TrackLab 2: a new solution for automatic recording of location, activity and social behaviour of group-housed animals

A. van Gijssel[1], B.J. Loke[1], W. Ouweltjes[2], T.B. Rodenburg[3,4], E.K. Visser[5] and L.P.J.J. Noldus[1]

[1]Noldus Information Technology BV, Wageningen, The Netherlands; [2]Animal Health & Welfare, Wageningen Livestock Research, Wageningen, The Netherlands; [3]Department of Animals in Science and Society, Faculty of Veterinary Medicine, Utrecht University, Utrecht, The Netherlands; [4]Adaptation Physiology Group, Wageningen University, Wageningen, The Netherlands; [5]Aeres University of Applied Sciences, Dronten, The Netherlands
Corresponding author: Arno.vanGijssel@noldus.nl

Abstract

The popularity of precision livestock farming is largely driven by a desire to optimise productivity, profitability and comfort. At the same time, there are growing societal concerns about animal welfare and animal health in relation to food safety and human health. These concerns can be addressed by academic and applied research into animal welfare and health indicators and increasingly by the utilisation of welfare and health metrics in operational farm management systems. TrackLab 2 is the latest tool for the measurement of livestock welfare and health indicators. It is designed to integrate and process multi-modal data for the capture of welfare and health indicators such as social behaviour, place-preference, activity, feeding and physiology. It was beta tested on four sites in the dairy cattle, poultry and pig farming domain. These first explorative tests revealed that TrackLab metrics are useful for both scientific, applied and commercial livestock research. TrackLab hardware is working well for large animals (cows, calves, pigs, sheep, poultry) but needs to be optimised for use on young birds and piglets. TrackLab 2 is also the first version to be applied in the operational farming context. The utilisation of welfare and health metrics in the operational context, to a level that exceeds the productivity focus, can prove a valuable asset in addressing societal concerns and enhancing livestock farming sustainability.

Keywords: TrackLab, livestock, welfare, health, monitoring, multi-modal

Introduction

With the trend towards larger group housing systems in farm animals, it becomes increasingly important to be able to monitor the behaviour, performance and welfare of individual animals housed in groups. Traditional methods, such as live and video-based observation and behavioural scoring, are difficult and time-consuming. Automated observation using video tracking is a powerful and versatile technique for detailed analysis of movement and behaviour of single animals, dyadic interactions or small groups. However, video tracking falls short when the number of animals to be monitored is large, and it does not work in large scale and outdoor environments. For large indoor spaces, ultra-wideband (UWB) radio tracking offers a robust and accurate alternative to video tracking: it offers real-time individual tracking of large numbers of animals (e.g. 100 animals or more), at a high spatial accuracy (up to 15 cm), in large areas (e.g. 60 × 40 m), with a high sampling rate (e.g. 1 Hz). In the field, GPS tracking is the technique of choice, with the latest chip sets offering positioning accuracies of around 2 m, and local networks, enabling long-range data communication in areas where there are no cellular networks. However, the sensors alone do not make a solution for the livestock researcher or the livestock industry. That requires a suitable software package for experiment design, data acquisition, storage, visualization and analysis. Together with the sensors and data processing hardware, it should provide a seamlessly integrated end-to-end solution for livestock research and R&D in the livestock industry.

Here we present TrackLab 2, a new software package and integrated system for the acquisition and analysis of location, activity and social behaviour of group-housed animals. It is the successor of TrackLab 1, which has been on the market since 2013 and which has been used in a wide variety of livestock research projects on cattle, pigs, poultry and sheep (Frondelius *et al.*, 2014, Van Mil *et al.*, 2015, Stadig *et al.*, 2016, Rodenburg *et al.*, 2017, De Haas *et al.*, 2017).

