The PigWise project: a novel approach in livestock farming through synergistic performances monitoring at individual level

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ABSTRACT

Optimizing production systems in agriculture and farming environments can nowadays be helped by advancements developed in other domains. In the field of precision livestock farming, solutions enriched with ICT, robotics and automation components are increasingly used to improve processes' efficiency and flexibility. This paper proposes a pervasive ICT system to monitor and record eating behavior of fattening pigs, leveraging on HF RFID ear tags identifiers (to detect animal eating while the head is on the trough) and on Camera Vision Systems (to cross-validate RFID reading). In addition a Synergistic Control algorithm is applied due to analyze information, extract feeding behaviors and detect eventual issues. Finally, these information are made available on the network, to the end-user, through the Virtus Middleware: it is an Internet of Things

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(IoT) system enabling seamless data integration and event sharing, able to manage heterogeneous information sources and geographically-distributed, large-scale deployments.

Keywords: PigWise, RFID, IoT, Algorithms, Camera, Middleware, VIRTUS.

1. INTRODUCTION AND RELATED WORK

Modern animal husbandry is characterized by an increasing herds size and production units number, at least as the market needs in terms of meat quality and safety. Accordingly is necessary to find new ICT solutions to improve farms efficiency, starting from the health and performance control of single animal within the herd. This article will present the project PigWise (PigWise site, 2013), which aims to answer to these needs. It focuses on fattening pigs, developing a management support system based on individual animal observation. Besides thorough knowledge about animals, this activity required a multidisciplinary approach linking state-of-the-art advanced data analysis and concepts sensor technologies. The system indeed provides early warning signals in case of potential health problems or drops in performance and welfare. Among the sensor used in the farm, there are the RFID (Radio Frequency Identification), since the 70s the key technology (Jansen and Eradus, 1999) for auto-identification, used for management and logistic. In the PigWise project the use of RFID is due to “presence detection”, defining the core methodology for the acquisition of feeding related information.

In 2004, Berckmans introduce the precision livestock farming (PLF) concept, which represents the non-invasive, on-line, production control process that leverages on an accurate process-relevant data acquisition and provides feedback at business level (e.g.: feeding strategies or growth monitoring). The PigWise project provide a PLF system based on HF (high frequency) RFID transponder. This represents an innovation, because mainly Low Frequency (LF) transponders are widely used for individual animal identification (Finkenzeller, 2006; Jansen and Eradus, 1999). The main disadvantage of LF tag are that can be only read individually, only if under radio coverage, and reading speed is relatively low (Finkenzeller, 2006). The usage of HF transponder fill this gap, in particular addressing the need of identify every single animal while eating. This is not trivial, because more than one animal eat simultaneously (Reiners et al., 2009) and feeding conditions change rapidly. Furthermore, the presented work leverages on the Synergistic Control (SGC) concept (Mertens et al., 2008, 2009), a fact-based analysis of acquired data making use of the principles of Statistical Process Control (SPC).

Many researches advantages of the Internet of Things (IoT) vision (Atzori et al., 2010, provides a wide survay), including those in the agri-farming environment (Kaloxylos et al., 2012). Accordingly, the PigWise projects indeed introduce another innovation in order to process acquired data and provide useful information to the farmer: the stable is considered as a data source and each pig as an IoT node. An existing IoT-oriented middleware, namely VIRTUS (Conzon et al., 2012), is used to collect data from the stable and to share information with end-users, leveraging on a standard, platform-independent, messaging protocol.

The remainder of the paper is organized as follows: Sec. II provides a brief overview of the state of the art of enabling technologies; Sec. III provides details about the reference architecture of the system and its main components; Sec. IV provides results used to validate the system; finally, Sec. V draws authors conclusions.

2 REFERENCE ARCHITECTURE AND DESIGN

The project has developed a tool used to monitor performance, growth and welfare of pigs at the individual level. This tool allows detecting problems in an early stage, providing monitoring and decision support therefore preventing economic damages. The innovative approach combines an individual online-monitoring system based on RFID with passive HF transponders, camera vision technology and software. The Figure 1 summarize the PigWise architecture, better described in following paragraphs.

2.1 Data Collecting

As previously mentioned, the acquisition system, acquire data regarding pigs activities. In order to record the moment when the pig eats, a circular HF antenna has been embedded in a trough (Figure 2). The antenna is connected to an HF long range RFID reader (Reiners et al. 2005). The reader is connected to an external PC and every pig was tagged with a passive HF transponder. The round transponders were clipped onto the ear tags of the pig. Anti-collision algorithms are used to facilitate simultaneous registration of animals that are simultaneously within the antenna reading range.

