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# Precision livestock farming technologies for welfare management in intensive livestock systems

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**Summary**

The worldwide demand for meat and animal products is expected to increase by at least 40% in the next 15 years. The first question is how to achieve high-quality, sustainable and safe meat production that can meet this demand. At the same time, livestock production is currently facing serious problems. Concerns about animal health in relation to food safety and human health are increasing. The European Union wants improved animal welfare and has made a significant investment in it. At the same time, the environmental impact of the livestock sector is a major issue. Finally, it is necessary to ask how the farmer, who is the central figure in this process, will make a living from more sustainable livestock production systems. One tool that might provide real opportunities is precision livestock farming (PLF). In contrast to previous approaches, PLF systems aim to offer a real-time monitoring and management system that focuses on improving the life of the animals by warning when problems arise so that the farmer may take immediate action. Continuous, fully automatic monitoring and improvement of animal health and welfare, product yields and environmental impacts should become possible. This paper presents examples of systems that have already been developed in order to demonstrate the potential benefits of this technology.

**Keywords**

Animal health – Animal welfare – Image analysis – Precision livestock farming – Real-time monitoring – Sound analysis.

# Problems

Most published forecasts predict that the worldwide demand for meat will increase by at least 40% in the next 15 years (1, 2). At the same time there are major concerns about disease transfer from livestock to humans and this makes animal health a high priority. Moreover, there is significant room for improvement in the treatment of health problems on farms, for example, use of antibiotics is too high and must be reduced (3).

The European Union (EU) has recently invested large sums of money in the Welfare Quality® project, which aims to develop a methodology to score animal welfare on farms (www.welfarequality.net). The EU seeks to implement this in practice (4) by means of new directives, but implementing a large number of new directives is likely to be rather expensive for the farmer. Farmers, already subject to many regulations and laws, will not find this an attractive prospect unless clear benefits are derived from this approach.

Finally, a means must be found to implement more sustainable livestock production systems, as the environmental impact of current systems is too high. For example, it is estimated that more than 92% of the ammonia in the environment is due to animal production (5), yet in naturally ventilated animal housing there is no accurate way to measure the ventilation rate and, consequently, the gas emissions. Most of the livestock houses worldwide are ventilated naturally.

As a result of these and other such factors, it is no longer easy to make a living from livestock farming. Farmers have to manage a complex situation in balancing feed and energy costs against financial returns on their animal-based products. Moreover, they are expected to manage a number of process outputs such as animal health and welfare, product quality and environmental impact, whilst endeavouring to achieve a decent economic return for their efforts.

Worldwide demand for animal products is increasing, but at the same time the number of farmers producing animals is decreasing year on year. As a consequence, the size of livestock farms and the number of stock units on them will continue to increase. This trend is also driven by the low profit margin per animal; the income from individual animals is so low that farmers must keep more animals to achieve a viable income. As a result, there is less time available to attend to individual animals, which makes it more difficult to monitor and manage the animals properly. This is a key problem, as the modern farmer, who is often seated at a computer, is becoming increasingly disconnected from the pivotal component of the biological process being managed, i.e. the animal.

Thus, the number of animals on farms is not likely to decrease. Even farms with a limited number of animals must deal with issues such as product quality control, animal health and welfare and biosecurity. Nowadays, many stakeholders are involved in the enterprise of livestock production. They include the animals themselves, as well as farmers, retailers, the equipment industry, consumers, the general public, the press and governments. Most recognise that a new approach is needed if current problems with livestock production systems are to be solved or ameliorated. Thus, throughout the world, farmers face the challenge of how to incorporate all the requirements of the individual animals under their care into sustainable production systems.

# Precision livestock farming: biology meets technology

Precision livestock farming (PLF) has the following objective: to create a management system based on continuous automatic real-time monitoring and control of production/reproduction, animal health and welfare, and the environmental impact of livestock production.

Precision livestock farming is based on the assumption that continuous direct monitoring or observation of animals will enable farmers to detect and control the health and welfare status of their animals at any given time. Ultimately, an animal enjoying good health and welfare might provide the best guarantee of product quality in the long term. Nowadays, the farmer can use modern technologies to measure different parameters on the farm, such as ventilation rate, feed supply and heating/cooling inputs, but few of the tools available up to now have focused on the most important participant in the production process, the animal.