Solution description

TrackLab is designed to support livestock research in academic institutes (health, welfare and environment focus), breeding and genetics, veterinary research (in biocontainment facilities) as well as livestock research for the development of animal nutrition and pharma. It is important to identify the differences in objectives and workflow in these application fields if you want to establish a versatile and broadly deployable solution. TrackLab 2 offers several functional and technical innovations relative to its predecessor:

System architecture and tracking technology

TrackLab 2 has a distributed and scalable client-server architecture, supporting multiple concurrent users and measurements at multiple locations. The TrackLab solution is designed for three types of livestock monitoring environments: Indoor tracking in barn environments, indoor tracking in biocontainment labs and outdoor tracking in feedlots and pastures. The indoor tracking solution uses both Angle-of-Arrival (AoA) and Time-Difference-of-Arrival (TDoA) techniques through wall-mounted sensors that use ultra wideband (UWB) radio communication to determine the location of the animals. The accuracy achieved with UWB-based localization (up to 15cm) allows for analysis of behaviour classes (e.g. social behaviour, accurate place-preference and activity statistics) that cannot be achieved with other positioning techniques (e.g. RFID, WiFi). The system hardware is suitable for use in BSL-3 with the sensors (IP65) and tags (IP69k) suitable to withstand commonly used sterilization methods.

The outdoor tracking system is based on GPS localization and, depending on the conditions (weather, blocking objects), can achieve an accuracy of around 2 m. The tag contains a solar panel to make it self-contained if applied in sunny regions, and with possibilities of applying a bigger battery in cloudy regions. The tag stores data locally and sends it in batches through a local LoRa data communication network. One antenna can receive data from within a radius of 2 - 10 km depending the geographical features.

Hardware: animal solutions

The TrackLab tracking hardware is compatible with the most common livestock animals. The indoor tracking solution comes with tag solutions for cows and horses (collar-based), sheep and goats (harness-based), poultry (backpack-based) and pigs (eartag-based). The outdoor tracking solution supports application on cows and horses (collar-based) as well as small ruminants (sheep and goats - harness-based). Each tag solution is designed and tested to be robust enough to endure high impact stress (e.g. cattle barns) and hostile environments where sterilization procedures are applied (e.g. biocontainment labs) or where low temperatures and high humidity occur (outdoor environments). The tag solutions for poultry and pigs are designed and tested to be light enough and to have a good ergonomical fit to prevent animal discomfort.

Analysis: raw data playback & export

The TrackLab software is based on a 'white box' concept: transparency is given on the logic and algorithms, and both raw data (coordinates) and derived measures can be exported for further analysis in other applications. Track data and aligned raw behavioral

measurement data can be played back (at different speeds) to enhance behavioral insights and to inspect contextual circumstances that may explain data outliers (Figure 1).

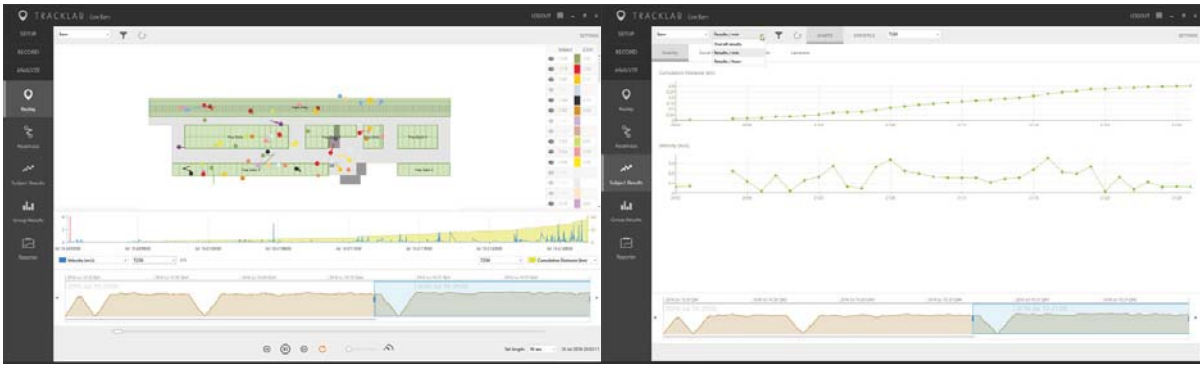

Figure 1. The data replay window (l) and statistics results per user-selectable timebin

Analysis: activity

Animal activity can be used as an indicator of animal health (e.g. as lameness indicator) or estrous behaviour (Roelofs & van Erp-van der Kooij, 2015). TrackLab has three different types of activity measurements available: distance moved, velocity and velocity-based movement categories, based on user-defined velocity thresholds.

