ICT-AGRI Call 1 Final Project Report

Acronym

PigWise

Title

"Optimizing performance and welfare of fattening pigs using High Frequent Radio Frequency Identification (HF RFID) and synergistic control on individual level"

Consortium

- Georg-August-University Göttingen (GAUG), Department of Animal Sciences, Division: Process Engineering, Germany (Coordinator)
- Institute for Agricultural and Fisheries Research (ILVO) –Technology and Food Science Unit – Agricultural Engineering – Livestock Precision Farming, Belgium
- Katholieke Universiteit Leuven (KUL), Department of Biosystems, Division of Mechatronics, Biostatistics and Sensors (MeBioS), Belgium
- Institut Superiore Mario Boella (ISMB), Service and Application Laboratory, Italy
- Aarhus University (AU), Aarhus University School of Engineering (ASE), Denmark

Final publishable summary report

Modern pig husbandry is characterized by an increasing herd size per production unit. As a result, new management solutions will be necessary in pig housing, in particular for monitoring the welfare and performance of individual animals within the herds. The aim of the project was the development of a sensor system based on HF-RFID technology, which can be used for an early warning in case of potential health problems and drops in performance or welfare. Furthermore, an innovative computer vision based identification system was supposed to be developed for validation of the HF-RFID technology. The new sensor systems were tested in fattening pigs.

Health and welfare problems in pigs are mostly recognised by changes in individual behaviour. Feeding behaviour and activity are often considered to be indicative of general health. Feeding behaviour was registered with the aid of HF-RFID and used as a valuable indicator of the pig's health.

All the hardware and software components of the sensor systems were integrated and federated through a unique infrastructure. Synergistic Control (SGC) algorithms processing the RFID-collected data were developed to detect any deviation and eventual correlations between the feeding parameters. Based on these algorithms, an Early Warning System (EWS) was developed.

In conclusion, with the aid of the innovative high-frequency HF-RFID system individual feeding behaviour of fattening pig could be monitored simultaneously, and online. Regarding feeding behaviour of pigs, the HF-RFID technology has a huge potential, it can be used for early warning systems for detection of health, production and welfare problems.

Carrying out PIGWISE on a transnational European basis brought the clear added value because the outcome solution became transferable, accounting the differences between the country-specific production processes

1. Description of activities and final results

Work Package 1: Optimization of the RFID hardware and development of Camera Vision Analysis

Task 1.1: Optimization of the RFID hardware

For optimization of the RFID hardware a new feeder prototype has been developed. At first different antenna constructions (diameter/power) were tested during one fattening with four pigs in Vechta, Germany. In order to analyse its identification accuracy as well as to evaluate its optimal position that pigs' feeding behaviour is not interfered, video recording were used.

The construction of the final circular antenna, which is used in all further PIGWISE experiments, is shown in Figure 1.

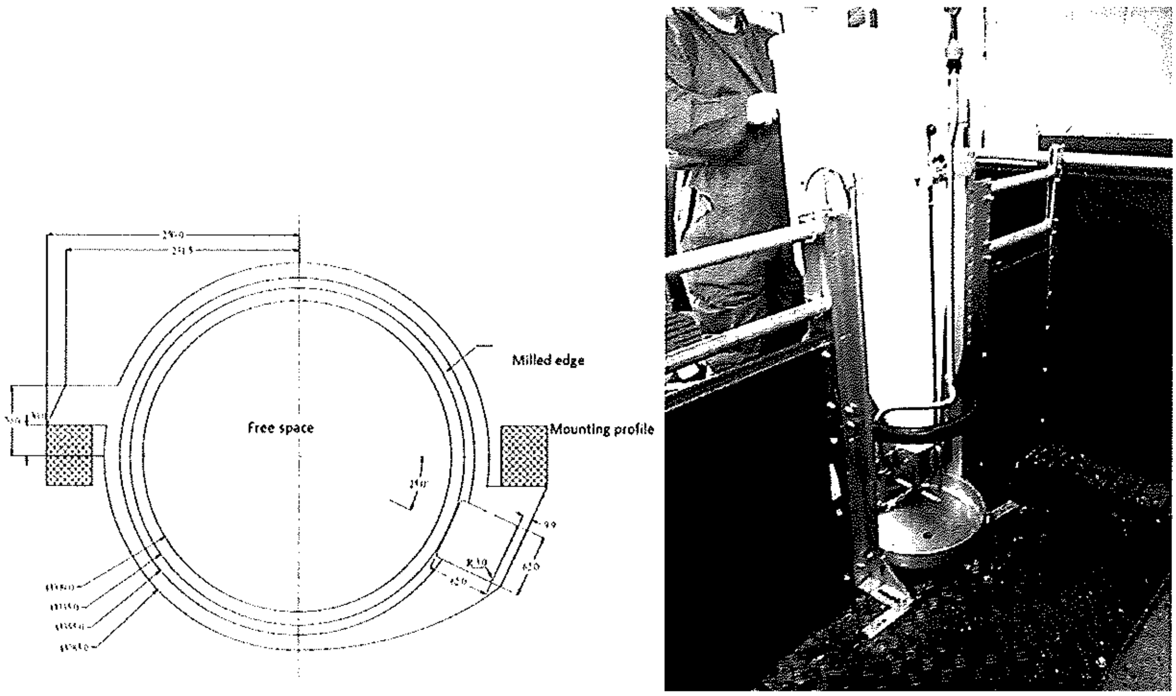


Figure 1. Construction of the modified antenna

The custom made antennas (13.56 MHz, DTE Automation GmbH, Enger, Germany) were attached to the feeders (Lean Machine, Big Dutchman, Vechta, Germany). The antennas have a diameter of 385 mm, the supporting martial is made of 30 mm rigid plastic in which an edge is milled for the antenna. The antenna, which is made of copper, works with a transmission power of 1.8 W and an operation frequency of 13.56 MHz. The antennas are positioned centre top in a height of 460 mm above the trough (diameter 400 mm). The antenna is connected to a Long Range Reader HF (Feig HF Long Range Reader ID ISC.LRM 200 B, FEIG ELECTRONIC GmbH, Weilburg, Germany), which was linked to a PC.

Every pig was tagged with a passive HF transponder with an operating frequency of 13.56 MHz (IN Tag 300 I-Code SLI tags, ISO 15693, HID Global Corporation, California, USA). The round transponders were clipped onto the ear tags (Allflex, Hamburg, Germany) of the pig (Figure 2).

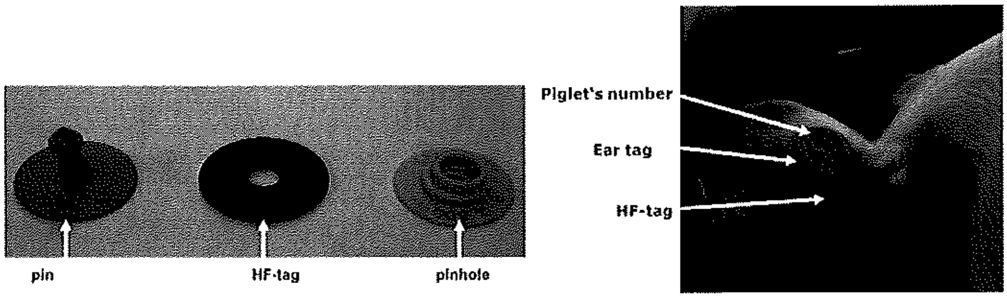


Figure 2. Use of eartag in combination with the HF-tag

After the final antenna construction has been defined one fattening period (4.10.2011 – 16.12.2011) with 4 pigs (35 – 90 kg) was carried out in Vechta, in which Camera Vision Analysis Technique (Task 1.2) has been also installed.

