longitudinal stability (rolling and tipping),
- ensure appropriate ergonomic standards, to ensure comfort to the drivers when working for long periods, in relation to both the risks of occupational diseases (in case of excessive exposure to conditions of various physical stress such as vibrations, noise and temperature), and the need of wellness during the execution of the work itself.

The range of commercial low-power, compact-utility tractors nowadays available already offers potential solutions that partly meet the above requirements. Among these, it is worth mentioning the possible use of: *i)* wheeled or tracked walking tractors, *ii)* wheeled small tractors (<20 kW, usually with isodiametric wheels), *iii)* small crawler power units (< 20kW), usually equipped with rubber tracks, also available as carrier tool version, permanently equipped with an on board sprayer, and *iv)* double half tracked articulated medium power units (65 kW), equipped with rubber crawlers, that despite their excellent maneuverability and operational flexibility, are usually too large for using in terraced pergola contests.

Each of these solutions has its own advantages and disadvantages. However, in the case of the pergola training systems, the disadvantages tend to prevail. This often led farmers to try to set up some personal solutions (directly in their own farm workshop), usually either providing changes to existing commercial solutions (walking tractors or crawlers), or developing new prototypes autonomously. Although working, they have always been provisional solutions, being largely constrained by several problems such as the lack of safety measures, poor ergonomic conditions, low labor productivity and lack of skilled technical assistance (Fargnoli et al., 2010; Fritz et al., 1991; Guan et al., 2011).

The prototype here proposed

The prototype was then designed to fulfil the following features: *a)* track as narrow as possible, *b)* centre of gravity as low as possible, *c)* absence of the cabin in order to limit the overall dimensions of the machine, which has been so provided with removable and/or reclining ROPS, *d)* articulated chassis to enable the highest performance in manoeuvring, *e)* propulsion system consisting of 4 permanent driving rubber wheels, *f)* wide use of hydraulic transmissions in order to simplify the mechanical connections between the front and the rear part of the chassis in a machine that is already featured by small size, *g)* high visibility and accessibility for operators, with the driver's seat to be placed directly in front of the machine, and *h)* oversimplification of the pilot's control board, by using a joystick instead of the conventional steering wheel /dashboard solution.


Figure 1. View of the first (left) and second prototype (right) here proposed. The former is equipped with a sprayer, the latter as dumper version front-coupled with a brusher.

This approach has also led to consider the need to identify multifunctional solutions, which in perspective could be potentially extended also to applications that are external to orchard farming systems or even to the agricultural sector. As a result the machine architecture was designed by providing a *front train* as the location of the main engine components and the driving seat, and a *rear train* as a platform on which the carried-implements that are necessary can be time to time mounted. So, we arrived to the development of a tractor with unprecedented architecture that, according to the current terminology (Molari and Rondelli, 2006), can be classified as a *narrow track width, tool-*

carrier articulated tractor. During the research period two distinct prototypes were developed (Figure 1). The former aiming at defining the general performances of the whole architecture of the new machine. The latter to improve the features of construction, with special reference to safety conditions of the machine. The second version also provides the possibility of coupling some small-size implements, through a front three-point hitch, directly positioned just under the point of observation of the driver.
seen as the main use), *b) mower*, *c) stalk chopper*, *d) brusher* for weed control, *e)* container for transporting bulk commodities (*dumper* version, Figure 1). The present model, therefore, is also already suitable to be applied to extra-viticulture operations, such as mowing, haymaking and transport and handling activities in the farm centre. Further potential fields of application could include: 1) *skidding* operations in coppice woods (skidder), 2) *fertilization*, with liquid or granular materials (according to conventional or site-specific approaches), 3) *weeding*, *earthing up* and hoeing on row crops, 4) *leveling* of small areas.

The version realized so far allows to operate with the following tools: *a)* atomizer (to be

In addition, it is also possible to foresee the extension its use to urban contexts for maintenance activities such as cleaning streets and sidewalks (as snowplow, street sweeper, harvesting of tree debris), mainly thanks to its extreme flexibility, able to perform manoeuvres in confined spaces. Thus, the concept "*of action at 360°*" cited in the original title of the project would be fully satisfied.

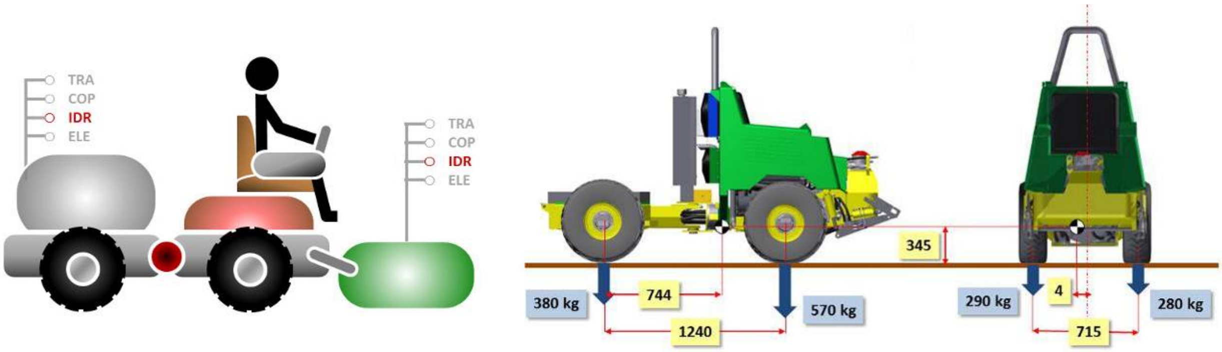

Figure 2. Architecture (left) and construction details (right) of the second prototype. The red circle and the red shape on the left indicate the point of the steering frame and the position of the engine, respectively. Dimensions on the right are in mm.

Materials and methods

The general scheme of the second prototype, including its related sizes and main features, are shown in Figure 2. The machines were tested both on laboratory and on field conditions following well consolidate approaches already proposed in literature (Chang et al., 2011; Crossley and Kilgour, 1983; Fabbri, 2004; Fargnoli et al., 2010; Silleli et al, 2007). The former for a general characterization of its features according to official OCSE measures and for verifying the *ergonomics and safety conditions* of the machine, the latter for carrying out a comparative evaluations with traditional equipment.The ergonomic tests involved the exposure to vibrations and noise which can be applied to the driver in various operating conditions.

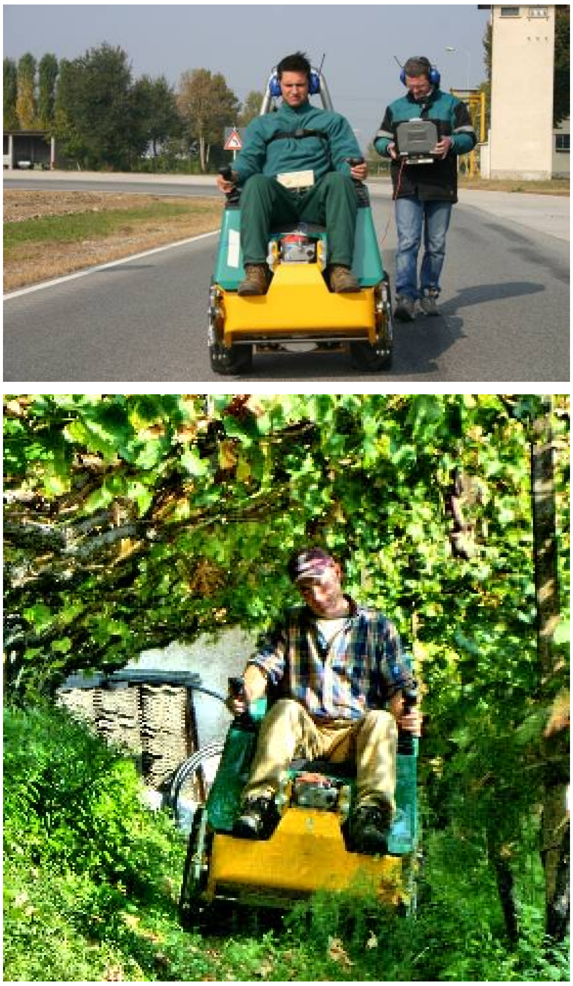

Figure 3. The second prototype during laboratory (vibration tests on asphalt) and field test.

With regard to the *vibrations*, the asphalt was firstly considered as reference surface (Figure 3) on which the tractor may perform both in-farm and out-farm activities, such as movements and transports. In addition, we have considered also some natural surfaces that may feature the among row space in vineyard at various roughness degree, such as: *i)* bare ground well leveled, *ii)* grass covered land and *iii)* bare soil with skeleton prevalent.