Technological development and progress have advanced to such an extent that accurate, powerful and affordable tools are now available. These include cameras, microphones, sensors (such as 3D accelerometers [including gyroscopes], temperature sensors, skin conductivity sensors and glucose sensors), wireless communication tools, Internet connections and cloud storage. Modern technology makes it possible to place cameras, microphones and sensors sufficiently close that they can replace the farmer's eyes and ears in monitoring individual animals.

The aim of PLF is to combine all the available hardware with intelligent software in order to extract information from a wide range of data. Precision livestock farming can offer a management tool that enables a farmer to monitor animals automatically and to create added value by helping to secure improved health, welfare, yields and environmental impact.

# Examples of monitoring by precision livestock farming

## Continuous health monitoring by real-time sound analysis

Respiratory pathologies are widespread in intensive pig farms (6); their incidence and prevalence are high and their principal clinical sign is coughing. The importance of these diseases must be viewed from an economic as well as a hygiene perspective; veterinary intervention can be expensive and farmers can experience substantial profit losses due to high mortality rates in growing/fattening pigs (which can be as high as 15%) (7) or to a drop in production as a result of reduced feed conversion and a lower growth rate. It is very unlikely that a pig will reach the slaughter weight without having some kind of respiratory problem (8). It is also known that detecting illness in individual animals and providing individual care or group-by-group mass treatment in response to illness are not very effective, and are also costly. It would therefore be beneficial to investigate cough sounds with the aims of both understanding respiratory diseases and using bioacoustics for real-time monitoring purposes.

The importance of coughing as a predictor of respiratory disease applies to animals as well as to humans. It has been shown that pig vocalisation is directly related to pain and classification of these sounds has been attempted (9). It is also common practice among veterinarians to assess cough sounds in pig houses for diagnostic purposes. In this regard, there have been attempts to identify the characteristics of coughing in animals (10, 11) and to automate the identification of cough sounds from field recordings (12, 13).

Since the sound produced while coughing has special characteristics when the respiratory system is infected, the ability to 'label' the different sounds to enable early recognition of those of concern could be very useful for prompt disease detection and targeted interventions, such as isolating individual animals and treating them with antibiotics. Algorithms to distinguish between pig coughs have already been validated. Initially, these algorithms were able to distinguish between different sounds, then between coughs and other sounds, and more recently between pathological and non-pathological coughs (14, 15, 16). Field validation of these algorithms, conducted in a piggery in Lombardy (Italy), has shown that they are able to classify coughs correctly in 86% of cases (17).

## Continuous welfare monitoring by real-time image analysis

It is now possible to monitor animals using normal cameras with an image speed of up to 25 images per second. Moreover, it is possible to develop many different monitoring algorithms that are easy to implement using top-view cameras placed in operating livestock houses.

In broiler chickens, for example, the eYeNamic system has been developed for continuous automatic monitoring of the behaviour of housed birds (18). The EU specifies that a broiler farmer must carry out a visual inspection of the birds at least twice a day, but the eYeNamic system does this continuously. The zone occupation index and zone activity index of the broilers is calculated from the birds' spatial distribution as detected with the top-view cameras (Fig. 1). Each camera covers a different zone in the broiler house. As shown in Figure 2, the zone occupation index of the birds can vary from 15% to 50%. If the zone occupation index is low, it may be a sign that there is a problem. For example, if the number of birds in the drinking and feeding zones is low, even though the drinking and feeder lines are operational, this usually indicates that something is wrong