Task 1.2: Development of Camera Vision Analysis

The main sensor system in the PIGWISE project is the HF based RFID system. This RFID-system is complex and vulnerable because it consists of multiple RFID-readers, multiplexers, long cables to the antennas placed at the feeders and a long cable to the PC containing the RFID-database. In addition ear tags can be lost at some pigs during a fattening period.

In earlier pre-studies before the PIGWISE project, the feeding situation was recorded as movies with timestamps. The feeding situation at a feeder, detected by the HF-RFID equipment, were inspected by employees and compared with the corresponding feeding situation in the recorded movies. This work was very time consuming. Therefore an automatic validation method was needed as add-on functionality to ensure valid RFID observations during the experimental studies in the project.

To detect lost or degraded functionality of the RFID system a computer vision based sensor verification system was developed to ensure valid RFID observations. This computer vision system was based on cheap consumer grade 3D infrared cameras (Kinect). Two of these cameras were placed above each feeder. The feeding coverage for each feeder, seen from above, was 360 degrees. Each camera could inspect 180 degrees of the complete coverage, seen from above. Therefore two cameras were required to inspect the complete feeding situation around each feeder.

The computer vision algorithm defines a feeding pig as a pig which body is placed above the trough at the feeder, in the same manner as an RFID registration. The part of the body is typically the pig's head. The computer vision system counts in real time the current number of feeding pigs (Figure 3).

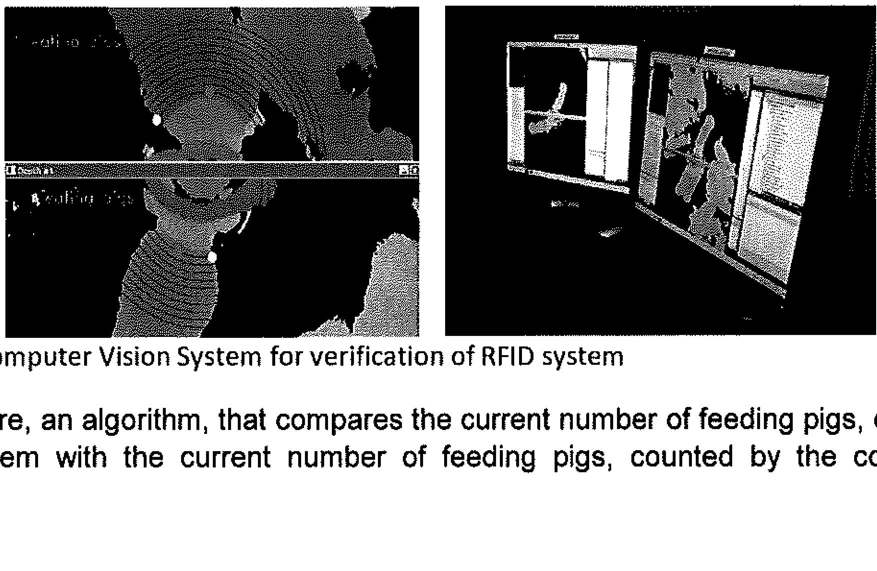


Figure 3. Computer Vision System for verification of RFID system

Furthermore, an algorithm, that compares the current number of feeding pigs, counted by the RFID system with the current number of feeding pigs, counted by the computer vision system, was developed. The events from the sensors are compared within a time window, set as a system parameter. If the compared, counted number of feeding pigs differs too much, the operator is notified.

The results of the installed system at ILVO (Belgium), consisting of two PC's and four 3D/IR cameras, were as follows:

- It was possible visually to inspect the feeding situation at any time, night and day. Dirt on the floor was removed by a digital filter, because it was possible to determine the view range of the each camera. The pigs were only shown and treated by the software algorithm as outlines, seen from above. The live situation, seen by the cameras, could visually be compared with the incoming RFID-registrations, which also were visible at the same screen as the camera screen. All events were logged for later inspection. By using a remote desktop connection it was possible to follow the camera-/RFID-situation from anywhere.
- The comparison algorithm that automatically compares feeding events from the RFID system with feeding events from the computer vision system was running. It was adjusted and improved during spring 2013. It was never possible to achieve the necessary precision of the comparison, to make the computer vision system to be a valid verification tool. The primary reason for this was that the computer vision algorithm was too sensitive. It often detected an ear of a feeding pig as an "extra" pig. This led to frequent mismatches between the compared RFID based feeding events and computer vision based feeding events. Furthermore the fast movements of the feeding pigs head in/out to/from the feeder led to a fast change of the number of computer vision based feeding events. The frequency of these changes was typically higher than the frequency of the RFID based feeding events. The difficulty in comparison of RFID based feeding events and computer vision based feeding events is similar to a comparison between the impressions from a humans ears and eyes.

The conclusion of the quality of the RFID/Computer vision system is that it worked, but it was not possible continuously to achieve an optimal precision.

Task 1.3: Validation of the setup

Experimental setup

Four Pigs were fed with one modified RFID-feeder, which has been equipped with the final antenna. Videos of feeding pigs were recorded digitally on the same PC used for recording the RFID data in order to ensure the same time stamp for both the video recordings as well as the RFID identification. With the aid of video recording the accuracy of the RFID technology was investigated in detail. Therefore on 6 fattening days (day 4, 21, 32, 47, 58 and 70) the **exact match** between video and RFID was analysed to the second during a 4 hour period (12 am -2 pm; 4 pm – 6 pm). In total 160 h were analysed. Furthermore, all pigs were tagged with two transponder ear tags, in order to evaluate whether the ear (left/right) has an influence on the identification accuracy.

Comparing the RFID data with the data of the video analysis a pretty good correlation can be found. Pigs which have been classified as eating on the video were also registered by the RFID technology, *status Video/RFID feeding.* As an example the period 4 - 6 pm of fattening day 47, pig 2, left ear is shown in Figure 4. However, looking in to the data in more detail, it was found out that the RFID technology does not register the pigs standing at the trough continuously. Gaps of few seconds occur between single registrations, resulting in a high number of *status RFID no feeding /video feeding (Figure 5)*

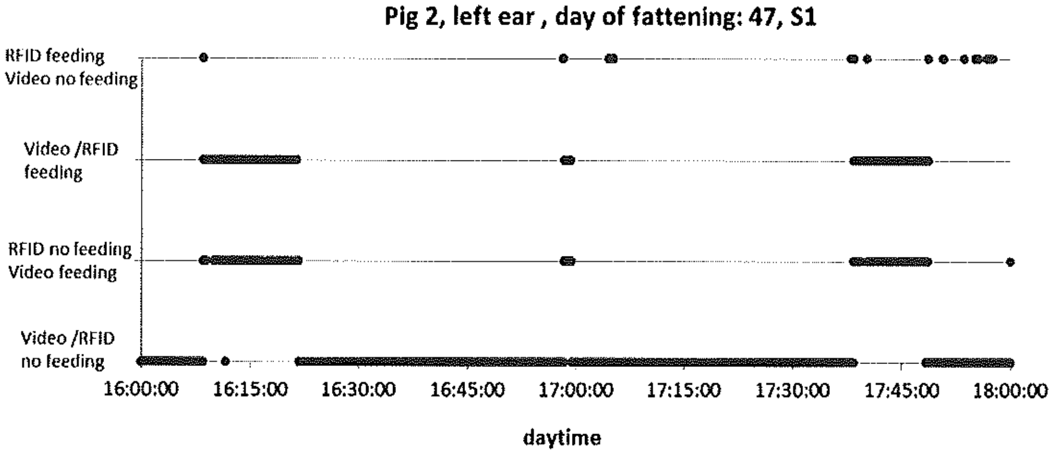


Figure 4. Four different statuses of pig 2, left ear, day of fattening 47 during 4 – 6 pm.
S1: RFID registered feeding analysed to the second.

