Development and evaluation of an autonomous and automatic monitoring system for grazing cattle

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Abstract

Increasingly, consumers shift to more sustainable food. Accordingly, cattle farmers pay increased attention to each animal using individualised automated monitoring. This is easy for cows in production, i.e. during milking, but complicated for grazing cattle. Therefore, we aim to develop and evaluate an individualised monitoring system for grazing animals based on electronic identification.

One indicator of welfare is the ability of animals to move, so we developed an energy-autonomous monitoring system located at the single entry to the trough. Using the RFID electronic identification tag, it automatically acquires the times of passage to the trough for each animal with a detection rate of 100%. Our hypothesis is that an animal that is unable to water needs human intervention. Although the animal is still able to water, its health condition may still deteriorate, so we take advantage of the animal's watering passage to collect information on its morphology using 3D cameras. The monitoring of well-being via point clouds is generally based on data from the animal's pelvis, so our gantry aims to collect 3D data from the pelvis from two different points of view.

When an animal is detected, each camera acquires a sequence of three-point clouds. 87% of these point clouds contain an animal and 29% can be used and selected automatically for further processing, all directly on site. In the future, the monitoring system could also collect data from wearable animal sensors.

Keywords: Welfare monitoring, Pasture, 3D point cloud

Introduction

The diminution of genetic diversity in herds as a result of intensification of milk production reduces herd resilience (Makanjuola and Taylor-Robinson 2020). Moreover, organic milk represents a growing portion of the production (from 3.5% in 2019 to an expected 8% in 2031 in Europe) (EC, 2021) to meet consumer demand for increased attention to health and animal welfare. Individualised monitoring of each animal is therefore increasingly essential on cattle farms.

Monitoring animals at the barn is facilitated because it is a protected environment that can easily be monitored by sensors or human observers. Pastures are an uncontrolled environment, sometimes located far away from the farm, which limits the possibility to install sensors and the time available for direct observation of the animals. Monitoring grazing herds is therefore a critical point in the management of a farm (Spigarelli et al. 2020).

There are two main approaches to monitoring grazing animals using sensors to help the farmer to monitor a herd: systems relying on stationary sensors or ones relying on sensors attached to animals (Frost et al. 1997). Ruuska et al. (2016**)** already compared these two approaches to monitor eating, rumination and drinking behaviour. It appears that sensors attached to animals can be expensive in the case of a large herd while the current trend in livestock farming is to increase the size of farms and herds. Fixed sensors could be capable to observe all animals, but size of the pastures makes it difficult to cover all the area. For this purpose, the waterhole access is an ideal location to observe free range animals as it constitutes a regular visiting point.

Each animal should then be identified so that measurements can be individualised. Different solutions can be considered. The first is to use visual recognition of the animal via computer vision. Given the decreasing price of cameras and processing hardware, this solution is financially interesting but most of the time they are based on the cow's coat which is a problem for breeds with very similar individuals (Okura et al. 2019), such as Aubrac or Limousin cattles. This technology is therefore restricted for herds where the individuals have a different coat from each other, such as Holsteins or Belgian Blue Whites. Another solution is to take advantage of electronic identification and use RFID chips placed directly in the animal's earring (Williams et al. 2020). This method avoids the problems associated with the breed of animal and is much more robust.

The identification of the animals at the entrance to the watering trough therefore makes it possible to monitor the frequency of watering of the animals (Williams et al. 2020). This indication can be used to detect an abnormality in the animal's behaviour. For example, an animal that does not come to the watering during the day, when in these climatic conditions it normally comes two times a day, may be unable to move to the watering trough and therefore need the intervention of the farmer.

Coupled with watering detection, monitoring the animal's physical development can provide useful information to the farmer. Therefore, regular evaluation of indicators such as Body Condition Score (BCS) or animal mass is a common tool for herd management (Anglart 2010). Most successful algorithms of this type are based on 3D data of the animal's pelvis (Spoliansky et al. 2016; Rodríguez Alvarez et al. 2018), so, adding 3D cameras on the watering access could produce valuable data for the farmer.

This data must be acquired and processed automatically to be completely free of human intervention. Another sensitive point linked to positioning in pastures is the energy aspect, as the monitoring tool must be able to operate autonomously since most pastures are far from the grid access.

The objective is therefore to propose an energy autonomous and automatic monitoring tool that can be placed on pasture, to produce qualitative data on cattle health and well-being.