Analysis: place-preference (+ indirect feeding, drinking)

Place-preference analysis is valuable for gathering various welfare-related insights (e.g. bedding preference investigations), insights into the efficiency of barn infrastructure layouts but can also be used as an indirect cue for eating and drinking behaviour (frequencies and time spend at the drinking trough or feed alley). It has also been used to measure the response and attention to new objects, such as new feed types or play objects, or it can be used to analyse the location-dependency of certain behaviours.

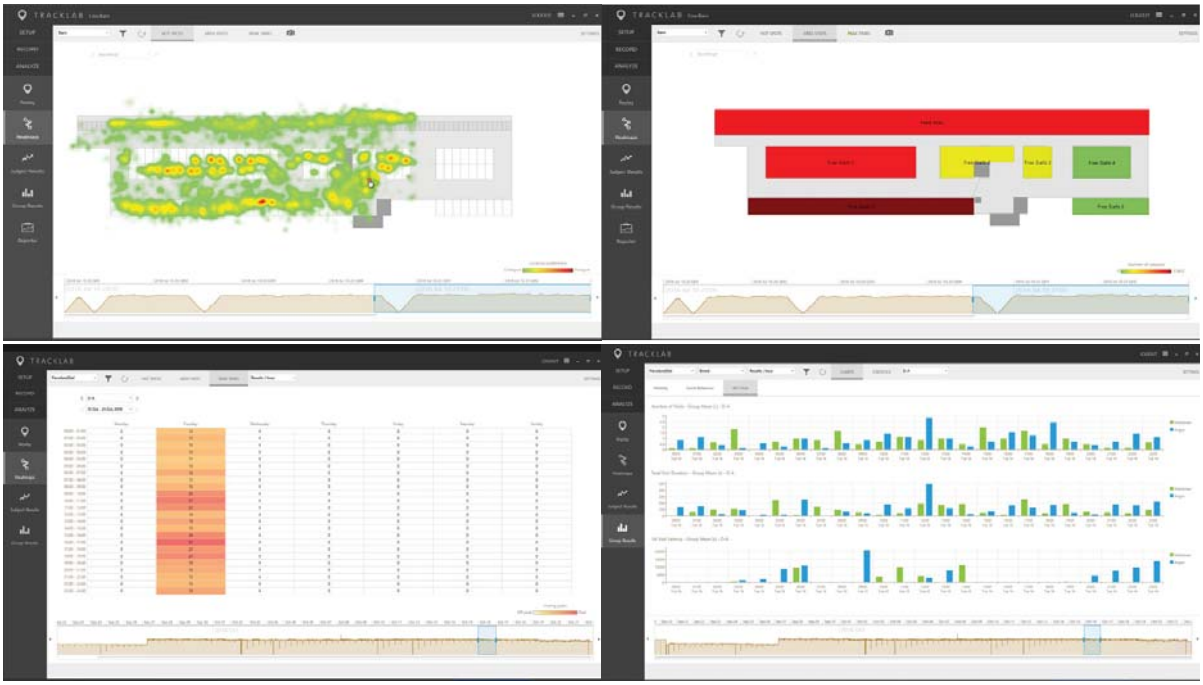

Figure 2. Qualitative heatmap (top left), areas of interest heatmap (top right), timetable heatmap (bottom left) and area visit statistics

Analysis: social behaviour

Social behaviour in cattle is receiving increasing interest from the research community. Insights in social behaviour can inform us about the effect of the hierarchy of a herd on overt aggression within the group. As sharing resources may be facilitated by social stability, aggression may have a negative effect on feeding of submissive cows and thus the productivity of the herd as a whole. Also, normal social development is assumed to have a positive effect on animal welfare. TrackLab 2 offers two types of social behaviour analysis: basic proximity analysis (Figure 3), which calculates the frequencies and time spent in proximity to any other animal, and social network analysis, which provides insight into the pair relations within the group.