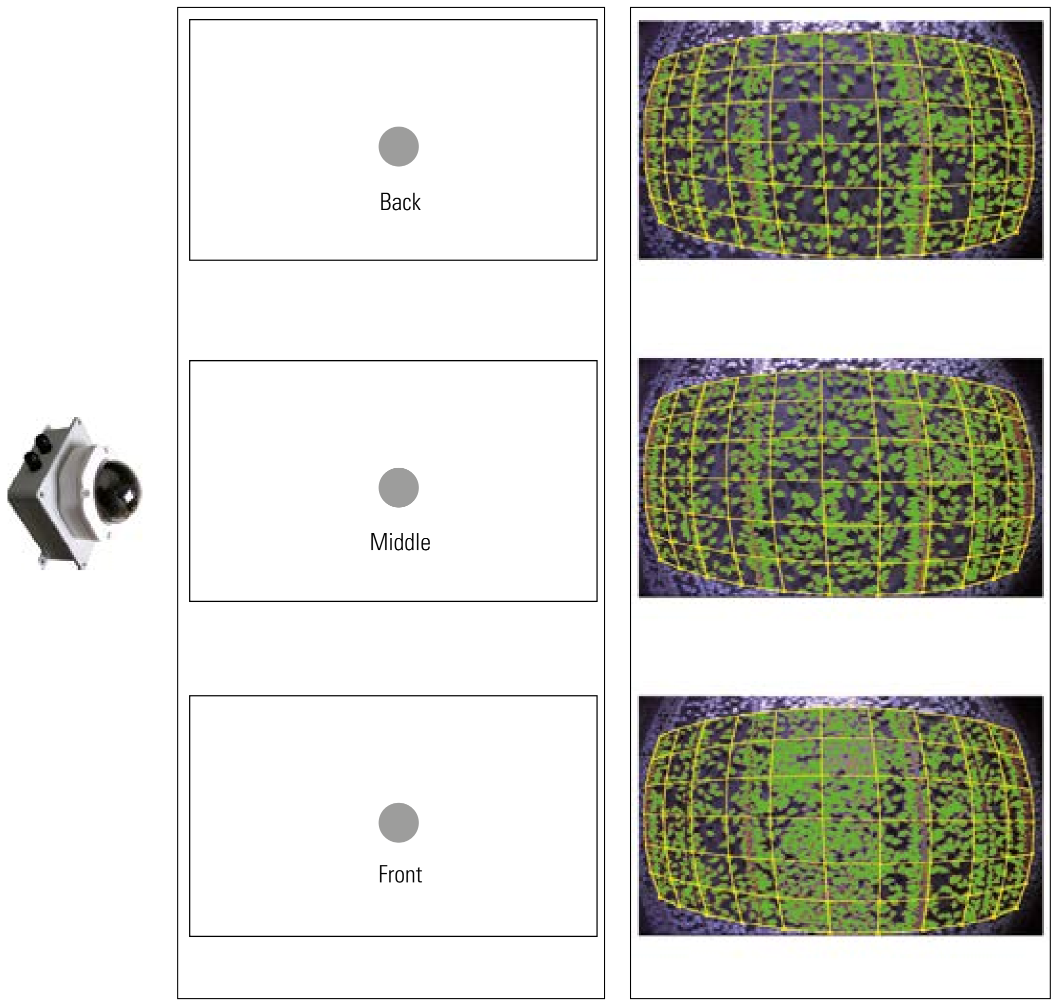


**Fig. 1**
**The eYeNamic camera system for monitoring broiler behaviour**
Left: positions of the three cameras in the house
Right: resulting images from the cameras

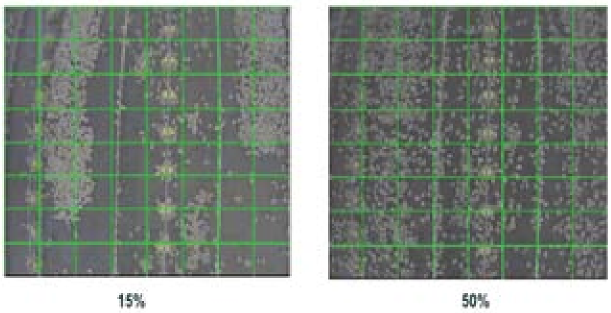


**Fig. 2**
**Images of bird distributions used to calculate the zone occupation indices of 15% and 50% illustrated here**
Vertical lines are feeder lines and drinking lines

with the temperature or air flow pattern in that zone. If the system detects abnormal values, it immediately generates an alarm message that alerts the farmer, who can then check what is wrong.

For monitoring potentially adverse events in a broiler house, an adaptive real-time model was developed. The distribution of broilers is calculated from the top-view images and varies over time. The model predicts the distribution index of the birds as expected from a normal response. If the measured distribution index varies from the prediction an event has happened and an alarm is given. Such events include electricity failure; problems with light, climate control, water supply or the feeding system; farmer inspections; unloading broilers into the house; and vaccination (19). The measured distribution indices are classified as: *i)* within a range of 25% above or below prediction; *ii)* greater than 25% above prediction; or *iii)* greater than 25% below prediction (19). If the distribution index remains in either of these last two categories for longer than 15 minutes, then an alarm is given. This was tested on a commercial broiler farm where 21 events were detected during one fattening period (19). True positive events were detected for over 95%, whereas false negatives were 4.7% and false positives 0%.