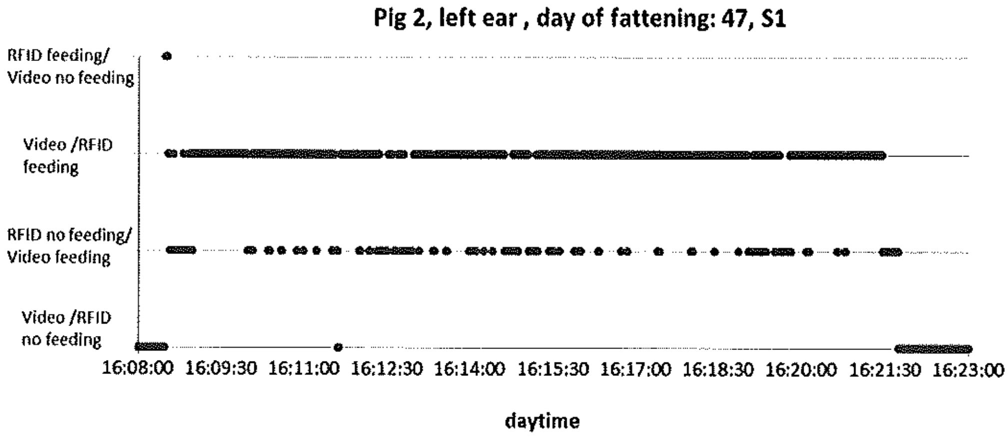


Figure 5: Four different statuses of pig 2, left ear, day of fattening 47 during the time slot 4:08:00 – 4:23:00 pm of figure 1, S1: RFID registered feeding analysed to the second.

These gaps lead to clearly lower values of feeding time registered by RFID compared to the video analysis.

When analysing the videos, a feeding pig was defined as a pig standing at the trough with its head down. However, during feeding pigs also lift their heads and sometimes go one step backwards, when swallowing the feed. The RFID- technique still registered the pig at the trough whereas the observer of the videos classified the pig as not feeding.

In total, 3924 gaps *(status RFID no feeding /video feeding)* were detected in the whole data set. The duration of these gaps lasted on average 10.9 s (SD 35.2 s), 95 % of these gaps were lower than 30 s, and 99 % of these gaps were lower than 100 s. (Figure 6).

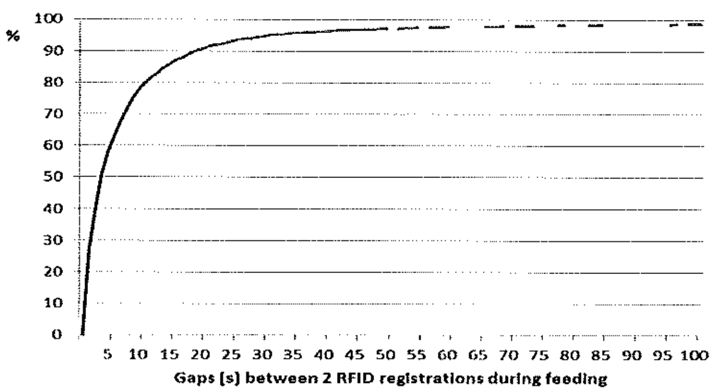


Figure 6. Gaps [s] between 2 RFID registrations during feeding (status RFID no feeding /video feeding)

Work Package 2: Development of data integration and management procedures

Task 2.1 Requirements and additional Middleware functionalities

In the initial phase of the work various solutions have been studied in the literature regarding the ICT applications in agriculture. In this activity project requirements, which were necessary for the application, for sharing of data and information between the various entities of the system, had been identified. The aim of this study was to identify the best approach to ensure greater efficiency, using the potential offered by ICT. During the study critical points and weak points of the system have been identified, directions of future work had been chosen and important factors, which were essentially the transmission speed and the technologies used for the definition of the platform, had been investigated.

Task 2.2 Middleware customization

The data sources are ad-hoc developed for the project, the proposed middleware architecture had to deal with any already existing data generation instrument. In particular the information which should be managed is divided into two types:

- *RFID reading information*: the HF RFID reader reads the pig's ear tags and a PC elaborates the data, applying some specific filtering features.
- *Computer vision system related information*: the computer vision system provides information regarding the number of pigs. which are feeding simultaneously interpolating information coming from HF readings and computer vision algorithms

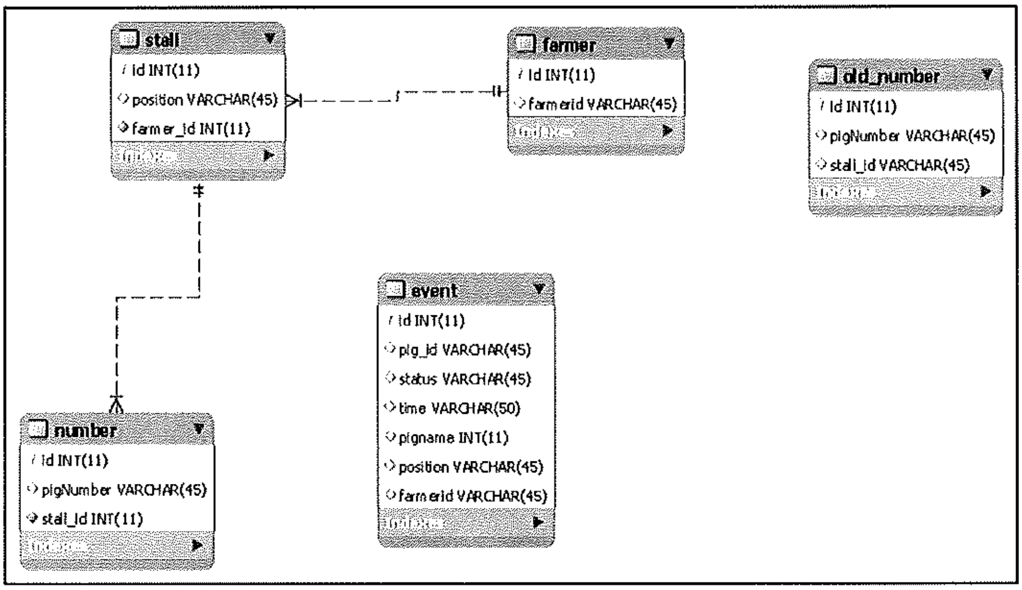
Both this information data are sent from the stable to the VIRTUS server (sited in Italy), through the use of the ICE Framework. Such framework provides Object-Oriented Remote Procedure Call (OO-RPC), grid computing and publish/subscribe functionalities. ICE has been used to develop internet applications without the need to rely on the HTTP protocol. In order to guarantee data compatibility with the VIRTUS infrastructure, a specific module has been developed.

A system architecture has been defined taking into account the requirements of the project:

- Receiving and managing the information coming from the stable (according to what was done in Work Package1);
- Managing the SGC algorithms (Work Package4)

Regarding the first point data generated by pigs (Drantum, Germany), were sent to the server (Turin, Italy) with the use of the Framework Ice [ZeroC http://www.zeroc.com/]. In agreement with the requirements, a new feature, which interfaces with any type of DB (SQL and NoSQL) for VIRTUS, has been implemented (Figure 7). The database used by VIRTUS was embedded; this made it very difficult to access information in the database from outside.

The second point concerns the activities associated with the Work Package4 but that also involves the Work Package2, in fact within the VIRTUS middleware a bundle that can manage the life cycles of external applications has set up, so that the system produces daily and automatically reports and



statistics on the health of pigs.

Figure 7: Data Base Architecture

Task 2.3 Pigs Monitoring Application and Trial

Middleware was the core element of the architecture of PigWise. The system was composed by a series of bundles that allow the execution of multiple processes at the same time. These services were able to communicate between each other even if they were not physically present on the same device. This technology has been designed to support and simplify the development of distributed applications.