Material and methods

This section presents the autonomous measuring gantry that was created to be installed on the water through passage to record animal accesses and 3-D views to fulfil the monitoring objective

Structure

Our gantry is made of galvanised steel. A 3D representation and the plans of the gantry are shown in Figure 1. It is 2.9m long and 3.4m high. The bars are hollow tubes of 6cm diameter for the lower part of the gantry. The roof is made of square tubes of 6cm side as well. All tubes are 3mm thick. The passageway is trapezoidal, 80cm wide at the base and 140cm at 2.3m high. Stability is ensured by two 140cm U-shaped beams placed towards the ground perpendicular to the passage of the animals. The details of the plans and the used materials are available online[1].

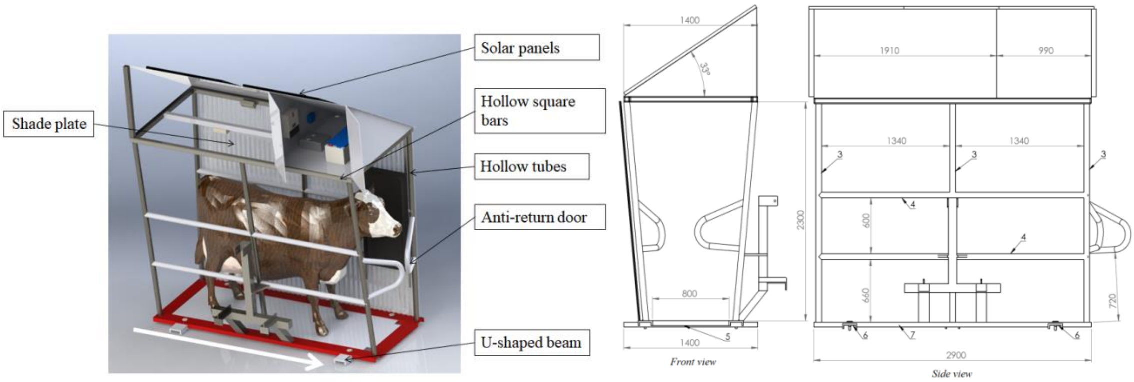

Figure 1 : 3D representation (left) and plans (right) of the measuring gantry.

One-way passage is ensured by an anti-return door located at the end of the passage. On top of the gantry, two solar panels are installed on a 33° slope roof for Belgium latitude. Under this roof there is a box where elements that need to be protected from the rain are stored. A shade plate is placed on one side of the gantry. This plate should be south facing in the north hemisphere when the gantry is installed so that maximum shading is provided over the measurement area during the day.

To test the structure of the gantry, it was installed in pasture for two pasture seasons. The first season was from 13 August to 23 October 2020 and the second was from 12 May to 15 November 2021. During these two periods, the maximum air temperature was 34°C, the minimum air temperature was 0°C and the maximum daily rainfall was 139mm. These measurements have been recorded by the meteorological station of the farm where the gantry was installed. This station was 700m away from the gantry for the first season and 160m away for the second season of measurements. The appearance

[1] Permanent link : https://gitlab.uliege.be/Justine.Plum/ecplf-justine-plum

of the gantry and observed damages to it after the two seasons of use was studied to conclude on the robustness of the device.

Taking measurements

As they pass by, the animals are identified via an Agrident ASR650 RFID reader for their ear tags placed on the animals' left ear. This detection triggers the acquisition of point clouds using two Intel Realsense D435 cameras via an on-site computer (AAEON UP Squared UPS-APLC2F-A20-0432). The acquisition code (python3.7) is available online[1]. After two months of experimentation, we were finally able to adjust the position of the RFID antenna to reach a 100% detection rate. The antenna (Agrident APA160 100 x 60cm panel antenna) is placed at 40cm from the ground. As animals tend to lower their heads to pass through the gates (Figure 2), this arrangement ensures detection during each passage. When an animal is identified, the time of its passage is recorded.

Figure 2 : Typical passage of an animal through the non-return door (left) and Protective housings containing Intel RealSense D435 cameras (right).

To verify the performance of the RFID sensor, we placed a trap camera in front of the gate to record all animal passages through the gate. The camera was placed for one day and recorded the passages of each animal on the pasture during that day. The images from the camera were then manually compared to the passages recorded by the camera and those recorded by the RFID reader.