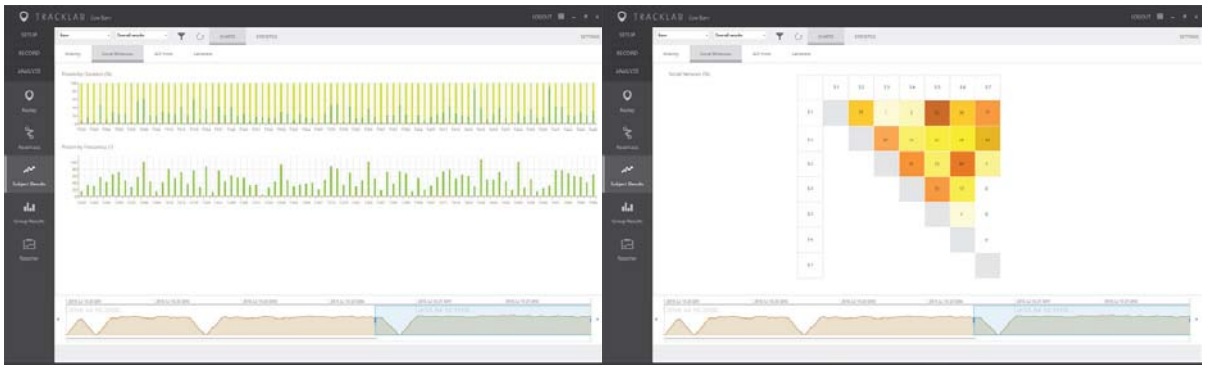

Figure 3. Social behaviour – proximity statistics (l) and pair relations (r)

Analysis: feeding behaviour

Besides the previously described indirect measurement of feeding and drinking based on animal presence in a feeding alley or near a drinking trough, accelerometer-based sensor technologies provide a means to measure these behaviours directly on the animal. The aim is to quantify durations and frequencies of eating versus rumination.

Analysis: posture and gait

Basic activity indicators such as standing and walking and movement states can be reliably detected with tracking technologies. Lying can theoretically also be detected with UWB localization techniques, however, it requires adjusting and extending the UWB sensor configuration. Accelerometry provides a more cost-effective and proven application for the measurement of lying, standing and walking (Munksgaard *et al.*, 2006; Trénel *et al.*, 2009). Moreover, todays accelerometers are often combined with other sensors such as magnetometers, gyroscope and/or altimeter. Combining the output of these sensors with machine learning techniques allows us to detect a broader range of behaviour nuances (e.g. lameness, head butts and mounting in cattle, pecking or jumping in poultry or aggression in pigs), with higher reliability.

Analysis: welfare metrics

In prototyping efforts, special interest goes out to welfare indicators such as related to agonistic behaviour (e.g. head butts, displacement, chasing or fighting), as described in the Welfare Quality® assessment protocol for cattle (Welfare Quality®, 2009), established by the Welfare Quality® Consortium. As opposed to the previously described social behaviour indicators proximity and pair relations, the challenge here is to identify the aggressor from the submissive animal; a received head-butt shows only a subtly different pattern in accelerometer data compared with an applied head butt.

First experiences in practice (beta tests)