VIRTUS provides methods for sharing information to the user (in the PigWise context is the farmer), VIRTUS guarantees:

- Flexibility: the system used is flexible to shows data and to send alarms in order to be adaptable to multiple situations and is easily reconfigurable in case of the addition of further features.
- Scalability: the designed system should be network independent, so always running (without bottlenecks) in case of network constrains, in case of network fall or in the case of high data rate. High scalability is obtained thanks to some features provided by the XMPP protocol, particularly:
  - The use of virtual addresses instead of IP addresses, which are independent from network location, topology and technology (preserving correct messages routing).
  - The ability to define gateways between the IP network and non IP networks.
- Reliability: the XMPP protocol allows storing messages for nodes that are temporary offline and deliver them as soon as they become available. The infrastructure buffers messages and deliver them in almost real-time when the objects become connected, without the need of polling from the destination nodes, so reducing the amount of traffic over the network.
- Multiplatform compatibility: users should be able to use the PigWise application regardless of the platform they are dealing with (mobile, smartphone, tablet or personal computer)

and operative system installed as today happens with web contents. In this case, the web page, despite being a reasonable solution, needs to be constantly polled. PigWise shared a big number of data and it sent messages to specific users in specific situations.

Furthermore, the development of methods for sharing information with users has been studied. The middleware has also been used for the exchange of information, using XMPP (an instant messaging protocol) and for sending information to users.

In order to provide further information to the farmer a web- based application has been also implemented, which shows pig activity as charts and statistical information regarding database status. This web application is complementary to the Early Warning System (based on XMPP messages), but requires major user interaction in order to access the page.

Finally, the proposed system was able to receive events generated by the activities of pigs and save them in the database. It was necessary, however, to use these data for the algorithm provided by Work Package4, the contribution ISMB in Work Package4 was to set up an infrastructure for:

- Making all data available to the SGC algorithms needed for the analysis
- Managing the life cycle of the system and in particular of the algorithms, in fact, the SGC algorithms were performed every 24 hours
- Generating alarms and information on the health status of pigs and system.
- Preparation of a multi-platform system, capable of sending alarms and statistics to mobile devices of different types (PC, Smartphone and Tablet) (Figure 8).

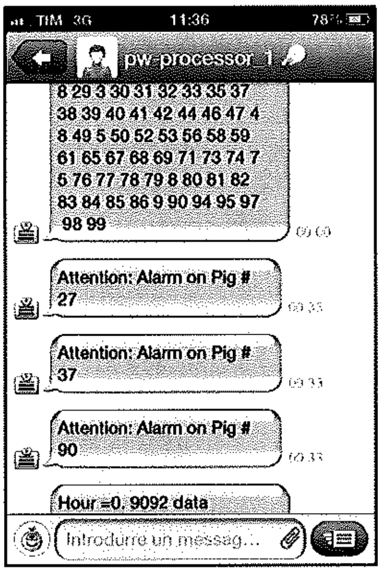


Figure 8: Smartphone application with XMPP Message

Work Package 3: Data Collection under two different conditions

Task 3.1.: Observational Study

On a farm located 22 km away from Vechta, Germany, four modified HF-RFID feeders had been installed in one mechanically ventilated pig house. In total 4 fattening period were carried out. The pens were equipped with fully slatted floor. One modified HF-RFID feeder each was positioned within the partition between two pens resulting in eight experimental pens. During the feeding period the height of the antenna was not changed. The custom made four antennas of the feeders were connected via multiplexer *(Feig HF Multiplexer 8* *fach ID ISC.Ant MUX)* to the Reader Feig HF Long Range Reader *ID ISC.LRM 200 B*, which was used in Task 1.1.

Additionally in two pens pigs' feeding behaviour is recorded on video for validation purposes. Fifteen pigs were housed in each pen, resulting in 120 pigs in total. Six pigs were marked individually on their back, feeding behaviour of the focal pigs were analysed in detail. All pigs were weighed individually on fattening day 1, and around fattening day 30, 60 and 90.

1. Fattening Period: March – July 2012

In the first weeks of this fattening period, problems occurred with the RFID technique. On a nearly daily basis, the HF-RFID-Technique intermitted. It was assumed that overvoltage, voltage fluctuation or the capacity of the PC might be the reason. However, after some weeks it turned out that the Reader *ID ISC.LRM 200 B* did not interact with the Multiplexer. A follow-up model *Feig HF Long Range Reader ID ISC.LRM 2500* B was bought.

2. Fattening Period: July 2013 – October 2012

After changing the HF-Long Reader the system was tested again under practical conditions on farm. HF-RFID data was stored locally on one PC on farm. The systems run without any considerable problems.

3. Fattening Period: November 2012 – February 2013

The aim of this fattening period was to find a solution how to transfer the HF RFID data online and in real-time to the Italian server. The PC in the German pig stable, which was located in the countryside, had to be connected to the Internet. Furthermore, the Danish partner developed a client application for the German stable PC that transmitted HF-RFID based feeding events from the farm in Germany via the Internet to the central server placed at ISMB in Italy, where the analysis of each pig's feeding behaviour took place. It took several weeks/months until this system run stable, lots of data got lost due to several PC crashes.

4. Fattening Period: March – June 2013

In this fattening period all technical problems could be solved, the system run stable. Data were sent to the Italian server, where the Belgian algorithm was implemented. By the end of this fattening period, it was possible to receive alarms/warnings of the Early Warning System on farm.

Furthermore pigs' feeding behaviour was analysed by the Belgian partner. Raw RFID registrations were clustered into feeding visits and into meals, the physiologically and biologically relevant unit of feed intake. Based on expertise, a visit criterion of 6s was used to make visits while discarding visits shorter than 10s and a meal criterion of 5min was used to generate meals. In figure 9 the normal variation in number of meals/day, meal duration/day and average gap between meals/day can be seen based on data of fattening period 3 and 4 in Germany with in total 213 healthy pigs and 82 days.

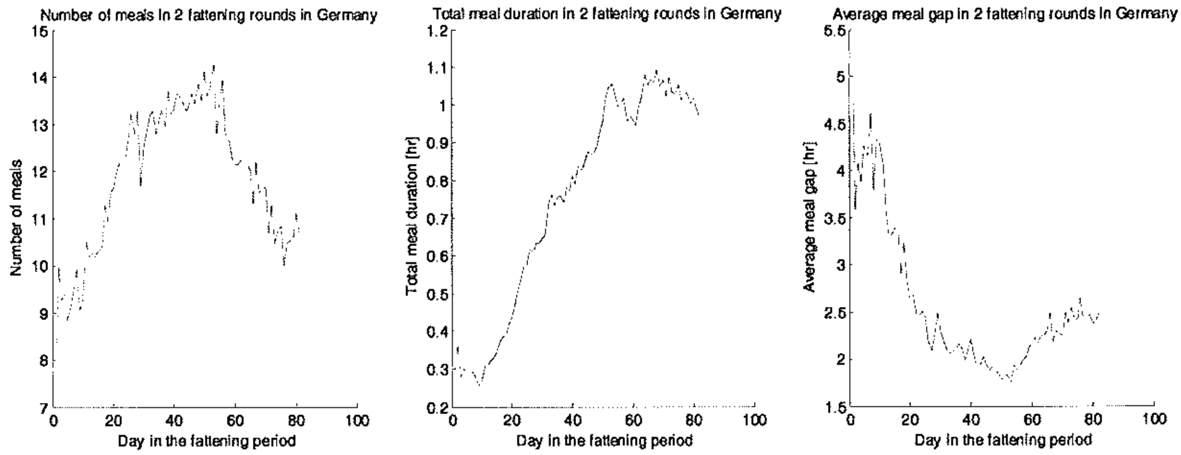


Figure 9: Normal variation in meal parameters in Germany, based on data of 213 healthy pigs.