The tests were carried out at two forward speeds (2.0 and 4.0 km/h) and were planned to acquire - using tri-axial accelerometers placed both on the sitting and on the back of the driver's seat - the vibrations transmitted to the operator in the three reference axes: longitudinal (**x**), transverse (**y**) and vertical (**z**). In addition, by a further single-axial accelerometer placed on the tractor hood, the vertical stresses (**z**) transmitted to the hood were recorded, as well, in order to evaluate the damping effect of the seat without a suspension. The analysis of data was twofold concerning both the *health risks* and the *comfort needs*. With regard to health aspects, an early risk assessment was obtained from the analysis of vibration data along the **z** axis, ie the one parallel to the driver's backbone and, therefore, and as such more influential on the risk of professional diseases. The data were then compared with the minimum safety requirements in order to identify possible health risks. With regard to comfort aspects, the acquired data were then processed according to the indications given in the reference standard here used to obtain the so-called *Comfort Index* (CI) expressing a concise judgment on driver's comfort conditions.

With regard to *noise tests*, finally, we proceeded on asphalt taking care not to exceed the maximum speed of 4.8 km/h and highlighting the different operating conditions that were determined by the switching on of the cooling fan, placed very near to the driver's head.

Results

As far as the laboratory survey is concerned, the lateral stability test revealed a rollover angle of 43.8°, highlighting the particular prototype ability to work in relevant slope conditions. The lateral slop on flat terraced space is never greater than 20° and on field tests the machine was able to climb up slopes of 78% (38°). Besides, a traction coefficient equal to 0.63 was measured on paved track tests (T = 6000 N). This value underlines the suitability of the machine to be used also for traction applications on difficult environment (e.g. skidding on coppice forests).

Table 1. Vibration test results

Parameter	Test conditions							
	Asphalt		Well leveled bare soil		Grass covered soil		Skeleton soil	
Speed (km/h)	**2**	**4**	**2**	**4**	**2**	**4**	**2**	**4**
Accel. sitting (x)	0,11	0,14	0,25	0,36	0,24	0,47	0,38	0,49
Accel. sitting (y)	0,16	0,12	0,31	0,47	0,33	0,57	0,37	0,57
Accel. sitting (z)	**0,29**	**0,35**	**0,44**	**0,97**	**0,48**	**1,29**	**0,65**	**1,22**
Accel. back seat (x)	0,44	0,74	0,70	1,17	0,62	1,09	0,67	1,28
Accel. back seat (y)	0,20	0,37	0,53	0,77	0,50	0,93	0,64	1,12
Accel. back seat (z)	0,12	0,14	0,33	0,51	0,27	0,88	0,49	1,12
Accel. hood (z)	0,82	1,17	0,94	1,49	1,00	1,82	1,14	1,74
Compfort Index (IC)^2	**0,50**	**0,73**	**0,86**	**1,51**	**0,83**	**1,80**	**1,04**	**1,87**

Legend:

Professional Risks on Health		**Comfort conditions**
No risk	green	*Comfortable*
Possible risk: take necessary precautions.	yellow	*Not Comfortable*
Danger: reduce working time	red	*Absolutely not comfortable*

The results of *vibration tests* are reported in Table1. From their analysis it can be observed that the transit on asphalt does not present any risk to the operator. In contrast, in the other cases the risk increases with the speed and with the degree of roughness of the surface. The risk is moderate on well leveled bare soils, while significantly increases on the parcel with skeleton prevalent. Anyhow, this is in accordance to what we expected, especially considering the present version of the prototype, still without any elastic suspension apart from the tires (inflated to 160 kPa) and the seat upholstery consisting of a polyurethane foam of 60 mm thickness. This upholstery, however, offered interesting performances when comparing the values of vertical accelerations (z) recorded on the hood, with those recorded on the seat cushion: it can be noted how the seat, with its foam, was significantly able to dampen acceleration transmitted to the operator on z-axis, despite the absence of silent-blocks between the frame and hood, or any active suspension in the seat itself. With regard to the comfort, the index IC displays results similar to those recorded for the safety, even if with ratings more stringent as regards the higher speeds, in all test conditions.

The maximum *noise levels* recorded at operator's ear (at 4.8 km/h on asphalt) were on ave. 83.3 and 84.5 dB, respectively without and with the cooling fan running. These values are aligned with the ones of the 4WD orchard/vineyard tractors without closed cabin. It is, however, highly recommended the use of ear muffs in case of prolonged work.

As far as *field tests* is concerned, always carried out during sprayers applications on vineyards, the surveys were mainly focused on operational performances. It was thus possible to find an overall work rate greater than 33% when compared to conventional walking driven equipment (say, the only ones that can be used in such extreme conditions). In details, in vineyard with row width <1.80 m, the prototype ensured a 1.00÷1.12 ha/h work rate. Conversely the common mechanisation solutions, when applied to the same operation, had only a 0.77÷0.82 ha/h work rate. The steering time is decreased by 30-40%.

Conclusions

All considered, the prototype always showed positive results mainly on the following aspects:

1. worker's comfort: driver's seat is comfortable and permits an easy control of the operations during the work; indeed, it is easily accessible if compared with other small tractors with analogous rate-power already commercially available;

2. safety feeling: the driving place is often perceived as very safe as it has no obstacle in front it, so the operator can have an easy accessibility and fast escape in case of overturning (when working with declined ROPS below *pergola*, the operator is allowed to stay with the unfasten belt;

3. easy manoeuvrability in headland and good labour productivity: the articulated structure of the tractor and his independent drive axles ensure good field performances: tests showed high adherence and good manoeuvrability also with close steering angle. So, in the headlands it has the possibility to shift directly from a row in the following one, without manoeuvring and halting;

4. transit in the rows: the narrow track wheel (715 mm), the all wheels drive system (AWD) and the low position of the centre of gravity (345 mm) allow to transit without troubles through rows with width of 1.10-1.20 m in plan. The prototype can also reach higher speed than the conventional mechanisation especially than the crawlers;

5. interaction machine-soil: the prototype enabled a very low impact at soil level, mainly in the headlands. Indeed the soil damage caused by the prototype is insignificant if compared to a tracked tractor;

The machine has proved to be very suitable to operate in extreme slope. Improvements will be made especially to fully meet safety standards prior its final commercialization.

References

Bonsignore R., Romano E., Manetto G., Caruso L., Schillaci G. 2010. Development of a towed multi-function row straddling machine for the cultivation of goblet vineyards. Proc. Work Safety and Risk Prevention in Agro-food and Forest Systems. Ragusa, Italy 16-18 September, 368-373.

Chang, D., Kim M., Kim K., Huh Y., Cho B., Chung S. 2011. Development of a small tractor for european orchard farming. Paper presented at the American Society of Agricultural and Biological Engineers Annual International Meeting 2011, , 2, 1480-1486.

Cots Folch R. 2006. Land terracing for new vineyard plantations in the north-eastern spanish mediterranean region: Landscape effects of the EU council regulation policy for vineyards' restructuring. Agriculture, Ecosystems Environment, 115(1-4), 88-96, doi: 10.1016/j.agee. 2005.11.030.

Crossley C. P., Kilgour J. 1983. The development and testing of a winch-based small tractor for developing countries. Journal of Agricultural Engineering Research, 28(2), 149-161. doi:10.1016/0021-8634(83)90084-7.

Fabbri A. 2004. Static measurement of the centre of gravity height on narrow-track agricultural tractors. Biosystems Engineering, 87(3), 299-304. doi: 10.1016/j.biosystemseng 2003.12.008.

Fargnoli M., Laurendi V. and Tronci M. 2010. A risk assessment procedure for the user of narrow track tractors. Proc. Work Safety and Risk Prevention in Agro-food and Forest Systems. Ragusa, Italy 16-18 September, 99-106.

Fargnoli M., Laurendi V., Tronci M. 2010. Design for safety in agricultural machinary. Proc. DESIGN 2010, Dubrovnik, Croatia, May 17-20, 701-710.

Fritz E. A., Case J. I., Switalski,W. G. 1991. Small agricultural tractor ROPS - new operator protective zone. SAE (Society of Automotive Engineers) Transactions, 100(Sect 2), 201-218.

Guan J., Hsiao H., Zwiener J. V., Current R. S., Lutz T. J., Cantis D. M. 2011. Evaluating the protective capacity of two-post ROPS for a seat-belted occupant during a farm tractor overturn. Journal of Agricultural Safety and Health, 17(1), 15-32.

Molari G., Rondelli V. 2004. On the definition of narrow-track wheeled agricultural tractors. Biosystems Engineering, 88(1), 75-80. doi:10.1016/j.biosystemseng.2004.02.001

Paul D. B., Kluger Y., Jeret J. S., Shackford S. R., Jacobson S., Abbuhl, S. 1993. Lawn and garden tractor accidents: Small machines-big injuries [2]. Journal of Trauma, 35(3), 489-494.

Ramos M.R., Cots-Folch R., Martínez-Casasnovas J.A. 2007. Sustainability of modern land terracing for vineyard plantation in a mediterranean mountain environment - The case of the Priorat region (NE spain). Geomorphology, 86(1-2), 1-11. doi: 10.1016/j.geomorph 2006.08.004.