Application in the dairy cattle domain

TrackLab 2 was installed on two dairy cattle sites: the Dairy Campus in Leeuwarden and Aeres Farms in Dronten, both in The Netherlands. At Aeres Farms, TrackLab 2 was installed in a high-tech dairy cattle unit. Over 55 dairy cows have been equipped with UWB tags and data are being collected for several months during the winter period. The cows in this high tech unit are being monitored with a variety of different sensors to study their production, health and welfare continuously. Aeres Farms is a practical farm connected to the Aeres University of Applied Sciences in which students, under the supervision of researchers, learn how to optimally manage dairy cattle. An important aspect is not only how to interpret the outcome of automated monitoring systems already available on the market but also what is behind the warning or alert of these systems. Students learn by doing observational studies how these systems work, what validity and reliability mean and what makes a system both sensitive and specific. The TrackLab 2 system at Aeres Farms has contributed to both a better understanding of how sensors can be applied in practice by the future generation farmers, and has given insights into how the cows use the facilities. Aeres Farms and the research unit are especially interested in individual differences between cows regarding the distance travelled daily and how it relates to cow factors (stage of lactation), health and welfare; which places in the facilities are preferred and which are avoided; and if there is a variation between cows for time spent at the feeding path, the water units and the lying areas. For all these questions it is assumed that there is large variation between animals, but sound scientific evidence is lacking. The next step is to relate these outcomes to productivity, health and welfare measures in order to optimise herd management.

Application in the poultry domain

UWB tracking and TrackLab have been applied in the PhenoLab project at Wageningen University, funded by Breed4Food. The aim of the project was to provide a proof of principle for automatic tracking of location, activity and proximity of individual laying hens when housed in a group. A test room at Wageningen University was equipped with the TrackLab system, as well as with the EthoVision XT video tracking system. In the first phase of the project, activity measurements measured with both systems was compared. Individual hens were equipped with the UWB tag in a backpack and placed in the PhenoLab. The recorded distance moved was very similar between both systems (Rodenburg *et al.*, 2017). In the second phase, we investigated if we could reproduce known line differences in activity using the PhenoLab. To meet this aim, we compared birds from a highly active line selected for high feather pecking (HFP) with birds from a low feather pecking line (LFP) or an unselected control line. As expected, HFP birds showed much higher activity levels in the PhenoLab than birds from the other two lines. Interestingly, within the HFP line, birds that had actually been observed to perform high levels of feather pecking in the home pen were much more active than victims of feather pecking from the same line (Rodenburg *et al.*, 2017). De Haas *et al.* (2017) also showed that feather peckers spent less time in close proximity compared with controls. One challenge with UWB in poultry is the relatively high weight of the tags (approximately 30 g). This means that the method cannot be used to track birds lighter than approximately 500 g. We are currently investigating the combination of UWB tracking with passive RFID tracking. For passive RFID tracking, the tags can be much lighter as they do not contain a battery. To conclude, for adult poultry, the UWB system offers perspective for application in research and allows automatic recording of activity and location. For younger birds, passive RFID tracking systems may be more suitable.

Application in the pig farming domain

An example of how TrackLab is applied not only in research but also in farming practice, is The Family Pig project ("Het Familievarken"). An innovative pig farm was built, designed to keep pigs in a natural environment (social context and enriched), thus avoiding stress and illness. TrackLab is used to measure animal proximities in support of an individualized feeding system, to measure the presence of pigs in a 'pig toilet' (in support of toilet flushing, thereby separating urine from faeces and reducing emission of methane and nitrous oxide as a result). This is a good example of TrackLab, by origin a research tool, can be utilised for improvement of animal welfare, health and the environment (antibiotics and emissions reduction), in an operational farming context.

Relevance of livestock research to the farming practice

Several research initiatives focus on so-called Precision Livestock Farming (PLF), which is driven by the increasing application of sensor technologies on-farm. Remarkably, projects on Precision Livestock Research are scarce and this is particularly true for the fields of animal welfare and animal behaviour. The majority of studies focusing on farm animal welfare still rely on visual observation for data collection, and therefore the frequency and duration of assessments and the number of animals observed are restricted. Because of the lack of practical tools to monitor behaviour, most farmers are not aware of the relevance of behaviour for their everyday decisions and due to the lack of demand and complexity of behaviour, suppliers of farm automation hardly develop tools in this area. Tools for automated monitoring of behaviour, if available, would enable much more accurate estimation of effects of treatments (e.g. housing conditions, feeding regimes) in scientific studies and thus contribute to our understanding of the impact of such factors on animal behaviour. Moreover, effects of interventions, whenever abnormal values of behavioural parameters are detected, can be investigated with automated monitoring tools. If such interventions show clear benefits, it is likely that farmers will be interested to implement such tools in their farm management. As with most other sensor applications, the combination of tracking data with other sensor data, e.g. from accelerometers, will improve the interpretation of abnormal values and application of appropriate measures.