Task 3.2.: Experimental Study

After the technical problems, which occurred in the first fattening period of task 3.1., were solved, further custom-made antennas were built for the experiments in Belgium. This was necessary since the construction and type of feeders used in ILVO's experiments (Swing MIDI feeders, Big Dutchman GmbH, Vechta) was slightly different from those in Germany (Lean Machine feeders, Big Dutchman GmbH, Vechta were no longer at sale).

Because of the new antenna-type and the high competitive environment in the pens containing 59 pigs, another validation of the system at ILVO was performed. In figure 10 part of the results of this validation procedure can be seen. A paper entitled 'Validation of a High Frequency Radio Frequency Identification (HF RFID) system for registering feeding patterns of growing-finishing pigs' was submitted to 'Computers and Electronics in Agriculture'.

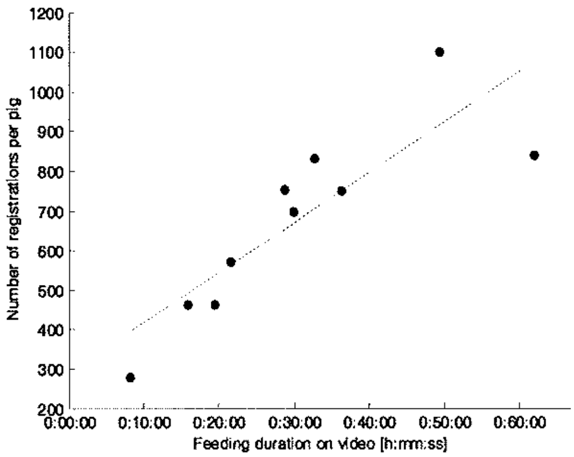


Figure 10: Correlation between number of RFID registrations and feeding duration on video, established through observations of 10 pigs during 11.5 hours.

It was found that gaps of various lengths existed between RFID registrations of a feeding pig. It was hypothesised that changes in position and orientation of the pigs' ear tags caused the RFID tags to move in and out of range of the antenna. To determine the range of the RFID antennas and the influencing factors, range measurements were performed. The results of these experiments were presented as a poster on the EC PLF 2013 conference and submitted to 'Computers and Electronics in Agriculture'.

With joint efforts of the five PigWise-partners also the Computer Vision Analysis was validated by comparing scorings of 5 persons with the counted 'number of feedings pigs' by the Kinect system during tests at ILVO.

At ILVO's experimental farm different feeding ratios were used in 3 experimental pens (3:1, 7:1 and 15:1) and a control pen (ratio 7:1). Three experimental rounds were performed. In the experimental pens stressors were applied to simulate problems in the stable that would have an effect on the feeding patterns and could possibly be used to validate the performance of the Early Warning System in Work Package4. In the first fattening period, weekly either the feed or water supply was stopped during 3hours or the flow of the water was reduced by half during 24hours (3 stressors divided across the 3 pens in random order). As can be seen in figure 11, the stressors did not seem to have an effect. A large change in feeding patterns can however be seen between day 70 and 80, possibly due to the high temperature in the stable and the change in the height of the antennas (pigs grew too large to eat comfortably under the antenna). On day 115, a problem with the feed delivery occurred and all pigs were deprived of food for more than 10 hours. As can be seen in figure 12, the largest effect on the number of meals occurs in pen 4, the control pen. The other experimental pens seem to have adapted to the occurring stressors and do not change their feeding pattern drastically when there is no food available.

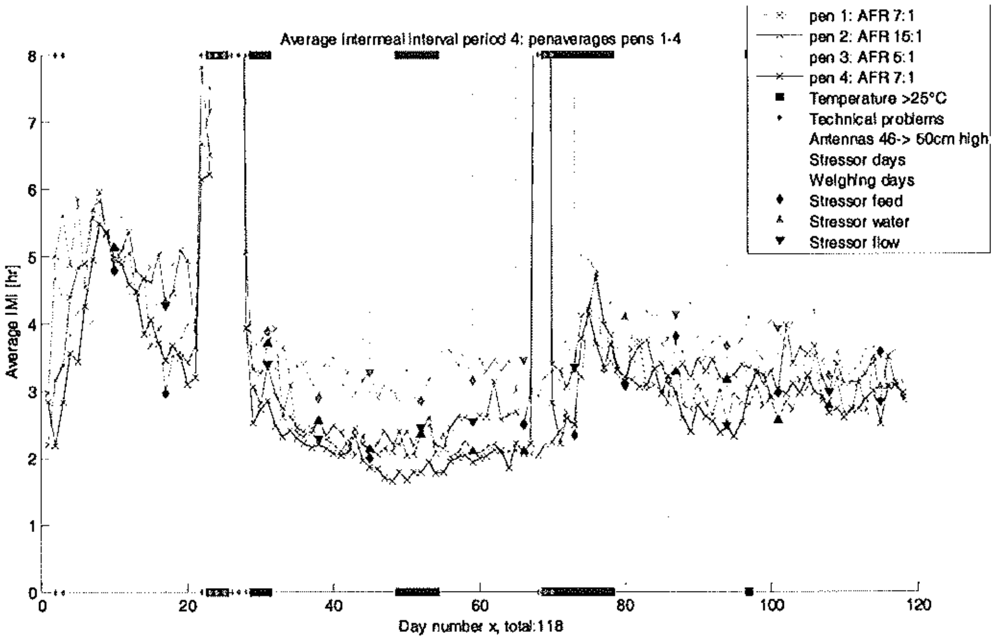


Figure 11: Pen-averages (59 pigs per pen) of the average meal gap during ILVO's first experimental round.

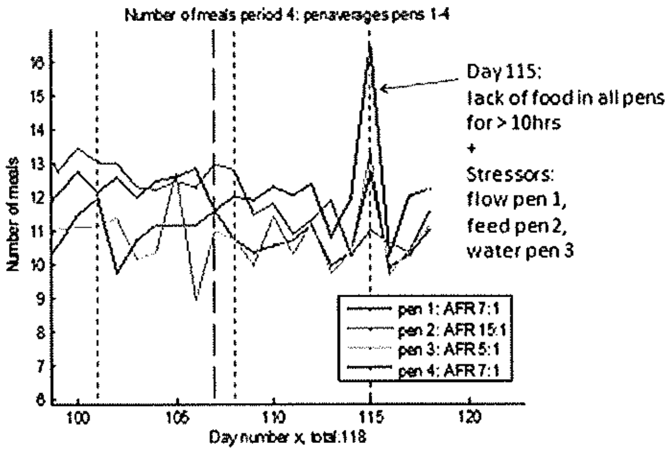


Figure 12: Effect of involuntary food deprivation in all pens for more than 10 hours on the number of meals per day

In the second fattening round, duration of stressors was increased and frequency was decreased (3-weekly, 13-24 hours of feed or water deprivation). However, again, the effect was not clear. It is hypothesized that not all pigs suffer (equally) from the stressor and pigs are very adaptive to the situation. Also it is not clear when the effect starts to become visible and when the effect dies out, and also which pigs are affected. As can be seen in figure 13, a large variation between and within (healthy) pigs in the same pen with approximately the same slaughter weight can be observed. In the last fattening round no temporary stressors were applied. There was a serious outbreak of tailbiting however.