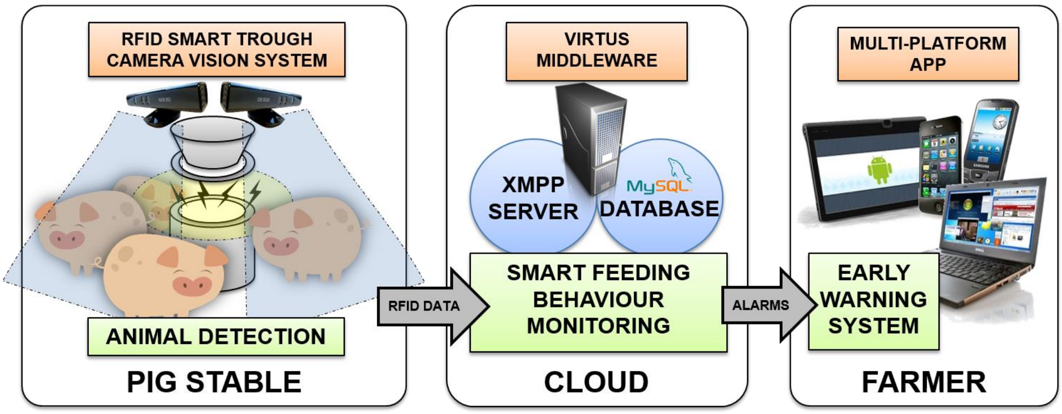

Figure 1: the PigWise architecture

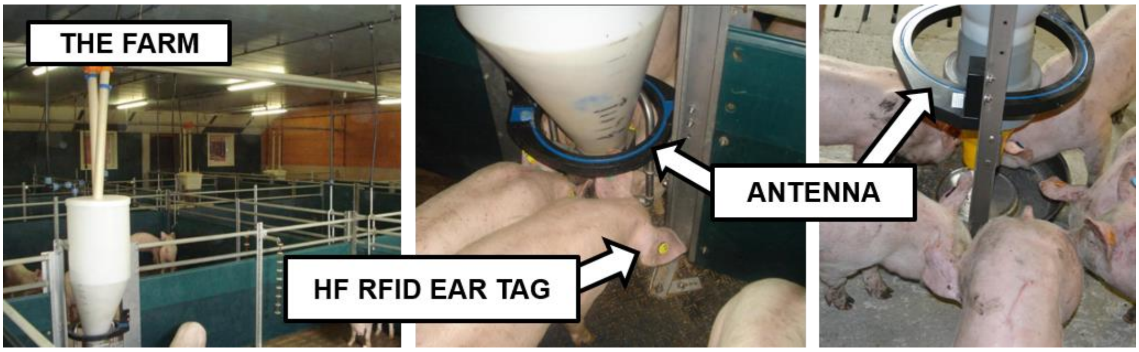

Figure 2: Trough with RIFD HF antenna

2.2 Data Validation

A camera vision based identification system, used as a layer upon the RFID identification system, is used to validate RFID readings. When a pig is approaching around the trough it is seen by a camera and it is automatically initialized as a graphical object in a computer connected to the camera. When the distance between the pig and the trough is small the pig is identified by the RFID reader and the computer binds the graphical object to the ID of the pig. The binding to the camera vision system can be used as verification for the identification by the RFID reader. Furthermore the camera vision system can detect the head of a pig when positioned above a trough or if it is just positioned beside the trough. By this detection the time measurement for each pigs' feed intake can be improved. At the end of this phase in order to make the data available there is the phase of integration and federation of all hardware and software components of the RFID system and sensors through a single infrastructure. In this way, the proposed camera vision system can verify the identification of the RFID tag associated to the animal, improving the quality of the overall process.