The point clouds are acquired via the two 3D cameras. They are placed at 2.3m from the ground, one is placed facing the ground, allowing a NADIR view of the animal. The other is placed at an angle of 33° to the horizontal. Both are placed 1.3m from the RFID antenna, at the beginning of the gantry. This arrangement ensures that the animal's pelvis is visible by the cameras when the head of the animal is positioned at the RFID antenna. The Intel RealSense D435 cameras are protected in customized housings. They have been created by machining aluminium casting waterproof enclosures (Figure 2).

For the camera with a NADIR viewpoint, the resulting point clouds must be usable for the most common algorithms for BCS estimation base on 3D data. Criteria have been established to define whether a point cloud is usable or not. A point cloud is therefore valid if it represents the entire area useful to the algorithms. From this point of view, a point cloud is considered valid if the pelvis of the animal is clearly visible and not cut off, if the point cloud does not contain any holes and if the noise of the point cloud is not too high. Examples of a valid and of an invalid point cloud are shown in Figure 3.

Figure 3 : Valid (left) and invalid (right) point cloud example

Regarding the camera with a tilted view, this type of view is not widely used in the literature. The criteria are therefore not yet established and need to be studied further.

Energy

The energy requirement of the gantry was estimated at a maximum of 600Wh per day with a peak power requirement of 30W. These values were obtained as follows: according to the manufacturer, the typical consumption of the computer is 18W, since it works 24 hours a day, we estimated the consumption of the computer at 432Wh, considering that it does not go on standby. When the computer was processing point clouds, its measured consumption rose to 25W maximum, the estimated calculation time per day being a maximum of 3 hours for a herd of 30 animals, the additional consumption linked to calculations is 21Wh. To obtain this calculation time, we counted 10s for a heavy processing per point cloud. Each animal can pass up to five times and each pass generates six point clouds. We therefore obtain a total of 9000s of processing for 30 animals and therefore 2h30min, rounded up to 3h for safety. According to our measurements, the RFID reader consumes up to 5W when an ear tag was detected. Since the reader works 24h a day, we have a consumption of 120Wh per day. The total maximum consumption is therefore 573Wh with a maximum peak of 30W.

We decided to use solar panels to power the gantry on the pasture because of the wide availability during the grazing season. The amount of energy produced depends on the amount of sunlight. A typical grazing season is from April to September, so we focused the sunshine during this period for the location. The average 24h exposure during this period is 4087Wh/m² in Belgium, where the experiment took place. The orientation of the panels will also have an influence. In Belgium, the recommended panel inclination is 30 to 35°, supporting the 33° applied to the roof of the gantry. Given the cloudy weather occurrence probability, it was decided that the gantry should be able to operate for three days without producing a significant amount of electricity. To meet these needs under these conditions, the gantry was equipped with two 300Wp monocrystalline solar panels, a 48V 60A MPPT controller, a 12V 200Ah GEL Ultracell battery, a 12V-5V converter and a 12V-12V converter. A summary diagram is presented in Figure 4. With this material, we can expect a production of 23kWh for our location and the most limiting month (November) while the monthly consumption is estimated at 18kWh.

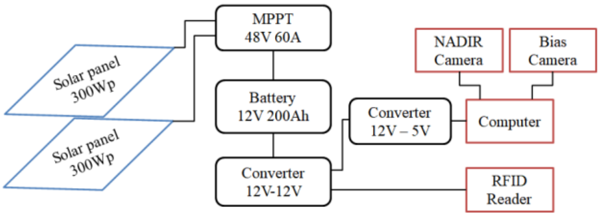

Figure 4 : Diagram of the electrical installation

Results and Discussion

Performance of the gantry structure

Initially, the box containing the equipment related to electricity generation was attached to the side of the gantry (Figure 2). This arrangement was modified as the box was a sensitive point of the gantry because of cow scratching themselves leading to a fell down during the first measurement campaign. The equipment is now placed under the roof of the gantry.

Both the galvanized steel and the shading panels held up for 2 seasons of measurements. No damage was found, neither from animals nor from the weather. The gantry remained in place during both seasons despite the interaction of the animals and the wind on the pasture. The structure also supported the various transports via tractor and forks for a total of six displacements. Currently, a three-point hitch is used to attach to the gantry during transport. As other transport methods than by tractor 3-point hitch can be more convenient as fork lifter, the structure can be adapted so that it can support the farmer's favorite carrier.