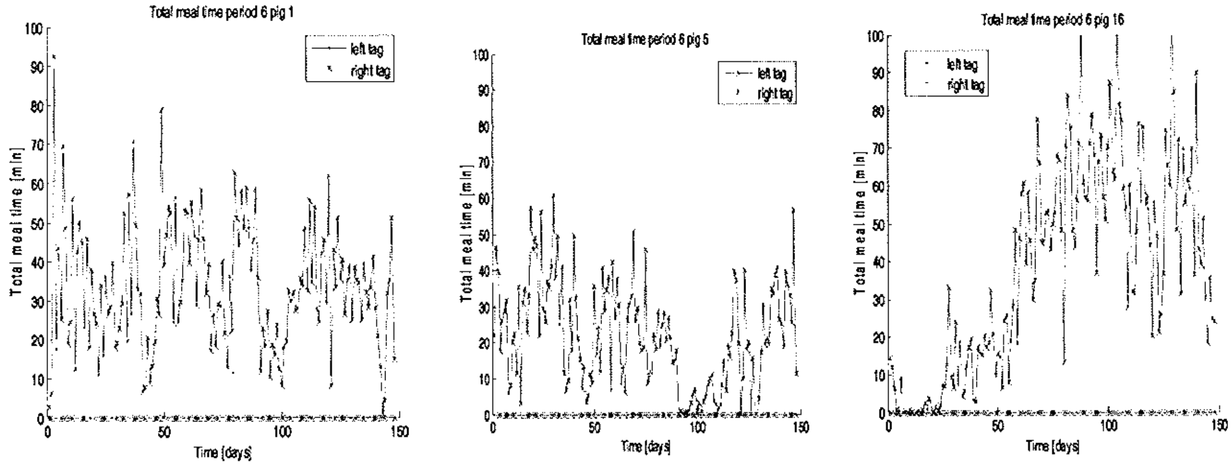


Figure 13: Total meal time of 3 pigs in the same pen, with the same slaughter weight during the 2nd fattening round at ILVO.

Work Package 4: Development of an RFID Early Warning System based on Synergistic Control

Task 4.1: Investigation of historical RFID-based data

Historical data collected in Vechta, Germany was used to investigate the statistical characteristics in the possible RFID based feeding parameters. The assumptions of the control charts were violated, but trend and autocorrelation were depending on the pig.

Task 4.2: Engineering Process Control for RFID based data

Engineering Process Control (EPC) was applied to the RFID based parameters to pre-process them for use in control charts. To remove non-stationarity a recursive linear regression model was used. An ARMA model could be used, but since the amount of autocorrelation was dependent on the pig, no ARMA model was implemented.

Task 4.3: Development of the statistical control charts

The residuals after the EPC step were used in the Statistical Process Control (SPC) step. A Shewhart control chart for individual measurements was used for individual pigs and several parameters were tested. Also Exponentially Weighted Moving Average control charts were tested. Generic algorithms were developed at KU Leuven.

Task 4.4: Post-hoc testing of the Early Warning System

Several results of correctly signalled ill pigs were presented at the EC PLF 2013 and the BTU 2013 conferences. In figure 14 a severly lame pig's alarms can be seen for a Shewhart chart on either the average meal gap or the average inter-registration interval. However, in general the number of alarms was quite high compared to the problems noted in the logbook. In table 1 the results of post-hoc application of a Shewhart chart with wide limits on the average meal gap of the validation round (Work Package 5) can be seen. Sensitivity is 86% and specificity 99% but 55 unexplained alarms were noted. The reasons for these alarms are the following:

- The subjective visit and meal criteria create artefacts in the data, that can be signalled by the SGC procedure
- There is yet not enough known about the effects on the parameters used, an increase in average meal gap might not have a problematic cause (f.e. if the pig eats in less, but perhaps longer or more clearly defined meals, the average meal gap can increase)
- It is hypothesised that a farmer or caretakers' logbook might not be a suitable 'golden standard' to compare alarms with, problems can be missed and the cause or severity of the problems is not always clear.

Therefore, video observations of pigs were collected and scored in order to be able to determine an objective visit and meal criterion. Also, the influence on the parameters used will be clarified during this procedure. Finally, a suitable 'golden standard' has to be found.

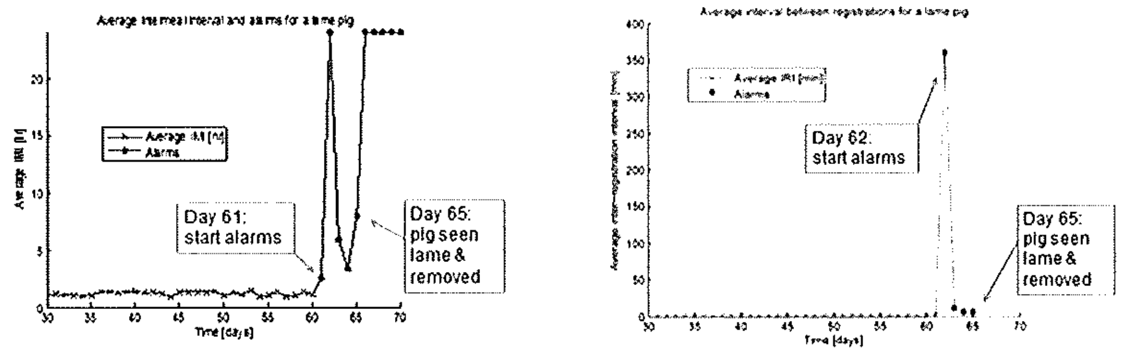


Figure 14: Alarms for a severely lame pig, using on the left a Shewhart chart on the average inter-meal interval and on the right a Shewhart chart on the average inter-registration interval.

Table 1: Overview of the alarms with post-hoc application of the current SGC procedure on the average meal gap of the validation round.

SGC wide limits	Ill pig	Healthy pig
Alarm	6	55
No alarm	1	8621

Work Package 5: Validation of the RFID based Early Warning System

Task 5.1: Setting up the data collection procedure

The setup of the Early Warning System was successfully performed in Workpackage 3.1. However, instead of three fattening periods, as initially planned in the Full-Proposal, four fattening had to be carried out to reach the goal of Workpackage 3.1. Consequently, the fifth fattening period in Drantum (July – October 2013), in which the Early Warning System was validated, started with a delay of 3½ month. The farmer as well as one research technician monitored on regular basis the health of the pigs by visually inspection. All abnormities, which were associated with a reduced health of the pigs, were monitored in a "stable book".

The hardware as well as the software operated smoothly, data of pigs' feeding behaviour was sent in real-time, online to the Server in Italy. Once a day the results of the analysed data were made available to the farmer via the in Work Package 2 developed internet page.

Task 5.2: Performance evaluation of the Early Warning System

The data, which was recorded by the farmer and research technician into the "stable book" was used to evaluate the performance of the Early Warning System. The thresholds of the system were set as follows: a warning was given, when the average meal gap of an individual pig exceeded 6 h/day and an alarm when the average meal gap of an individual pig exceeded 11.5 h/day. These fixed limits were determined based on historical data and were used to prevent too much alarms to occur. As can be seen in table 2, sensitivity was 67 % and specificity nearly 100 %.

Table 2: Overview of the alarms during the validation round, using fixed limits.

Fixed limits	Ill pig	Healthy pig
Alarm/warning	2	2
No alarm/warning	1	8616

However, during that final fattening period, only very few pigs showed a decrease in health. Furthermore, even if the farmer or the research technician scored the pig as healthy by visual inspection during the daily routine in the stable, pigs showing health problems might be missed.

As an example of the performance of the Early Warning System the parameter intermeal interval of pig 61 is shown in figure 15. The intermeal interval of this pig normally varied between 1 and 2 hours. On August 11, the intermeal interval raised up to 12 hours, an alarm was sent the farmer. Although the farmer had not scored the pig as sick, he treated the pig shortly after he received the alarm. It seems to be that the intermeal interval seems to be an appropriate measure for early detecting health problems in pigs.