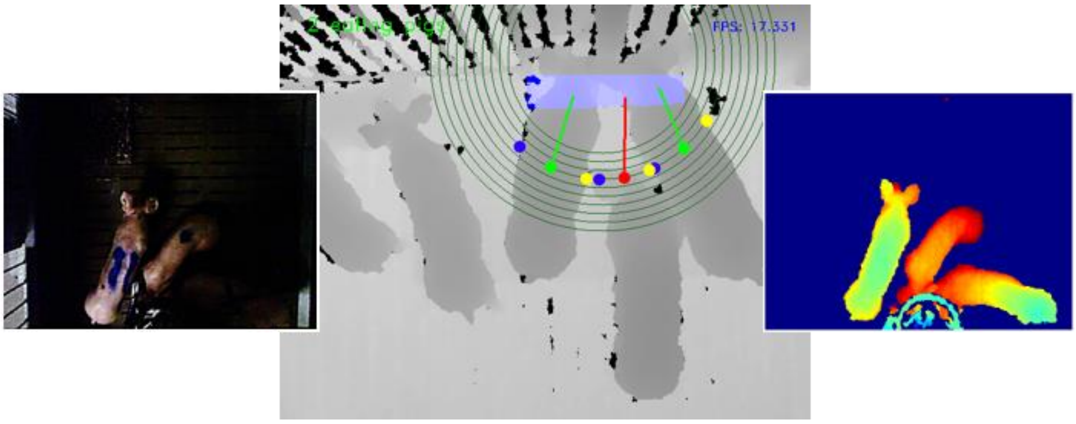

Figure 3: Some screenshot of the Camera Vision System

2.3 Early Warning System

Data produced and acquired by the system described above need to be processed in order to provide useful information to the farmer. Each stable is considered as a data producer and each pig as an IoT node, an existing IoT-oriented middleware, namely VIRTUS, is used to collect data from previous components and to share information with end-users, leveraging a standard platform-indipendent messaging protocol.

This information data are sent from the stable to the Middleware server (sited in Italy) through the use of the ICE Framework (ICE, 2013). Such framework provides Object-Oriented Remote Procedure Call (OO-RPC), grid computing and publish/subscribe functionalities. In the case of the PigWise project, ICE has been used to develop internet applications without the need to rely on the HTTP protocol.

Every day the amount of data recorded and sent to the server is very high, to generate understandable and usable, the data must be processed, is therefore necessary to develop a system able to process these data. On the basis of what has been said above it has been developed an SGC (Synergistic Control) algorithms, able to detect deviations in the RFID data which are collected and which are transformed into performance and welfare. The concept of SGC combines the power of Engineering Process Control (EPC) and Statistical Process Control (SPC). The EPC step pretreats the raw livestock production data to meet the assumptions (stationarity & independence) related to the use of the SPC step. The SPC technique used is the statistical control chart which basically visualizes the production system (parameter) and detects the occurrence of deviations (Mertens et al., 2009; Mertens, 2009). Biological processes are not likely to fit all three criteria (Mertens et al., 2011). Using EPC, the undesired trend and autocorrelation are modelled in separate steps and the residuals after model-subtraction, meeting the SPC conditions, are then used in the control chart.

The SGC procedure is performed for every individual pig. After checking the statistical characteristics, the pigs' feeding pattern is modelled if necessary. A small reference period in the beginning of each production period is used in order to estimate the in-control model parameters. The residuals after subtracting the model from the raw data are used to calculate the standard deviation of the variables. With this information, control-limits for the reference period are determined. After the reference period a recursive approach is used. With every new data-point, the model estimation and control-limits are updated. Any out-of-control points are signalled when falling outside the limits and are not used for the recursive estimation of the model and the in-control variability (Mertens et al., 2008). Based on these algorithms, the Early Warning System (EWS), which includes mechanism to process SGC output, has been developed.

Figure 4: Alarm message

The control charts which result from the SGC algorithm are the basis of the EWS, which has been integrated in the VIRTUS Middleware; in fact has been developed a VIRTUS component able to manage the SGC algorithm and alarms which generates. VIRTUS includes a component able to send this alarms to the farmer. To send alert messages the system uses the XMPP (XMPP, 2013) protocol. The Figure 4 shows the possibility to send via XMPP messages to disparate device, the figure shows for example a screenshot of XMPP client available for Apple devices (QIP (QIP, 2013) application).

In order to provide further information to the farmer has been also implemented a web-based application (Fig. 5), showing the activity of pig, the site offers the ability to view and download charts and statistical information about the state of the database and the information it contains. This web application is complementary to the EWS, but require major user interaction in order to access the page, login and choose time period and animal ID to be plotted.