Silleli H., Dayoğlu M. A., Gültekin A., Ekmekçi K., Yıldız M. A., Akay E. 2007. Anchor mechanism to increase the operator clearance zone on narrow-track wheeled agricultural tractors: Prototype and first tests. Biosystems Engineering, 97(2), 153-161. doi: 10.1016/j.biosystemseng.2007.02.016.

First investigation on the applicability of an active noise control system on a tracked tractor without cab

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Keywords: sound pressure level, attenuation, agricultural machine

Aim

In last years, several research teams pointed their attention on the application of active noise control systems (ANC) inside the cabs of agricultural tractor and industrial vehicles, with the purpose of reducing the driver exposition to noise, that is only partially controlled by the frame of the cab.
This paper reports the results of a first experience that aimed at verifying the applicability of an ANC on a medium-high power, tracked tractor without cab.

Methodology

The tested tractor was a Fiat Allis 150 A, equipped with rear power take off, used in the execution of deep primary tillage in compact soils. It is a tracked tractor without cab, with maximum power of 108.8 kW at 1840 min^{-1} of the engine. The ANC consists of a control unit box based on a digital signal processor (DPS), two microphones, two speakers and a power amplifier. The instrumentation used in noise data collecting and processing consisted of a multichannel signal analyzer (Sinus - Soundbook), a ½" microphone capsule and an acoustic calibrator, both Bruel & Kjaer.
The study aimed at evaluating the behaviour of the ANC by means of tests carried out under repeatable conditions, characterized by pre-defined engine speed values. Three replications have been made for each engine speed. The sampling time was 30 s. Two series of tests were performed in order to compare the results observed with the ANC on and off. The engine speed adopted in the study ranged from 600 min^{-1}, up to 2000 min^{-1} (maximum speed) with steps of 100 min^{-1}.

Results and Conclusions

The ANC proved to be effective particularly in the interval of speed between 1400 and 1700 min^{-1}, where the samplings have been intensified, adopting steps of 50 min^{-1}. In such an interval, the attenuation observed with the ANC system on appeared evident both as weighed A sound pressure level (from 1.29 up to 2.46 dB(A)) and linear (from 4.54 up to 8.53 dB). The best performance has been observed at the engine speed of 1550 min^{-1}, with attenuations, respectively of 2.46 dB(A) and 7.67 dB. Outside of the engine speed interval 1400 - 1700 min^{-1}, the attenuations always resulted lower than 1 dB(A) for the weighed A sound pressure level and between 0.66 and 7.72 dB.

Detecting tomato crops in greenhouses using a vision based method

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Abstract
Precision Farming is generally defined as an information and technology basedfarm management system that allow to identify, analyse and manage variability within fields for optimum profitability, sustainability and protection of the land resource (Singh).
The use of intelligent systems could significantly contribute to increase overall performances in intensive culture management and production efficiency, reducing costs, and, not least, to improve labour quality and safety.
This work targets the problem of the implementation of a machine vision algorithm that allow tomato detection in images and, as future development, once it will be integrated with arobot (Balloni*et al.* 2009, Longo *et al.* 2010, Schillaci*et al.* 2009), it will be really useful to perform precision farming activities: fruit classification, harvesting, local chemicals treatment etc.
The overall tomatoes detection architecture is built around a method for classifying individual imageregions. This is divided into two phases. The *off-line* learning phase creates a binary classifier thatprovides object/non-object decisions for fixed sized image regions ("windows") while the *on-line*detectionphase uses the classifier to perform a dense multi-scale scan reporting preliminary objectdecisions at each location of the test image. These preliminary decisions are then fused to obtain the final object detections. The approach is *data-driven* and purely bottom-up using low-level visual features to detect objects.
The performance of the method depends strongly on the dataset creation (as much bigger is the dataset as better the machine vision will know about a tomato) and detector choice (which is the best representation of the tomato class?).

Keywords: precision farming, computer vision, support vector machine

Introduction
Agricultural automation may take advantage of computer vision resources, which can be applied to a number of different tasks, such as inspection (Brosnan *et al.* 2002), classification of plants (Tang *et al.* 2003, Neto *et al.* 2003, Steward *et al.* 2004), estimated production (Annamalai *et al.* 2004), automated collection (Plebe *et al.* 2001) and guidance of autonomous machines (Lulio *et al.* 2009).
In the context of monitoring and localization of important objects in the greenhouses environment, one of the performed activities is the localization and detection of the fruit. Most of the works, for developing their project, have chosen the productive cycle of tomato plants in a greenhouse environment since it presents a sequence of cultural operations (as explained below) rather diversified and not trivial. At the same time tomato plant is characterized by certain regularity in its structure that could partially simplify the development of cultural operations by means of a robotic system and so it is a valid test.
Tomato's fruit generally doesn't ripe simultaneously. On each tomato plant, green, yellow, orange, and red tomatoes can be found. Tomato can be detected basing on: colour, shape or highlights.

Fruit image segmentation issue on colour difference between mature fruits and backgrounds under natural illumination condition is an important and difficult content of fruit-harvesting robot vision. Some studies concerning fruit image segmentation have been presented in the last few years. However, these studies are focused on particular fruit and different from segmentation results. In Yin J. *et al*. 2008, four kinds of segmentation methods are presented and applied into fruit image segmentation. The tests show that these methods can segment successful several kinds of fruits image, even tomatoes.

One of the drawbacks of the segmentations method based on the colour information relies on the fact that it can detect only fruit at the same maturity or colour distribution: how detect tomato when different colour appearance occurs?

In Whittaker *et al.* 1987, digital image analysis with a modified circular Hough transform, proved to be able to locate tomatoes based on shape and not colour, even when the scenes contained substantial background noise and the fruit were partially hidden from view. In Hayashi *et al.* 2005, authors have developed a stereoscopic vision system that relies on highlights (Figure 1). The system consists of a halogen light, two cameras, a travelling carriage, and a computer.

Occlusion, highlights presence, illumination variability and so on, are all parameters that have to be taken into account and till the moment it doesn't exist a robust method to solve the detection issues. Our approach starts directly from the object/tomato and proposes a new algorithm method based on detecting classes of objects, in our case tomato (Blasco *et al.* 2003a).

System Description

The classical problem in computer vision, image processing, and machine vision is that of determining whether or not the image data contains some specific object, feature, or activity. This task can normally be solved robustly and without effort by a human, but is still not satisfactorily solved in computer vision for the general case: arbitrary objects in arbitrary situations. The existing methods for dealing with this problem can at best solve it only for specific objects, such as simple geometric objects (e.g., polyhedral), human faces, printed or hand-written characters, or vehicles, and in specific situations, typically described in terms of well-defined illumination, background, and pose of the object relative to the camera.

Tomato detection is a computer vision system that determines the locations and sizes of objects in arbitrary (digital) images. It detects objects features we are interested in and ignores anything else, such as every kind of object in the background.

The overall object detection architecture is built around a method for classifying individual image regions and can be summarized in the following two steps: the learning and the detection phase.

The learning phase creates a binary classifier that provides object/non-object decisions for fixed sized image regions ("windows"); while the detection phase uses the classifier to perform a dense multi-scale scan, reporting preliminary object decisions at each location of the test image. These preliminary decisions are then fused to obtain the final object detections.

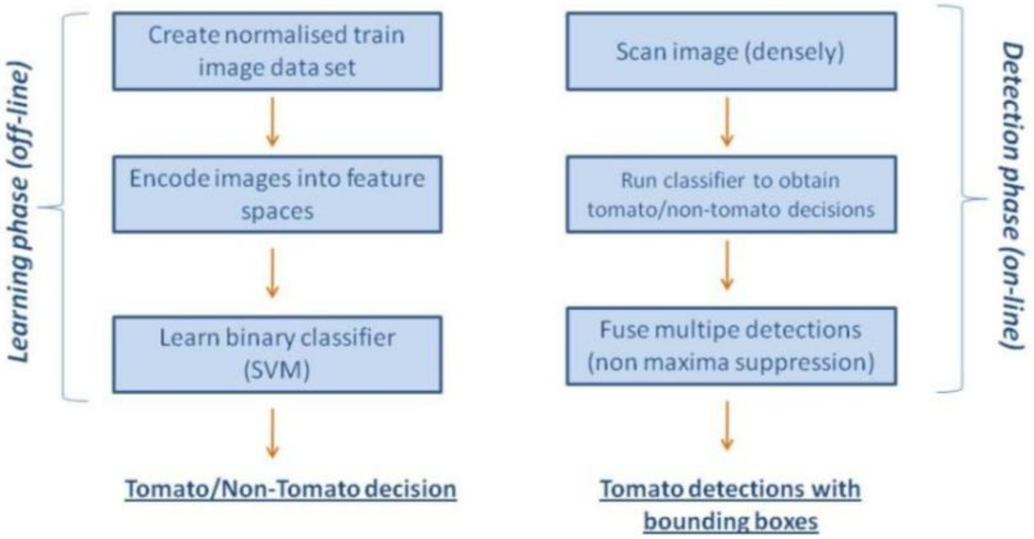

Figure 1.Tomato Detections Overview(a) The learning phase extracts robust visual features from fixed size training windows, and trains a binary object/non-object classifier over them. (b) The detection phase uses the learned binary classifier to scan the test image at all locations and scales for object/non-object decisions.