Another example of PLF is automatic camera analysis of dairy cows whenever they approach a milking robot. By carrying out image analysis and calculating model parameters from the image information, it was possible to develop an algorithm for automatic detection of lameness problems in dairy cows (20). Such techniques provide frequent and fully automatic monitoring of each individual cow (Fig. 3), a process that the farmer can no longer carry out easily. As soon as the calculated individual gait parameters change, a warning alerts the farmer. This can have significant benefits, because lameness is a major welfare problem in modern dairy cows, where up to 25% may be badly affected (20).

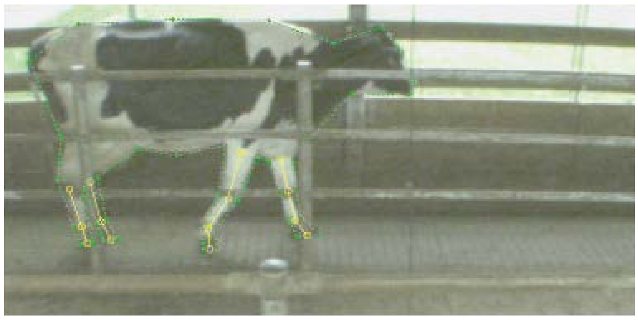

**Fig. 3**
**Real-time image-based model to calculate gait parameters for lameness detection**

# Controlling processes using precision livestock farming tools

By carrying out real-time measurements and developing real-time models it becomes possible to apply the global concept summarised in Figure 4. When the weight of growing broilers is measured as a process output and the amount of feed delivered is also measured, it is possible to model the dynamic response of weight to feed supply (21).

The computer calculates this relationship every day and the relationship obtained from the results for the last five days will predict the expected variation for the next day. The fact that daily information can now be obtained about how the weight of a given flock of broilers will respond to a given feed supply makes it possible to calculate the daily feed requirement that will enable those broilers to follow a specific growth curve. Figure 5 shows how this approach enabled broilers to achieve a predefined growth trajectory which was different from that of the control group, which was fed *ad libitum* (21). The predefined target line could be achieved quite accurately and had the advantage that bird growth was initially slower, which allowed better development of bone structure. From approximately 20 days of age, controlled growth increased to reach a similar end weight but with significantly fewer leg problems and less mortality.

# Technology is ready to meet biology

Fortunately, the new technology is now reaching the point where its application to biological processes has become realistic. Wireless data transmission, for example, is becoming cheap and reliable. The sensor and sensing (e.g. camera, microphone) technologies that are needed to develop PLF products have become small and reliable