Measurements performance

The observation with the trap camera resulted in a 100% detection rate of the 21 passages of the day. Typical cases of passage were represented during this day. These included animals passing quickly and slowly, animals of different sizes and two animals following each other directly. The RFID sensor is therefore robust and works perfectly for this type of use.

The second season of measurements recorded 1478 animal passages, with an average of about 14 hours between two passages for the same animal. The total number of passages in one day and the number of animals present on the pasture that day are presented in Figure 5. We see that the number of passages is not proportional to the number of animals present on the pasture, which means that external elements influence the behaviour of the animals, pushing them to move more or less frequently to the watering place. These factors will be investigated further in a later study.

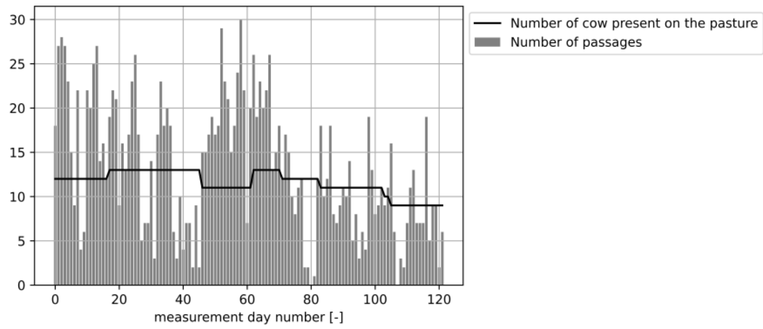

Figure 5 : Number of passages recorded per day and the number of animals present on the pasture for the second measurement campaign.

The 3D camera with a NADIR viewpoint was able to obtain 87% of point clouds containing an animal. A rate of 29% was constituted of valid images for conventional processing. This proportion results from the fact that during each passage, a set of 3 successive point clouds is acquired to accommodate the variable speed animals move through the gantry. As the acquisition frequency of the camera is set 3Hz, the time elapsed between the first and the last image is 1sec. This delay allows the animal to move through the gantry. In the case of a fast passage, the last image tends to be invalid and the first tends to be valid, whereas in the case of a slow passage the opposite phenomenon is observed.

During the first season, interruptions were recorded in the measurement process, due to hot summer combined resulting in overheating of the computer equipment placed in plastic cases. These cases were replaced by aluminum enclosures to dissipated excess heat, which solved the problem. This problem will depend on the consumption of the computer equipment placed on the gantry and therefore on the application of the gantry. In both seasons there were interruptions due to hardware failures in the USB ports. The problems were related to the hardware itself, so they shall not be repeated in other conditions.

<u>Energy autonomy</u>

There were no interruptions due to a lack of energy. However, the point clouds have not yet been processed locally. In our energy consumption calculations we estimated the extra consumption due to computing at 21Wh per day. The current energy design allows for this increase in consumption. Moreover, we estimated a calculation time of 10s per point cloud, whereas our algorithms give us a calculation time of less than 2s, the overconsumption linked to calculations does not therefore represent a problem to be addressed.

<u>Data obtained and usage</u>

The data obtained during the passages are a time of passages to the water point and point clouds. The processing of the point clouds consists, first of all of, segmenting them in order to extract the points representing the animal. It then consists on sorting them into valid and invalid point clouds. Our firsts algorithms give us encouraging results, both for the estimation of the BCS and for the sorting of valid and invalid point clouds. The passages study allows us to hope to use the monitoring of passages at the watering point as a tool for monitoring the health status of the animals. In all cases, algorithm development is still in progress.

Conclusions and perspectives

We conducted research to develop a monitoring tool for grazing cattle herds. To do so, we built a gantry to acquire data to calculate indicators of the health status of the animals. We then tested the gantry during two grazing seasons to prove its resilience to climatic conditions, the presence of animals and to several displacements in the farm. At the same time, we established the ideal positioning for sensors classically used for the calculation of animal health indices. We also tested the aspect of energy autonomy provided by solar panels and battery on the gantry level.

The gantry has met the requirements for two seasons. It can therefore be used for further research and for practical implementation. On this basis we built three new gantries. These will be placed in three more farms in order to collect a large amount of new data with a higher variability. This new measurement campaign will also be used to get feedback on the use of the gantry on the farm. These gantries have been adapted to each farm, with a customised attachment for movement according to the farmer's needs.

As the gantry is placed in a pasture, it is planned to integrate a data transmission system to facilitate access to the data. For example, a Low Power Wide Area Network, such as LoRaWAN, could be used to report indicators such as the BCS.

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