Learning phase

The first stage of learning is the creation of the training data. The positive training examples are fixed resolution/size image windows containing the centred object, and the negative examples are similar windows that are usually randomly sub-sampled and cropped from set of images not containing any instances of the object.

Figure 2. Positive samples (a) and negative samples (b)

The binary classifier is trained using these examples. Ideally, each positive window contains only one instance of the object, at a size that is approximately fixed with regard to the window size.

We use linear Support Vector Machines as our benchmark classifiers. In more detail, the Matlab implementation of the SVM algorithm proposed by Chang *et al.* 2011 has been used.

The output of the learning process to be provided for the detection phase is a *model*: a predict tool allowing the classifier, during the detection phase, to discriminate between tomato and not-tomato selection in a test image.

<u>*Detection phase*</u>

During detection, the input test image can be scanned at all scales and locations (moving each time of one or more pixel).

Figure 3. Scanning Windows in a test image

For each scale and location, the feature vector is computed over the detection window, just as in the learning phase, and the binary classifier is run to produce object/non-object decision for the window. Image regions that contain objects typically produce multiple firings and it is necessary to fuse these overlapping detections into a single coherent one.

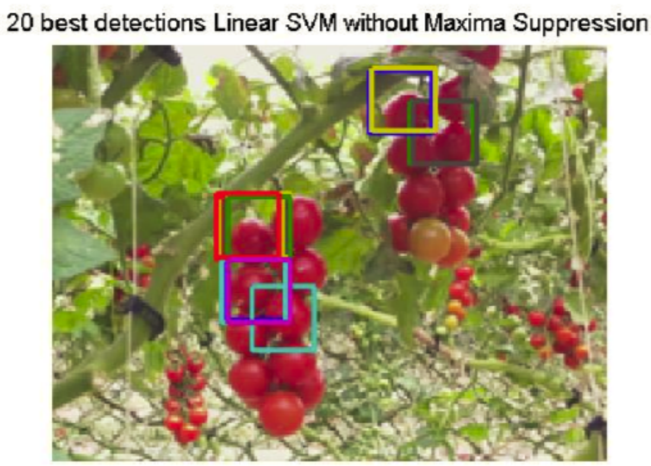

Figure 4. 20 best detections Linear SVM without Maxima Suppression

Non-maximum suppression (Szelinski, 2010) is often used along with detection algorithms. The image is scanned in windows and if the pixels are not part of the local maxima they are set to zero. This has the effect of suppressing all image information that is not part of local maxima.

The overall detection score depends both on the dataset creation and on how finely the test image is scanned and the detections fused.

Results
Some samples of testing images used for the results are shown in the figures below:

Figure 5. Test images

The images have been extracted from a video and different conditions (illumination, distance from the raw and the tomato detection) have been tested in order to demonstrate the robustness of the proposed approach.
The video were acquired in tomato greenhouses located in Vittoria (Ragusa - Sicily) during daylight in the month of June 2011.
Different typology of tomato has been analysed; the method can be exploited for any kind (it will be needed just to change the dataset) but the results are focused on cherry variety.
A threshold value can be used in order to select which of the confidence value can be associated to a tomato or not.
If the scope of the research is to detect the grape of tomato, leaving a high threshold, the precision of the detection method is high and allow detecting the tomato grapes presence. Decreasing the threshold, more tomatoes will be detect but with a worse precision (because of the false detections). In this last case, if a high precision is requested the false positives number can decrease by using the retraining process or increasing the dataset).

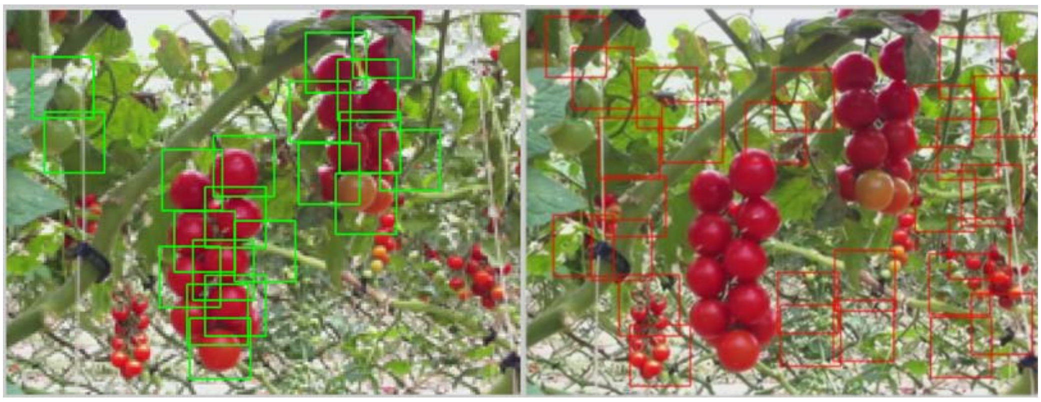

Figure 6. 20 True Positives against 26 False Positive with threshold of 0.2

Conclusions

Taking into account the state of the art available nowadays, the results and performances related the object/fruit detection offer great improvement cues. Till now there is no a mathematical law or algorithm allowing representing or recognizing nature: no general rules. So many components and factors should be taken into account that, currently, a robust and reliable method allowing object detection doesn't exist.

The implemented algorithm has shown good performance during experimental trials and its usage allows the detection of the grape of tomatoes with such acceptable precision.

Despite all, the developed algorithm has not such accuracy to allow harvesting operation or counting precisely tomatoes in a crop, but despite all opposition, improvements in the detection method can be provided and extended to other context.

References

ANNAMALAI P., LEE W. S., BURKS T. F., Color vision system for estimating citrus yield in real-time. In: CSAE ANNUAL INTERNATIONAL MEETING, 2004.

BALLONI S., CARUSO L., CERRUTO E., EMMA G., SCHILLACI G.(2008). A prototype of self-propelled sprayer to reduce operator exposure in greenhouse treatment, Attisu CD-ROM dell'International Conference on "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", Ragusa, Italy 15–17 September.

BALLONI S., CARUSO L., CONTI A., SCHILLACI G., LONGO D., MUSCATO G. (2008). Preliminary study for the development of an electrical autonomous vehicle for safe agricultural chemicals distribution inside greenhouses. Attisu CD-ROM dell'International Conference on "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agrofood Systems", Ragusa, Italy 15–17 September.

BLASCO J., ALEIXOS N., MOLTÓ E., (2003). Machine vision system for automatic quality grading of fruit. Biosystems Engineering, 85(4), 415–423.

BROSNAN T., SUN D., Inspection and grading of agricultural and food products by computer vision systems – a review. Computer and Electronics in Agriculture, v. 36, p. 192-213, 2002.

CHANG C.-C., LIN. C.-J.; LIBSVM : a library for support vector machines. ACM Transactions on Intelligent Systems and Technology, 2:27:1--27:27, 2011

HAYASHI S., OTA T., KUBOTA K., GANNO K., KOND N., Robotic Harvesting Technology for Fruit Vegetables in Protected Horticultural Production, Information and Technology for Sustainable Fruit and Vegetable Production, FRUTIC 05, 12-16 September, Montpellier, France, 2005

LONGO D., PENNISI A., CARUSO L., MUSCATO G., SCHILLACI G.; An autonomous electrical vehicle based on low-cost ultrasound sensors for safer operations inside greenhouses. International Conference Ragusa SHWA2010 -September 16-18, 2010 Ragusa Ibla Campus-Italy "Work safety and risk prevention in agro-food and forest systems"

LULIO L.C., TRONCO M.L., PORTO A.J.V..JSEG-based Image Segmentation in Computer Vision for Agricultural Mobile Robot Navigation. Computational Intelligence in Robotics and Automation (CIRA), 2009 IEEE International Symposium, pp 240 - 245, Daejeon, 15-18 Dec. 2009

NETOJ. C., MEYERG. E., JONESD. D., SURKAN A. J., Adaptive image segmentation using a fuzzy neural network and genetic algorithm for weed detection. In: Asae Annual International Meeting, 2003.

PLEBE A., GRASSO G., Localization of spherical fruits for robotic harvesting. Machine Vision and Applications, v. 13, p. 70-79, 2001.