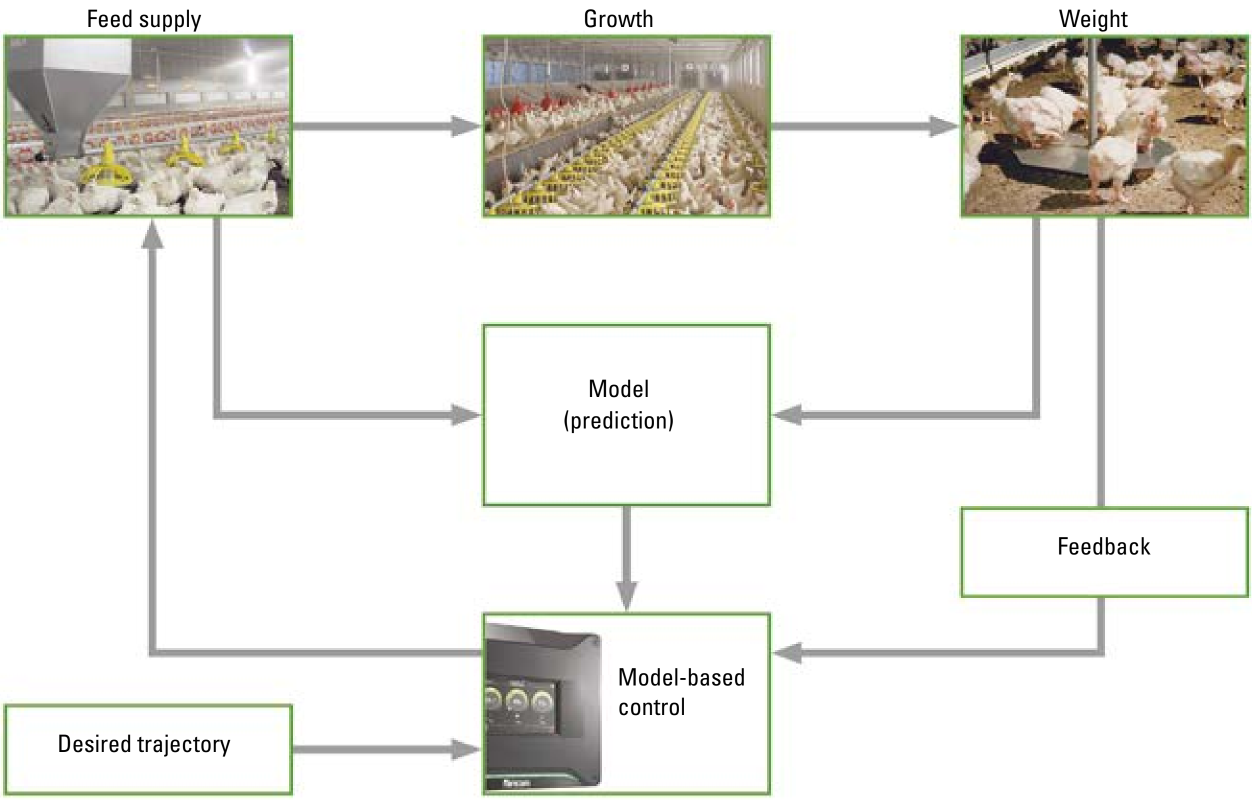


**Fig. 4**
**The basic precision livestock farming scheme applied to the monitoring and control of broiler growth using feed supply as the control input** (21)

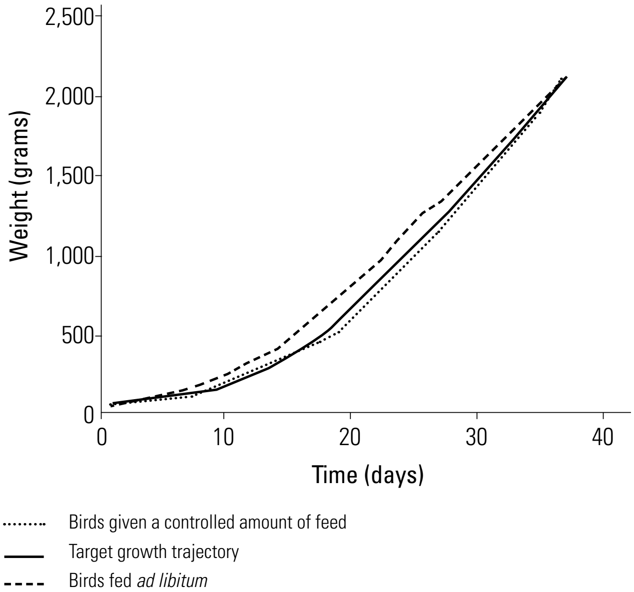


**Fig. 5**
**The difference in the growth trajectories of broilers fed *ad libitum* and those given a controlled amount of feed to enable them to meet the target growth curve** (21)

enough to be used within the harsh environment of livestock production. Unit costs are also decreasing. For example, the worldwide success of devices such as mobile phones has reduced the cost of wireless communication and is pushing this technology into other applications such as PLF. Moreover, the livestock market involves huge numbers of animals and processes, making it possible to produce customised, applied technology at reduced costs. An automated system is cheaper than the cost of experts visiting farms: a fully automated system, 24 h a day, seven days a week, costs the same as just four farm visits.

# Conclusion

If properly applied, PLF will offer new opportunities to increase the efficiency and sustainability of farming and livestock production, to improve the health and welfare of animals and to support traceability across the entire supply chain, thus providing the consumer with some assurance of food safety. Precision livestock farming systems aim to be fully automated, continuous management systems.