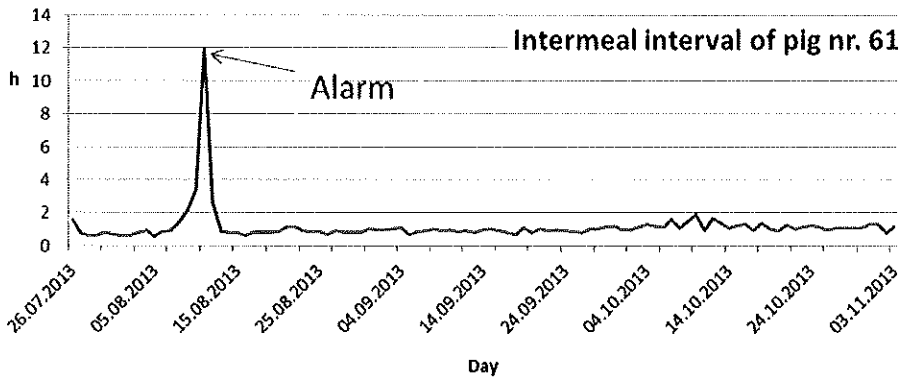


Figure 15: Intermeal interval (h) of pig number 61 based on HF-RFID data

Work Package 6: Project management and dissemination

Task 6.1: Project Management.

In total, four consortium meetings were held, the kick-off meeting (5.-6. September 2011) was organised by the German partner and took place in Vechta. The second meeting (21.-22. March 2012) was held in Aarhus and was organised by the Danish partner. The third meeting (10 -11 October 2012) was organised in Ghent by the Belgian Partners (ILVO/KU Leuven). The final consortium meeting took place during the European congress of Precision Livestock Farming (ECPLF), Leuven, in September 2013.

Results from the PigWise Project were presented on 3 International congresses. One presentation was held on the EFITA Congress in Turin, June2013. In September 2013 all partners presented results on the ECPLF as well as on the Conference Construction, Engineering and Environment in Livestock Farming (BTU) congress. On the ECPLF congress the German PigWise contribution was honoured with the "best presentation award".

Task 6.2: Dissemination

Dissemination activities of all partners are listed in "4. Exploitation and dissemination measures" later on in this document.

2. General description of the cooperation over the duration of the project

Workpackage 1:

A study trip was made to Germany by the PhD student of ILVO and KU Leuven to gain insight into the HF-RFID system. The computer vision system was installed in the Germany experimental stable in Vechta and thereafter into the ILVO's stable by the Danish partners. Technical support on-site was provided by the German Partner as well as the Belgian partners in order to ensure the success of the Danish measurements. Validation of the Kinect system was organised by Belgian partners.

Partners from Italy and Denmark worked together on a) configuration of the data transmission via the ICE framework, b) development of an application for processing the data in the stable, c) development of a client for an ICE interface incorporated in VIRTUS middleware.

Workpackage 2

The Italian and Belgian Partners cooperated for managing the life cycle of the SGC data processing algorithm. The Belgian partners have provided the algorithm and the specifications for its use; this algorithm allows extracting knowledge from the events recorded in Germany, which were stored in the data base in Italy.

Workpackage 3:

Extensive cooperation existed between partners from Belgium (ILVO/KU Leuven) and Germany to organise the set-up of the experiments in Work package 3. The data resulting from the observational and experimental rounds in Germany and Belgium was used for analysis in Work Package 4 performed by the Belgian Partner. The data could be analysed and the RFID based parameters could be determined through generic Matlab algorithms written by ILVO/KU Leuven.

Workpackage 4:

Work package 4 was executed in Belgium (ILVO/KU Leuven). Analysis of the historical data collected in Germany was performed. The synergistic control procedure and its resulting generic algorithms were developed based on the data in Work Package3. Both Engineering Process Control and Statistical Process Control were applied on the data of individual pigs and compared with the problems noted in the logbook of farmer or caretakers. A database of the pigs and their HF-RFID based parameters was made at ILVO/KU Leuven.

Workpackage 5:

Cooperation between the Italian, Belgian (ILVO/KU Leuven) and German partners were performed for validation of the early warning system. Data from Germany were sent online and in real-time to the Italian server. With the aid of the Belgian algorithms HF-RFID based feeding parameters were calculated, visualised and analysed. Alarms and warnings were sent to the German partner. Post-hoc validation of the Early Warning System was performed at ILVO/KU Leuven by calculating sensitivity and specificity of the system using either several types of Synergistic Control or fixed limits for every pig.

3. Impact statement

Carrying out PIGWISE on a transnational European basis brings the clear added value because the outcome solution will become transferable, accounting the differences between the country-specific production processes. The consortium encompasses some of leading groups which are absolutely necessary for carrying out the interdisciplinary research in the ICT-AGRI fields. The transnational cooperation between engineers and animal scientists had a great value for all PigWise Partners.

Within this Project, the HF-RFID technology was successfully implemented into a pig stable under practical condition. The hardware of the system was in practical use for five fattening periods, and it lasted the harsh pig environment without any technical failures. It was found out, that it is possible to record feeding behaviour of group housed pig simultaneously at an individual level in form of attendance monitoring at the trough. The parameter "intermeal interval" seems to be a promising value for its use in an Early Warning System.

Furthermore, it has been shown that it is possible to use a Kinect camera as sensors in a stable for more than one year. The cameras emit IR light, but the cameras did not disturb each other. The cameras were still working after one year in the harsh environment in the stable. A computer vision based algorithm that estimates the current number of feeding pigs is developed. The output from computer vision system is compared with the feeding events from the HF-RFID system. If the result of this comparison exceeds a given limit, the farmer is notified. The computer vision algorithm and the comparison algorithm can be further improved.

The project has also given the opportunity to study new methods of management and storage of data, with particular attention to the safety and reliability of the data base. It was also tested the approach of big data management, i.e. to understand how to manage the flow of incoming data, streamline processes rescue, preventing collisions at input and retrieval of data (at the end of the project in the DB have saved more than 50 million data). Moreover, VIRTUS manages the life cycle of more than one application at the same

In the project, Syngeristic Control was applied to individual pigs for the first time. A lot of interesting information was gained and several other research projects on monitoring of individual animals are starting. The experimental rounds and group-housing pigs in groups of 59 was an interesting new case for the Belgian partners. RFID based feeding parameters and early warning of individual problems are an innovative field of research and the results are very promising. Also the equipment in the stable in Belgium endured the harsh conditions remarkably well. The equipment will be used further on during the PhD of the Belgian candidate. More progress on the HF RFID system, the feeding parameters and the early warning system are expected in the following years.

4. Exploitation and dissemination measures

Publications

Scientific articles

GREGERSEN T., JENSEN, T., ANDERSEN, M.R., MORTENSEN, L., MASELYNE, J., HESSEL, E., AHRENDT, P. 2013. Consumer Grade Range Cameras for Monitoring Pig Feeding Behaviour. In: Berckmans, D. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 360-369.

GREGERSEN, T., JENSEN, T., ANDERSEN, M.A., MORTENSEN, L., MASELYNE, J., HESSEL, E., 2013: Computer vision based monitoring of performance of an RFID based eating registration system. In: 11th Conference Construction, Engineering and Environment in Livestock Farming, September 24th-26th 2013, Vechta, 438-443, ISBN 978-3-941583-80-1.

HESSEL, E. F., HÖMMEN, A., VAN DEN WEGHE, H. 2013: Accuracy of an innovative high-frequency RFID system for monitoring feeding behaviour of fattening pigs under practical conditions. In: 11th Conference Construction, Engineering and Environment in Livestock Farming, September 24th-26th 2013, Vechta, 432-437, ISBN 978-3-941583-80-1.

HESSEL, E. F. , VAN DEN WEGHE, H. F.A. 2013. Simultaneous monitoring of feeding behaviour by means of high frequent RFID in group housed fattening pigs. In: Berckmans, D. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 812-818.