SCHILLACI G., BALLONI S., CARUSO L., CONTI A., RAPISARDA V. (2009). Health and Safety Aspects Connected with the Use of a Self Propelled Sprayer in Greenhouses. Atti del XXXIII CIOSTA - CIGR V Conference 2009"Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety", Reggio Calabria, Italy, 17-19 june.

SCHILLACI G., BALLONI S., CARUSO L., CONTI A., PENNISI A., LONGO D., MUSCATO G., Prove di funzionamento telecomandato e autonomo di un veicolo elettrico multifunzionale destinato alle colture in serra, Proceedings of the IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria AIIA 2009, Memoria n. 7-37, 12-16 september 2009, Ischia Porto, Italy

SINGH A. K., Precision farming, Water technology center, New Delhi

STEWARD B. L., TIAN L. F., NETTLETON D., TANG L., Reduced-dimension clustering for vegetation segmentation. Transactions of the ASAE, v. 47, p. 609-616, 2004.

SZELINSKI R., Computer Vision - Algorithms and Applications, Series: Texts in Computer Science, Springer, 2010

TANG L., TIAN L., STEWARD B. L., Classification of broadleaf and grass weeds using gabor wavelets and an artificial neural network. Transactions of the ASAE, v. 46, p. 1247-1254, 2003.

WHITTAKER D., MILES G. E., MITCHELL O. R., GAULTNEY L. D., Fruit Location in a Partially Occluded Image, Transactions of the ASABE. 30 (3), pp 0591-0596, 1987

YIN J., MAO H., XIE Y., *Segmentation Methods of Fruit Image and Comparative Experiments*, Computer Science and Software Engineering, 2008 International Conference, pp 1098 - 1102, Wuhan, Hubei, 12-14 Dec. 2008

Topic 5

“Automation, Remote Control, Robot and Innovative Vehicle”

Poster Presentation

The accuracy assessment of crop-shelter coverage classifications obtained from per-pixel methods combined with texture analyses

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Abstract

This paper shows the outcomes of the application of some statistical techniques to analyse the quality of the accuracy assessment of crop-shelter coverage classifications obtained from image texture analyses combined with information contained in RGB-bands layers.

The imagery used in this study was composed of satellite multispectral images and digital images in vector format of the crop-shelter coverage obtained by visual recognition of the satellite images.

Several combinations of information from RGB bands and textures were used in the classifications carried out in a study area located in South-Eastern Sicily (Italy).

Error matrices were derived from each classification and some accuracy measures were computed and subject to statistical tests. A more complete information on the quality of the classification results was obtained, which allowed comparison between different classifications and selection of the combinations that produced the highest map accuracy.

Keywords: greenhouses; satellite images; object recognition.

Introduction

In the field of rural areas management, the analysis of the environmental effects of anthropic loads is generally carried out with the support of specific thematic maps. The automated classification of land use coverage which determines these loads is a useful tool to produce thematic maps with a reduced amount of time and specialized work.

As regards crop-shelter coverage (CSC), its accurate classification may represent a basic territorial knowledge useful for the management of the environmental loads produced by crop shelters.

However, the complexity of digital classifications generally requires that accuracy assessment should be carried out to verify the reliability of the results.

In literature, a great number of research papers in the field of land-use/land-cover change lacked in adopting accuracy measures (AMs) to assess the quality of thematic maps obtained from automated image classifications of remote sensing images. This was due to some key concerns, e.g., no single universally acceptable measure of the accuracy, the definition of the most adequate sampling scheme and sample size, non-thematic errors. These issues, by resulting in misunderstanding of errors and their likely implications, limit the field of application of such thematic maps. Moreover, in the few cases wherein AMs were used, the results showed a poor quality of the obtained classifications (Foody, 2002).

The use of AMs may be grouped into two broad application classes: reporting the accuracy of a thematic map, in which the accuracy assessment objective is to provide a description of classification error; and comparing maps, in which the objective is to determine which thematic maps result in the highest accuracy (Stehman, 1997).

In this paper some AMs were computed on the error matrices obtained from CSC classifications carried out by combining texture analyses and multispectral information.

Some statistical techniques were applied to these AMs in order to compare the classifications among them and, therefore, to obtain those which characterize the considered CSC.

Materials and methods

In this paper the CSC thematic maps derived from the application of an automated classification method developed and tested in a previous study (Arcidiacono and Porto, 2010) were analyzed. The method was applied to a study area which includes the coastal areas of two municipalities of the Province of Ragusa located in South-Eastern Sicily (Italy), where CSC is widespread. In detail, three areas were considered which show a different crop-shelter spread: in the first area (A1 hereafter) the coverage was representative of the crop-shelter spatial development from the coastal area to the inland territory; the second area (A2 hereafter) was located near the coast where crop shelters are primarily concentrated and aligned parallel to each other; the third area (A3 hereafter) which represents the inland territory where crop shelters are oriented in different directions.

The imagery used in this study was composed of satellite multispectral images of the considered territory and digital images in vector format of the CSC obtained by visual recognition of the satellite images.

Several combinations of information from RGB bands and textures were used in the classifications carried out in the three different areas. In detail, the following textures were computed: Homogeneity (Ho), Contrast (Con), Dissimilarity (Di), Mean (Me), Standard deviation (SD), Entropy (En), Angular Second Moment (ASM), Correlation (Cor), GLDV-Angular Second Moment (G_ASM), and GLDV-Entropy (G_En).

Ten images were obtained by combining the spectral data of the RGB-band layers with the information contained in each texture layer, and classifications were carried out to obtain ten crop-shelter thematic maps ('RGB-texture maps' hereafter). The RGB-band layers were used to produce an additional crop-shelter thematic map ('RGB map' hereafter).

A systematic sampling approach with Ground Control Points (GCPs) located at the vertices of a 5 m × 5 m square mesh grid which entirely covered the considered areas and was aligned in the North-South direction, was employed. Since crop shelters were not aligned in the grid's direction, the sampling scheme did not yield systematic errors.

All the possible land-cover classes not classified as CSC, were merged into a single class referred to as 'background'. This made it possible to limit the errors within the error matrices caused by misinterpretations of other types of land cover.

The visual analysis of the satellite images and the production of a vector layer containing polygons representing the CSC were performed in order to assign, by means of spatial queries, each GCP to the right class, i.e., crop shelters or background.

The error matrices related to each classification were generated, some AMs were computed, and statistical tests were carried out on this measures.

The error matrix represents the degree of agreement/disagreement between the highest quality reference data set and the map data. In its columns reference data are reported whereas in the rows the classification obtained from the remote-sensing image (i.e., the map) is described.

Overall accuracy (OA) is the rate between the total correct number of pixels (i.e., the sum of the matrix diagonal) and the total number of pixels in the error matrix.

Accuracies of crop-shelter category, i.e., user's accuracy (UA) and producer's accuracy (PA), were obtained by dividing the number of correct pixels in that category by the total number of pixels in the corresponding row or the corresponding column, respectively. Since these accuracies provide errors of commission and omission for crop shelter category, respectively, they were suitable to assess underestimation or overestimation of CSC extents (Congalton, 1991).

The coefficient kappa (K), the user's and producer's conditional kappa for CSC class (CKu and CKp, respectively)(Liu *et al.*,007; Congalton, 1991; Congalton and Green, 2009), give indications of the proportion of agreement among the two classes or into the crop-shelter class, respectively, after adjusting for chance agreement.

The OA, UA and PA thanks to their direct interpretation as probabilities characterizing data quality of maps, are seen as more suitable to report the accuracy of thematic maps, whereas K, CKu, and CKp, consistently smaller than the related parameters, are considered more adequate for map comparisons (Stehman, 1997).

With the aim to select the best set of AMs to describe the accuracy of the produced RGB-texture maps, one-way ANOVA tests were performed to ascertain if any AM was not affected by the choice of the selected area.

For each of the three considered area, statistical tests were carried out on the AMs selected by the ANOVA tests in order to compare the RGB-texture maps among them and, therefore, to select those suitable to provide a level of accuracy which is significantly different from that of the other RGB-texture maps. In detail, the Z test of significance was used to compare the maps, two at a time, by the following relation (Congalton and Green, 2009):

$$Z = \frac{\left|k_1 - k_2\right|}{\sqrt{\operatorname{var}\left(k_1\right) + \operatorname{var}\left(k_2\right)}}$$

where k_1 and k_2 are CKp values and var (k_1) and var (k_2) are their variances. If the value of Z was higher than 1.96 the two considered RGB-texture maps were significantly different from each other.

Therefore, the RGB-texture maps which showed the best values of the selected AMs and were found significantly different from the others were defined as those characterizing the considered areas, i.e., providing a similar accuracy level for the different areas.

Results and discussion

From the one-way ANOVA tests UA and CKp were found to be the AMs which were not influenced by the selected areas (data not shown), and therefore these AMs were considered in the analyses reported in this study.