Figure 5: PigWise web site

3 CONCLUSIONS

With the aid of the innovative HF RFID feeding system the behaviour of fattening pig can be accurately monitored. Thanks to the use of the camera system and the cross-correlation with the RFID readings, it has been possible to identify some crucial figures to optimize the algorithm: e.g. the minimum delay between two RFID readings in order to consider an animal in a state of "feeding" or "not feeding". Some future improvements are e.g. preventing the registration of the pigs continuously standing at the trough without eating. However, the innovative methodology proposed, based on the integration of different technologies to monitor the pigs' health status and the overall distributed early warning system have shown huge potential. Moreover, thanks to the proposed IoT approach, many farm can be ideally managed simultaneously and most devices can be added in order to combine heterogeneous data sources or information; this approach enables the possibility to easily create new value added services, applicable to the wide agricultural/farming environment.

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5 REFERENCES

(Atzori et al., 2010) Atzori L., Iera A., Morabito G. "The internet of things: A survey". Computer Networks, 54(15), 2787-2805. 2010.

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Scalera A., Brizzi P., Tomasi R., Gregersen T., Mertens K., Maselyne J. ,Van Nuffel A., Hessel E., Van den Weghe H. "The PigWise project: a novel approach in livestock farming through synergistic performances monitoring at individual level". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

(Berckmans, 2004) Berckmans D. "Automatic on-line monitoring of animals by precision livestock farming". Animal production in Europe: The way forward in a changing world. International congress of the International Society for Animal Hygiene Saint-Malo, France, 27-30, 2004.

(Conzon et al., 2012) Conzon D., Bolognesi T., Brizzi P., Lotito A., Tomasi R., & Spirito M. A.. "The VIRTUS Middleware: An XMPP Based Architecture for Secure IoT Communications". In Computer Communications and Networks (ICCCN), 21st International Conference on (pp. 1-6). IEEE, 2012.

(Eradus et al., 1999) Eradus W.J., and M. B. Jansen. "Animal identification and monitoring". ComputElec-tron Agr 24:91–98, 1999.

(Finkenzeller, 2006) Finkenzeller, K. "RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, vol. 2". Wiley, Chichester, 2006.

(Hawkins et al., 1998) Hawkins, D. & Olwell, D. "Cumulative Sum Charts and Charting for Quality Improvement". Springer-Verlag Inc., New York, USA, 1998.

(ICE, 2013) ICE Framework, Online available: http://www.zeroc.com/, 2013.

(Kutner et al., 2005) Kutner, M., Nachtsheim, C., Neter, J. & Li, W. (2005): Applied linear statistical models - Fifth Edition. McGraw-Hill/Irwin, New York, USA.

(Mertens, 2008) Mertens, K., De Ketelaere, B., Vaesen, I., Löffel, J., Ostyn, B., Kemps, B., Kamers, B., Bamelis, F., Zoons, J., Darius, P., Decuypere, E. & De Baerdemaeker, J. (2008). Data-based design of an intelligent quality control chart for the daily monitoring of the average egg weight. Comput Electron Agr 61, 222–232.

(Mertens, 2009) Mertens, K., Vaesen, I., Löffel, J., Kemps, B., Kamers, B., Zoons, J., Darius, P., Decuypere, E., De Baerdemaeker, J. & De Ketelaere, B. (2009). An intelligent control chart for monitoring of autocorrelated egg production process data based on a synergistic control strategy. Comput Electron Agr 69, 100–111.

(Montgomery, 2005)Montgomery, C. (2005): Introduction to statistical quality control - Fifth Edition. John Wiley & Sons, Inc., Hoboken, NJ, USA.

(PigWise, 2013) PigWise project site. Online available: http://www.pigwise.eu/, 2013

(QIP, 2013) QIP Mobile Messenger. Available on Apple app Store: https://itunes.apple.com/us/app/qip-mobile-messenger, 2013

(Reiners et al., 2009) Reiners, K., Hegger, A., Hessel, E., Böck, S., Wendl, G., Van den Weghe, H. (2009). "Application of RFID technology using passive HF transponders for the individual identification of weaned piglets at the feed trough". Comput Electron Agr 68, 178-184.

(XMPP, 2013) XMPP Standards Foundation, Online available: http://xmpp.org/, 2013

(Kaloxylos et al., 2012) Kaloxylos A., Eigenmann R., Teye F., Politopoulou Z., Wolfert S., Shrank C., Kormentzas G. "Farm management systems and the Future Internet era". Computers and Electronics in Agriculture, 89, 130-144, 2012.

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Scalera A., Brizzi P., Tomasi R., Gregersen T., Mertens K., Maselyne J. ,Van Nuffel A., Hessel E., Van den Weghe H. "The PigWise project: a novel approach in livestock farming through synergistic performances monitoring at individual level". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.