This means that they provide information to farmers. The systems replace their eyes and ears since they cannot be continuously with their animals. The farmers, however, remain the most important factor. They have to make decisions and take action, as the technology only offers a support tool via, for example, a dashboard that gives information and alarms based on continuous monitoring of the animals.

New milestones could be reached in a short time. For rapid results, however, a number of disciplines will need to come together to create new synergies across a wide range of skills allied to veterinary, agricultural, ethological, medical, physical, mathematical, engineering and other specialities.

Precision livestock farming technology clearly has great potential to create added value for many stakeholders, especially as a management tool for farmers, making it possible to improve animal welfare, health, efficiency and the environmental impact.

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# Les technologies de l'élevage de précision appliquées à la gestion du bien-être animal dans les systèmes d'élevage intensif

D. Berckmans

**Résumé**

On estime que la demande mondiale en viande et en produits d'origine animale va augmenter d'au moins 40 % dans les quinze prochaines années. La première question est de savoir comment répondre à cette demande tout en assurant une production durable, de bonne qualité et sans risques au plan sanitaire. En même temps, le secteur de la production animale est actuellement confronté à des problèmes graves. Les liens entre la santé animale, d'une part, et la sécurité sanitaire des aliments et la santé publique, d'autre part, suscitent des préoccupations croissantes. L'Union européenne souhaite améliorer le bien-être animal et s'est donc fortement investie dans ce domaine. Parallèlement, l'impact environnemental du secteur de l'élevage est un véritable enjeu. Enfin, il convient de se demander si les éleveurs, c'est-à-dire les principaux acteurs de ce processus, vont pouvoir tirer un revenu suffisant de leur évolution vers des systèmes de production durable. L'élevage de précision est un outil qui pourrait ouvrir de réelles opportunités à cet égard. Contrairement à d'autres approches expérimentées dans le passé, les technologies de l'élevage de précision visent à mettre en place un système de contrôle et de gestion en temps réel véritablement axé sur l'amélioration de la qualité de vie des animaux qui permet de donner l'alerte en cas de problème afin que l'éleveur puisse intervenir immédiatement. Ainsi, il deviendra possible d'améliorer et de contrôler de manière continue et entièrement automatisée la santé et le bien-être des animaux, ainsi que leurs rendements et l'impact environnemental des élevages. Les auteurs illustrent leurs propos par quelques exemples de systèmes déjà en place afin d'exposer les avantages potentiels de cette technologie.

**Mots-clés**

Analyse d'images – Analyse sonore – Bien-être animal – Contrôle en temps réel – Élevage de précision – Santé animale.

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# Tecnologías de ganadería de precisión para la gestión del bienestar en sistemas de ganadería intensiva

D. Berckmans

**Resumen**

Se calcula que en los próximos 15 años la demanda mundial de carne y productos de origen animal aumentará por lo menos en un 40%. El primer interrogante que se plantea es cómo lograr una producción de carne de buena calidad, sostenible y segura para satisfacer esa demanda. Al mismo tiempo, la producción ganadera afronta actualmente graves problemas. La sanidad animal, en relación con la inocuidad de los alimentos y la salud humana, es objeto de creciente preocupación. La Unión Europea aspira a mejorar el bienestar animal y ha invertido muchos recursos en ello, a la vez que el impacto ambiental del sector ganadero constituye un importante problema. Hay que preguntarse, por último, cómo hará el productor, que es la figura central de este proceso, para ganarse la vida con sistemas de producción ganadera más sostenibles. Una herramienta que podría ofrecer posibilidades reales es la ganadería de precisión *(precision livestock farming)*. A diferencia de otros métodos anteriores, los sistemas de ganadería de precisión apuntan a ofrecer un sistema de seguimiento y gestión en tiempo real con el objetivo básico de mejorar la vida de los animales, alertando de todo eventual problema para que el ganadero pueda tomar medidas inmediatas. Ello debería hacer posible un seguimiento y perfeccionamiento continuos y completamente automatizados de la salud y el bienestar de los animales, su rendimiento y su impacto ambiental. Con objeto de demostrar los posibles beneficios que puede deparar esta tecnología, el autor presenta ejemplos de sistemas ya implantados.

**Palabras clave**

Análisis de imágenes – Análisis de sonidos – Bienestar animal – Ganadería de precisión – Sanidad animal – Seguimiento en tiempo real.

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