From Table 1, UA values showed that a higher classification accuracy was achieved in A1 and A3 if compared to A2. This was confirmed by very high OA values (>85 %) for A1 and A3 , and generally high PA values, revealing an omission error rate between 9.8 % and 22.8 %. However, commission error rate ranged between 17.0 % and 34.4 %. In A2, though the highest PA values were found, OA values were lower than 85 % yet still high (>73.5 %), and UA values were related to a commission error ranging between 22.4 % and 36.3 % for the different textures. This result demonstrated that the crop-shelter classification in this image suffered from higher 'confusion' with the background than that obtained for the other two areas. These findings highlight that the spectral signatures extracted in A1 are more suitable to classify A3 coverage as opposed to A2 coverage. This could be due to the high number of uncovered crop shelters in the area. It was found (Arcidiacono and Porto, 2008; Arcidiacono and Porto, 2011), in fact, that this occurrence causes an increase of false positives and it is due to the similarity of signatures related to the uncovered crop shelters and some soils.

The best UA values obtained for each considered area were not associated to the same set of RGB-texture maps (Table 1). In order to perform map comparisons within the same area, Z tests were carried out on CKp values (Tables 2, 3, and 4). In these tables the RGB-textures maps are ranked in the decreasing order of CKp values and the results of the Z test are described as significant (S) or non significant (NS).

Table 1. Ranking of RGB-textures maps on the basis of UA values, and mean UA values for the three considered areas

	UA					
	A1		A2		A3	
classifications	RGB-ASM	0,830	RGB-ASM	0,776	RGB-En	0,755
	RGB-En	0,824	RGB-En	0,763	RGB-Ho	0,753
	RGB-G_ASM	0,806	RGB-G_ASM	0,738	RGB-ASM	0,752
	RGB-Ho	0,800	RGB-Ho	0,729	RGB-G_ASM	0,745
	RGB-G_En	0,785	RGB-G_En	0,717	RGB-G_En	0,736
	RGB-Di	0,725	RGB-Di	0,664	RGB-Di	0,721
	RGB-SD	0,700	RGB-SD	0,651	RGB-SD	0,709
	RGB-Con	0,678	RGB-Me	0,649	RGB-Con	0,694
	RGB-Me	0,654	RGB-Cor	0,637	RGB-Me	0,660
	RGB-Cor	0,644	RGB-Con	0,634	RGB-Cor	0,656
Mean		0,745		0,696		0,718

Once more, the results obtained for A1 were more similar to those found for A3 confirming what observed for UA elaborations.

Finally, the RGB-texture maps which had the best CKp values and were found significantly different from the others were selected as those providing a common accuracy level for the three considered areas. In detail, the combinations RGB-ASM and RGB-En were significantly different from the others and showed the best values of CKp. The combinations RGB-SD, RGB-Di and RGB-Con, instead, showed the worst significantly different results.

Therefore, the level of accuracy related to RGB-ASM or RGB-En classifications characterized the classification accuracy related to the area under study and may be reported within thematic maps obtained by using one of these combinations.

Conclusions

The analysis of the accuracy assessment through the computation of accuracy measures derived by the error matrix of each classification and the performance of statistical tests made it possible to give a more complete information on the quality of the classification results, and allowed comparison between different RGB-texture maps. In detail, within a wide study area which includes more municipalities, three areas were selected to carry out automated classifications of high resolution satellite images by applying a per-pixel method coupled with texture analyses. The accuracy measures that were not affected by the area selection (i.e., user's accuracy (UA) and producer's conditional *kappa* (CKp)) were used. Next, tests of significance were carried out on CKp values related to two RGB-texture maps at a time for the considered areas. From these tests the level of accuracy of some RGB-texture maps was found suitable to characterize the whole area under study.

Table 2. Tests of significance on CKp values related to two RGB-texture maps at a time for the first area

A1	RGB-ASM	RGB-En	RGB-G_ASM	RGB-Ho	RGB-Cor	RGB-G_En	RGB-Me	RGB-Di	RGB-SD	RGB-Con
RGB-ASM										
RGB-En	S									
RGB-G_ASM	S	S								
RGB-Ho	S	S	NS							
RGB-Cor	S	S	S	NS						
RGB-G_En	S	S	S	S	NS					
RGB-Me	S	S	S	S	S	NS				
RGB-Di	S	S	S	S	S	S	S			
RGB-SD	S	S	S	S	S	S	S	NS		
RGB-Con	S	S	S	S	S	S	S	S	S	

Table 3. Tests of significance on CKp values related to two RGB-texture maps at a time for the second area

A2	RGB-ASM	RGB-En	RGB-Ho	RGB-Me	RGB-G_ASM	RGB-Cor	RGB-G_En	RGB-SD	RGB-Di	RGB-Con
RGB-ASM										
RGB-En	S									
RGB-Ho	S	S								
RGB-Me	S	S	NS							
RGB-G_ASM	S	S	NS	NS						
RGB-Cor	S	S	S	NS	NS					
RGB-G_En	S	S	S	S	S	NS				
RGB-SD	S	S	S	S	S	S	S			
RGB-Di	S	S	S	S	S	S	S	NS		
RGB-Con	S	S	S	S	S	S	S	NS	NS	

Table 4. Tests of significance on CKp values related to two RGB-texture maps at a time for the third area

A3	RGB-ASM	RGB-En	RGB-G_ASM	RGB-Ho	RGB-Cor	RGB-G_En	RGB-Me	RGB-SD	RGB-Con	RGB-Di
RGB-ASM										
RGB-En	S									
RGB-G_ASM	S	S								
RGB-Ho	S	S	NS							
RGB-Cor	S	S	S	NS						
RGB-G_En	S	S	S	NS	NS					
RGB-Me	S	S	S	S	S	S				
RGB-SD	S	S	S	S	S	S	NS			
RGB-Con	S	S	S	S	S	S	NS	NS		
RGB-Di	S	S	S	S	S	S	S	NS	NS	

References

Arcidiacono, C., Porto, S.M.C. 2008. Image processing for the classification of crop shelters. Acta Horticulturae, 801, 309-316.

Arcidiacono, C., Porto, S. M. C. 2010. Pixel-based Classification of High-Resolution Satellite Images for Crop-Shelter Coverage Recognition. Proceedings of the 28th IHC Congress, 22-27 August 2010, Lisbon, Portugal (in press on Acta Horticulturae).

Arcidiacono, C., Porto, S.M.C. 2011. Improving Per-pixel Classification of Crop-Shelter Coverage by Texture Analyses of High-Resolution Satellite Panchromatic Images. Journal of Agricultural Engineering, 4, 9-16.

Congalton R. G. 1991. A review of assessing the Accuracy of Classifications of Remotely Sensed Data. Remote Sensing of Environment, 37, 35-46.

Congalton, R. G., Green, K. 2009. Assessing the accuracy of remotely sensed data: principles and practices. CRC Press, 1, pp.183.

Foody, G. M. 2002. Status of land cover classification accuracy assessment. Remote Sensing of Environment 80, 185-201.

Liu, C., Frazier, P., and Kumar, L. 2007. Comparative assessment of the measures of thematic classification accuracy. Remote Sensing of Environment, 107, 606-616.

Stehman, S. V. 1997. Selecting and Interpreting Measures of Thematic Classification Accuracy. Remote Sensing of Environment, 62, 77-89.

Detecting cows at the feed barrier by means of an image analysis algorithm

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Abstract

The objective of this study was to investigate the applicability of the Viola-Jones algorithm for continuous detection of the presence of cows at the feed barrier.
A methodology was proposed in order to train and validate the detector. A lower number of positive and negative images than those used by Viola and Jones were required during the training.
The validation was carried out by an accuracy assessment procedure which required the time-consuming work of an operator who labelled the true position of the cows within the barn. The accuracy assessment revealed that among the 715 frames about 90.63% contained only true positives, whereas about 9.37% were affected by underestimation, i.e., contained also one or two false negatives. False positives occurred only in the 2.93% of the analyzed frames. The results obtained revealed the adequacy of Viola-Jones algorithm for detecting the presence of cows at the feed barrier. This, in turn, opens up opportunities for an automatic analysis of cows' behaviour.

Keywords: precision livestock farming, dairy farming, vision techniques

Introduction

The automatic analysis of digital images from a video recording system was used in several research works aimed at monitoring the behaviour of animals in different breeding environment (Shao *et al.*, 1998; Shao and Xin, 2008; Cangar *et al.*, 2008). Such a monitoring system shows some weak points when the images of the observed animals are not sufficiently contrasted from the background since it generally requires the adoption of a number of image pre-processing algorithms to segment out the animal features in the scene.

To overcome this limitation, a wider research which the authors are carrying out, aims at assessing the application of a detector based on the Viola-Jones algorithm to recognize some behavioural activities of dairy cows (e.g., lying down in stalls, eating, drinking, standing, and walking along the alleys) housed in open free-stall barns. From literature, it results that the robustness of this algorithm could provide accurate detections also when significant brightness and background variations occur in the sequence of the analyzed images. Furthermore, since this algorithm is suitable for real-time elaborations, it would avoid the burdensome activity of video-recording storage.