Conclusions

The TrackLab 2 solution was successfully probed in explorative tests in the dairy cattle, poultry and pig behaviour domain. First experiences with version 2 reveal that it can be useful not only for scientific research but also for the applied livestock sciences. Moreover, for the first time, TrackLab was utilised in an operational (pig) farming context where its behaviour analysis output (e.g. subject proximities, area visits) was used as input for individualized feeding and toilet systems, designed to improve animal welfare, productivity and emissions reduction. On the tracking hardware side, we can conclude that the system is compatible with farm conditions (e.g. humidity, low temperature) and that it works well on larger animals (cows, cattle, pigs, adult chicken, sheep) but that it needs to be optimised (lighter, smaller) to be suitable for young birds and piglets as well.

Discussion

We hope that TrackLab 2 will contribute to livestock research (behavioural phenotyping, testing different diets, welfare and health monitoring) and increasingly to precision livestock farming as well (monitoring individual animal health and welfare and enhancing housing and management systems). Societal concern over food safety, the health and welfare of livestock animals and the environment may pose an existential risk to the livestock farming industry. Metrics for animal health and welfare do not only give valuable insight for livestock researchers; there is great potential in utilising these metrics in the

operational farming context. This combination can prove a valuable asset that can help the livestock industry to remain sustainable towards the future.

References

De Haas, E.N., van der Eijk, J.A.J., van Mil, B., Rodenburg, T.B. (2017). Phenolab: ultra-wide band tracking shows feather-pecking hens spent less time in close proximity compared to controls. In *Proceedings of the 51st Congress of the International Society for Applied Ethology*. Aarhus, Denmark.

Frondelius, L., Pastell, M., Mononen, J. (2014). Validation of the TrackLab Positioning System in a Cow Barn Environment. *Proceedings of Measuring Behavior 2014* (Wageningen, The Netherlands, August 27-29, 2014).

Munksgaard, L., Reenen, C.G., Boyce, R. (2006). Automatic monitoring of lying, standing and walking behavior in dairy cattle. *Journal of Animal Science,* 84(Suppl.): 304.

Rodenburg, T.B., van der Eijk, J.A.J., Pichová1, K., van Mil, B., de Haas, E.N. (2017). PhenoLab: automatic recording of location, activity and proximity in group-housed laying hens. In *Precision Livestock Farming '17*. Nantes, France.

Roelofs, J.B., van Erp-van der Kooij, E (2015). Estrus detection tools and their applicability in cattle: recent and perspectival situation HAS University of Applied Sciences, Den Bosch, The Netherlands in *Animal reproduction,* 12(3): 498–504.

Trénel, P., Jensen, M.B., Decker, E.L., Skjøth, F. (2009). Technical note: Quantifying and characterizing behavior in dairy calves using the IceTag automatic recording device. *Journal of Dairy Science,* 92: 3397–3401.

Van Mil, B., Frondelius, L., Spink, A.J., Pastell, M., Mononen, J., Noldus, L.P.J.J. (2015). Accurate tracking of cows in a barn environment using TrackLab. *Proceedings Second Dairy Care Conference* (Cordoba, Spain, 3-4 March 2015), p.48.

Welfare Quality® (2009). *Welfare Quality® Assessment Protocol for Cattle*. Welfare Quality® Consortium, Lelystad, Netherlands.

Het Familievarken. Retrieved from http://www.hetfamilievarken.nl/.

Precision Livestock Farming '19

Papers presented at the
9th European Conference on Precision Livestock Farming
Cork, Ireland
26-29 August '19

Edited by:

B. O'Brien
D. Hennessy
L. Shalloo

eagasc
Agriculture and Food Development Authority