MASELYNE J., SAEYS W., DE KETELAERE, B., MERTENS, K., VANGEYTE, J., HESSEL, E. F. ,MILLET, S., VAN NUFFEL, A. 2013. Validation of a High Frequency Radio Frequency Identification (HF RFID) system for registering feeding patterns of growing-finishing pigs. Computer and Electronics in Agriculture (submitted)

MASELYNE J., VAN NUFFEL, A., DE KETELAERE, B., VANGEYTE, J., HESSEL, E. F., SONCK B, SAEYS W., 2013: Range measurements of a High Frequency Radio Frequency Identification (HF RFID) system for registering feeding patterns of growing-finishing pigs. Computer and Electronics in Agriculture (submitted)

MASELYNE, J., SAEYS, W., VAN NUFFEL, A., DE KETELAERE, B., MERTENS, K., MILLET, S., GREGERSEN, T., BRIZZI, P., HESSEL, E. 2013. A health monitoring system for growing-finishing pigs based on the individual feeding pattern using Radio Frequency

Identification and Synergistic Control. In: Berckmans, D. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 825-833.

MASELYNE, J., VAN NUFFEL, A., DE KETELAERE, B., MERTENS, K., HESSEL, E., SONCK, B., SAEYS, W. 2013. Range measurements of a Radio Frequency Identification System for registering growing-finishing pigs near a feed trough. In: Berckmans, D. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 433-439.

MASELYNE, J., VAN NUFFEL, A., DE KETELAERE, B., MERTENS, K., SONCK, B., HESSEL, E., SAEYS, W., 2013: Individual pig health monitoring based on an automated registration of feeding pigs and synergistic control. In: 11th Conference Construction, Engineering and Environment in Livestock Farming, September 24th-26th 2013, Vechta, 450-455, ISBN 978-3-941583-80-1.

MASELYNE, J., VAN NUFFEL, A., VANGEYTE, J., DE KETELAERE, B., HESSEL, E., SONCK, B., SAEYS, W., 2013: Registering feeding pigs in a commercial-like situation. AgEng 2014 (written).

SCALERA A., CONZON D., BRIZZI P., TOMASI R., SPIRITO A. M., MERTENS K.2013: From animal monitoring to early warning systems through the Internet of Things. In: Berckmans, D. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 185-193

SCALERA A., BRIZZI P., TOMASI R., GREGERSEN T., MERTENS K., MASELYNE J., VAN NUFFEL A., HESSEL E., VAN DEN WEGHE H. 2013 The PigWise project: a novel approach in livestock farming through synergistic performances monitoring at individual level. EFITA2013, Sustainable Agriculture through ICT innovation, Turino 23-27. Juni 2013

SCALERA A., CONZON D., BRIZZI P., TOMASI R., SPIRITO A. M., MERTENS K.2013: From animal monitoring to early warning systems through the Internet of Things. In: Berckmans, d. und Vandermeulen, J.(eds.), Precision Livestock Farming '13, 185-193

SCALERA, A., CONZON, P., BRIZZI, R., TOMASI, A., SPIRITO, M., HESSEL, E., 2013: En Internet of Thing-based approach for single animal monitoring in a distributed farms environment. In: 11th Conference Construction, Engineering and Environment in Livestock Farming, September 24th-26th 2013, Vechta, 444-449, ISBN 978-3-941583-80-1.

Presentations:

HESSEL, E.: ICT-Agri Research Consortium PigWise. Programming Innovation in Rural Development - Linking Science and Practice, European Innovation Program Seminar, 25. -26. November 2013 in Berlin

HESSEL, E.: ICT-Agri Research Consortium – Research for animal welfare. ERA-Net Initiatives joint research for Europe, Innovation drivers for agricultural technology, 3. September 2013 in Berlin

MASELYNE, J.: Early detection of health- and productionproblems with fattening pigs: (future) perspectives. Symposium on dust and gasses in pig stables. 26 April 2013 in Merelbeke.

MASELYNE, J.: Automatic monitoring of individual fattening pigs. Symposium on livestock welfare. 12 October 2011 in Merelbeke.

Others:

MASELYNE, J.: Automatic monitoring of individual fattening pigs. ILVO brochure: "Research for livestock welfare". 2011.

Furthermore, the experiences with the Kinect Cameras are described in this technical report:

M.R. ANDERSEN, T. JENSEN, P. LISOUSKI, A.K. MORTENSEN, M.K. HANSEN, T. GREGERSEN, P. AHRENDT "Kinect depth sensor evaluation for computer vision algorithms", Aarhus University, Department of Engineering, February 2012.

The goals of the PIGWISE projects appeared in the following technical magazines:

Landbouw & Techniek (Belgium) 20, Nov-Dec 2011: Early detection of problems is beneficial to the pig(farmer).

Pig Progress volume 27, no. 10, 2011: Keeping an eye on every single finisher pig.

Since December 2011 a website was online, on which information about the project is available for the public (http://www.pigwise.eu/.) (figure 15).

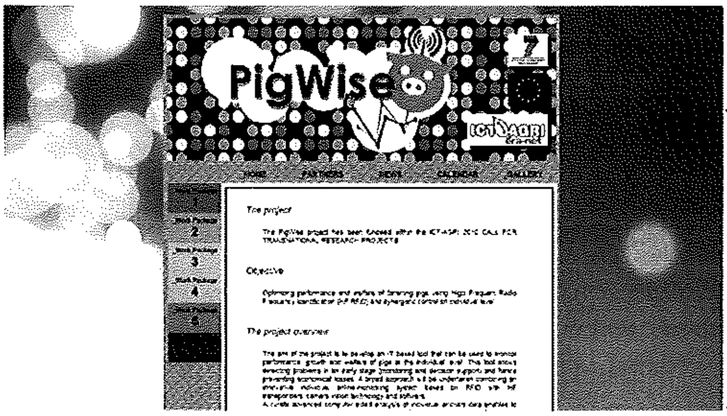


Figure 15: Webpage

The website was designed and developed by the Italian partner. General information about the project was presented to the stakeholders and farmers. A Pigwise workshop has been held during the BTU congress in Vechta, Gemany, September 2013.

Further cooperation between ILVO and KU Leuven on the topic of Synergistic Control in agricultural applications has been established since the start of the PIGWISE project, such as the SILF project (ICT Agri ERA-net call 2012, accepted project).

5. Explanation of the use of resources

According to the PigWise proposal, the *German* partner requested funding for 2 years. Due to the technical problems with the hardware and software that occurred in work package 3.1 the Germany partner, after consultation with the ICT-Agri secretary, applied successfully for a prolongation of the project of 4 month (mainly funding of salary).

As a result the funding was spent as follows:

Salary:	98,927.86 €
Travelling, meetings:	5,843.10 €
Equipment	15,499.89 €
Total	120,270.85 €

According to the PigWise proposal, the *Danish* partner requested funding for 2 years. As a result the funding was spent as follows:

Salary:	73,853 €
Travelling, meetings:	4,902 €
Equipment:	2,164 €
In total, excl. overhead:	80,919 €

Overhead:	35,605 €
In total, incl. overhead:	116,524 €

The contribution of the *Belgian* partners (ILVO and KU Leuven) to personnel costs of a PhD student was fully funded by an IWT Flanders scholarship of the PhD student; salary of a post-doc fellow, renovations of the stable and installation of equipment was funded by own resources .

WT salary PhD student	47,901.00 €
IWT travelling & working costs	7,436.88 €
ILVO stable renovation costs	53,210.17 €
ILVO stable equipment costs	39,840.71 €
KU Leuven post-doc salary	117,000.00 €
Total Belgian contribution (estimate)	265,388.76 €

According to the proposal, the *Italian* partner requested funding for 2 years. These funding has been due to only salaries, while other costs, like travelling/overhead, were not funded and considered the investment provided by ISMB. Overall, among € 140.606,58 spent for salaries by ISMB, € 139.260,00 has been funded by the Italian Ministry. Furthermore ISMB has provided full support for the 4 month prolongation of the project without extra funding requirements."