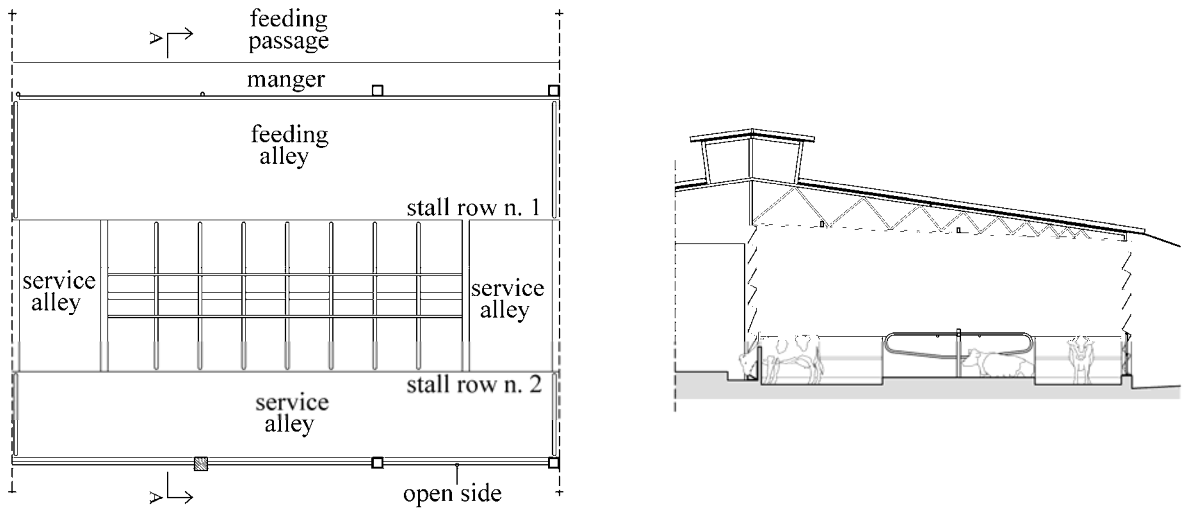
This paper shows the mains outcomes of the implementation of the Viola-Jones algorithm for the detection of the dairy cow presence at the feed barrier. The scenes used for modelling the detector were extracted from the video recordings of one video camera placed above the feeding area which provided the plan view of a region of the feeding alley. More details about this study can be found in Porto *et al.* (2011).

Materials and methods

The barn under study

The research has been carried out in a cubicle free-stall barn for dairy cows equipped with innovative devices for microclimate control used to improve the thermal comfort of the cows. Within the barn, an area was selected where a group of 15 dairy cows was housed. Within this area, two functional units were observed by means of video cameras, i.e., the feeding area, which is a rectangular area of about 15.3 m × 3.30 m, and the resting area which is a rectangular area of about 10.4 m × 4.30 m adjacent to the feeding area (Fig.1).

In the alleys there is presence of slurry accumulation as the cleaning is not automated but it is carried out 1-2 times a day by a scraper. As a consequence, sunlight reflection on wet floors occurs. High floor brightness is observed on the service alley along the southern open side and the resting area.



(a) (b)

Figure 1. Plan (a) and section (b) of the part of the barn under study.

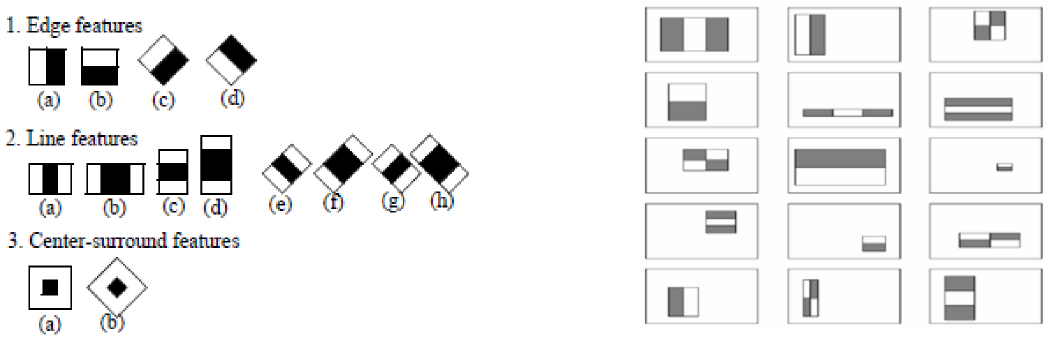
Viola-Jones algorithm requirements

The Viola-Jones detection algorithm uses a trained object detector over sliding sub-windows of W×H pixels, starting from the upper left corner and ending in the down right corner of the input image. For each sub-window, the detector calculates the values of a set of Haar-like features and compares them with reference values obtained in the training phase. Lienhart and Maydit (2002) have extended the prototypes of features originally defined by Viola and Jones (2001; 2004) to a set of 14 prototypes of Haar-like features prototypes (Fig. 2a). A Haar-like feature considers adjacent white and black rectangular regions at a specific location in a detection window (Fig. 2b), sums up the pixel intensities in these regions and calculates the difference between them.

The result of the comparison between the Haar-like feature values obtained during the detection phase with those of the training phase can ascertain if the sub-window is an object or is a part of the background (Figure 3).

The Viola-Jones algorithm does not use the original input image, but computes an integral image by making each pixel value equal to the entire sum of all pixel values above and at the left of the considered pixel of the original image. The use of such integral image combined with the Haar-like features allows for a faster object detection than that performable by using other set of features.

Concerning the number of Haar-like features to be used in the detection process, Viola-Jones algorithm considered a set of 261,600 features which derived from all possible scales and positions of each extended features prototypes within a sliding sub-window of 24×24 pixels.



a) b)

Figure 2. a) The set of extended Haar-like feature prototypes; b) Localization of Haar-like features within a sub-window.

The detector is a cascade of stages (Fig. 3), each one containing a strong classifier. The role of each stage is to determine whether a given sub-window is definitely “not an object” or “probably an object”. When at a given stage a sub-window is classified as “not an object” , it is immediately discarded and thus it is considered as part of the background. Conversely, if a sub-window is classified as “probably an object”, it is passed on to the next stage in the cascade. The more the stages a given sub-window passes, the higher the chance that it actually contains the object to be detected.

To train the different stages in the cascade, the Viola-Jones algorithm requires positive and negative image samples of W×H pixels. A positive image is a rectangular image containing the object to be detected, whereas a negative image does not contain such an object. Positive images should have the same aspect ratio *r*, i.e. the same ratio of the width to its height. Negative images must not have smaller dimensions than those of the largest selected positive image. For face detection, a good proportion between the number of selected positive images and that of the negative ones is equal to 1:2. To form the positive image sample, each positive image is resized to W×H pixels. Whereas, the negative image sample was generated by the algorithm by scanning a number of negative images of w×h pixels (w ≥ W, h ≥ H) which showed background details. In particular, for each negative image a sliding sub-window of W×H pixels ran through the negative image from the upper left corner to the down right corner and for each position an image sub-set of the considered negative image was extracted. Therefore, the total number of negative image samples can be determined by the following relation:

$$N = \sum_{i=1}^{n} \left(w_i - W + 1\right) \times \left(h_i - H + 1\right)$$

where n is the number of the selected negative images and w_i and h_i the size of each negative image.

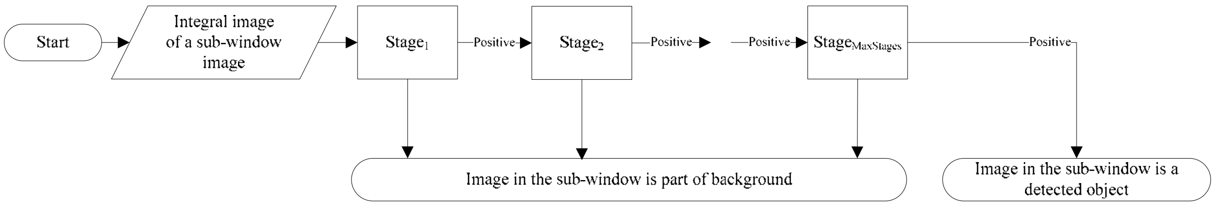


Figure 3. Detection process performed by a cascade of strong classifiers (stages).

The training of the detector

In this work the Viola-Jones algorithm was used for the detection of the dairy cow presence at the feed barrier. As in previous studies (De Vries 2003; Wilson 2005), this kind of behaviour is operationally defined as "feeding behaviour" in the following of this paper.

The scenes used to extract positive and negative samples were selected from the video recordings of one camera placed above the feeding area and related to two different days (characterized by different brightness conditions, i.e., a sunny day and a cloudy one) of the experimental trial carried out during December 2010.

This choice was made with the aim to train the detector in different brightness conditions inside the barn. Though the cameras were provided with built-in white-light illuminators that could be activated when the environment lacks a sufficient light source, the sequence of image scenes acquired during the late afternoon and the night were not of good quality for the purpose of the present study and, thus, were discarded. Therefore, the scenes used to extract the image samples were selected within the time interval between 7:00 a.m. and 4:00 p.m. for each day considered. In detail, the sampling was systematically extracted by selecting 6 frames within one hour to obtain 54 frames for each day considered.

For each of the two days considered, about 3-4 positive images were extracted from the selected frames. To facilitate the image sample selection, a specific functionality was implemented in order to make it possible to easily cut out parts of the images from the video-recording frames. The compiler Visual C++ 2008 express edition was used, within an integrated environment of software programming (IDE) free distributed by Microsoft, which allows the development of applications written in C++ language and the use of all the graphical components of the operating system.

A total number of 352 positive images were selected from the video recordings. The value of the aspect ratio *r* of positive images was on average 2:1 with image widths between 180 pixels and 288 pixels, and image heights between 90 pixels and 144 pixels. These pixel ranges derived from the dimensions of the positive images that were affected by animal positions at the feeding barrier. For instance, if animals were perpendicular to the feeding barrier the minimum values of the image height was found.

A total amount of 134 negative images were obtained from the selected frames. The width of the negative images ranged between 338 pixels and 640 pixels, whereas height ranged between 220 pixels and 480 pixels.

The dimensions of the sliding sub-windows were fixed to 30×15 pixels. These dimensions were chosen to limit the number of features to be used that increases along with the image dimensions. Therefore, a total number of 352 positive image samples was obtained by resizing to 30×15 pixels each selected positive image. Whereas a total number of 4.8×10^7 negative images samples was obtained from the 134 negative images.

Twenty-five stages were input and the thresholds for false positive and detection rates were fixed at 0.5 and 0.997, respectively.

The validation of the detector

The validation of the detector was carried out by the following accuracy assessment procedures. Within the time interval between 7:00 a.m. and 4:00 p.m. of one day different from that considered in the training, 715 frames were selected. In detail, 2 frames per minute were extracted and then checked to eliminate those not significant for the accuracy assessment, i.e., consecutive frames showing no substantial differences in their contents. Firstly, an operator labelled the true position of the cows and their observable behavioural activity within the feeding area (i.e., feeding along the feeding fence, walking or standing) by visual examination of the selected frames. The execution of the detector produced for each selected frame a set of sub-windows surrounding each cow image related only to the feeding behaviour. Finally, the output results of the detector were compared to those produced by the operator.

Results and discussion

The setting of the minimum image dimensions (30 × 15 pixels) required the use of 150,250 extended Haar features to be applied to the 352 resized positive images and to the 4.8×10^{7} negative sub-windows obtained from the 134 negative images. After the training of the classifier, 110 features were selected among those available and subdivided into 25 stages.

The global detection rate reached 98.88%, whereas the global false positive rate was 2.84×10^{-4} %. The training time was 8 hours using an Intel® Core (TM) 2 Quad CPU Q6700.

The results of the training demonstrated that the use of a moderate number of positive and negative images in comparison to that used by Viola and Jones to train the face detector (2001; 2004) produced a high value of the detection rate and a low value of the false positive rate. Furthermore, the number of negative images required to perform the training was less than that of the positive ones. This last result highlights that in this research the variability of the background was moderate compared to that found by Viola and Jones (2001; 2004). Moreover, the training results revealed that though the presence of manure in the feeding alley caused the continuous changing of the background, these variations did not affect the quality of the classification.

The obtained detector was used to detect the presence of cows at the feed barrier within the 715 frames selected for the accuracy assessment of the classification results. The elapsed time for the detection process was 80 msec using an Intel® Core (TM) 2 Quad CPU Q6700. This result demonstrates that the algorithm is suitable for real-time elaborations.

The visual recognition required about 8 hour work of an operator.

The final results of this procedure were grouped according to the number of cows in each analyzed frame, which ranged between 0 and 4. For each group of cow, Figure 4 shows the percentage of true positives and false negatives. Among the 715 frames, 648 contained only true positives (90.63%), 67 contained also false negatives (9.37%). Finally, only 21 false positives occurred (2.93%).

Conclusions

This study described the methodology developed to investigate the feasibility of applying Viola-Jones algorithm for detecting the presence of cows at the feed barrier.

Since the proposed methodology did not require any image pre-processing step for segmenting out the animal features in the video-recorded scenes, its application overcomes some difficulties that can occur when images of the observed animals are not sufficiently contrasted from the background.

As the results of the training demonstrated that a moderate number of positive and negative images can produce high value of the detection rate and low values of the false positive rate, the application of the proposed methodology would not lead to an excessive amount of time for the selection of image samples required to recognize other cows' behaviours.

During the validation stages, the obtained detector also gave good classification results when significant brightness and background variations occurred in the sequence of the analyzed images.

Finally, since the validation stage demonstrated that the real-time execution of the detector is feasible, the application of the methodology would avoid the burdensome activity of video-recording storage.

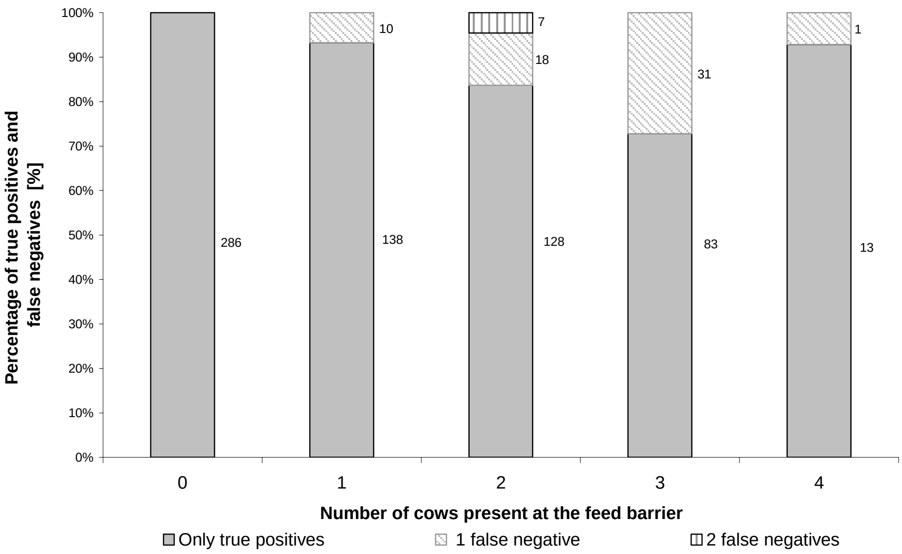


Figure 4. Percentage of true positives and false negatives computed for each class defined by the number of cows present at the feed barrier.

References

Cangar, Ő., Leroy, T., Guarino, M., Vranken, E., Fallon, R., Lenehan, J., Mee, J., Berckmans, D. 2008. Automatic real-time monitoring of locomotion and posture behaviour of pregnant cows prior to calving using online image analysis. Computers and electronics in agriculture, 64, 53-60.

DeVries, T. J., von Keyserlingk, M. A. G. ,Weary, D. M., & Beauchemin, K. A. 2003. Measuring the Feeding Behavior of Lactating Dairy Cows in Early to Peak Lactation. Journal of Dairy Science, 86, 3354-3361.

Lienhart, R., Maydit, J. 2002. An extended set of haar-like features for rapid object detection. In: Proceedings of the IEEE International Conference on Image Processing, Rochester, New York, vol. 1, 900-903.

Porto, S.M.C., Arcidiacono, C., Guarnera, G. C., Cascone, G. 2011. Preliminary study for the implementation of an image analysis algorithm to detect dairy cow presence at the feed barrier. Journal of Agricultural Engineering, 4, 17-23.

Shao, B., Xin, H., Harmon, J.D. 1998. Comparison of image feature extraction for classification of swine thermal comfort behavior. Computers and electronics in agriculture 19, 223-232.

Shao, B., Xin, H. 2008. A real-time computer vision assessment and control of thermal comfort for group-housed pigs. Computers and electronics in agriculture 62, 15-21.
Viola, P., Jones, M. 2001. Rapid object detection using a boosted cascade of simple features. In: IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 1, 511-518.

Viola, P., Jones, M. (2001). Rapid object detection using a boosted cascade of simple features. Computer Vision and Pattern Recognition, 1, 511-518. IEEE Computer Society, 2001.

Viola, P., Jones, M. 2004. Robust real-time face detection, International Journal of Computer Vision, 57(2), 137-154.

Wilson, S. C. 2005. Spectral analysis of feeding and lying behavior of cattle kept under different feedlot conditions. Journal of applied animal welfare science, 8(1), 13-24.