International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2017)
R. Lindeman, G. Bruder, and D. Iwai (Editors)

A New Approach to Utilize Augmented Reality on Precision Livestock Farming

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Abstract

This paper proposes a new method that utilizes AR to assist pasture-based dairy farmers identify and locate animal within large herds. Our proposed method uses GPS collars on cows and digital camera and on-board GPS on a mobile device to locate a selected cow and show the behavioral and other associated key metrics on our mobile application. The augmented cow's information shown on real scene video steam will help users (farmers) manage their animals with respect to welfare, health, and management interventions. By integrating GPS data with computer vision (CV) and machine learning, our mobile AR application has two major functions: 1. Searching a cow by its unique ID, and 2. Displaying information associated with a selected cow visible on screen. Our proof-of-concept application shows the potential of utilizing AR in precision livestock farming.

CCS Concepts
• **Human-centered computing** → Mixed/augmented reality

1. Introduction

Over the last 35 years there has been a decline in Australian dairy farm numbers but an increasing number of dairy cows per farm. With increasing herd size, particularly in pasture based dairy systems where herd sizes of in excess of 600 cows is common, identification and associated individual management of cows has been an increasing challenge. Whilst the identification of individual animals using radio frequency identification devices (RFID) has enabled routine collection of data relating to an individual animal in a herd [HRH*16], it is impractical to utilize the RFID technology to identify or locate when grazing. The monitoring of individual animal behaviors has been an increasing focus of precision dairy research and much application exits for this technology [SRB*16] [DSR*16] [SDH*15]. However, the ability to match said data with an animal in view is limited by her identification whilst the display of near or real-time information when in view provides much application. Augment reality (AR) provides a possible means for overcoming such limitations.

AR is aimed to create the visual perception that virtual images seamlessly co-exist in the real world [BCL15]. As efficient and entertaining ways of interaction, AR systems have covered real world applications such as health care, industry and manufacturing, navigation, education and learning and others [Azu97].

It is common to use Global Positioning System (GPS) in outdoor AR systems. In the design of our AR application, GPS collars on animals are used. The contributions of this paper are the design and implementation of two main functions in our AR application that can help farmers manage their herd. First, users can click on any cow on the screen of the AR application to view the information associated with that cow such as her behavioral, current milk production, weight, parity, age etc. This function can help farmers quickly identify and view cow's information without having to walk too close to cows to retrieve the information from the RFID device attached to the cow. This is very useful as trying to get close to cows often is problematic as cows tend to move away. Second, this AR application can help farmers search for a particular cow. For example, if the cow behavioral data identifies a health concern or the need for a management intervention such as an estrus event, the system will provide an alert and the farmers can locate that cow by our AR application's navigational instructions on the mobile device's screen. This is an important feature for large herds and has application for herds of young animals or for herds of cows that are non-lactating (dry) and therefore not presenting to the dairy twice daily.

DOI: 10.2312/egve.20171357

2. Related Work

2.1 Livestock Monitoring Systems

Livestock Monitoring Systems (LMS) aim to monitor animal transactions to enhance productions and deliver safety animal products to consumers [EKC15]. The most common methods of monitoring livestock behavior over long periods of time are collaring the target animals with VHF beacons or GPS modules, visual investigation by humans from fly-overs or drones [MT04]. Among these methods, GPS collar has advantages in the aspect of coping with animal's mobility and movement and covering large areas between nodes [GCP*06]. Initially used in wildlife tracking, GPS tracking has been applied to livestock tracking as the improvement of GPS receivers, differential correction and satellite availability [SFB*11]. Many applications have been developed and applied in large farms. [GCP*06] presented a GPS based system for cattle management. Combining with other sensors on its own developed hardware Fleck2, their platform can observe and collect information of cows without significantly interfering with them. Perotto-Baldivieso et.al [PCC*12] focused on finding the optimal sampling time intervals for GPS collar schedules. [HSB*09] used wireless sensor networks to combine GPS and other ground-based sensors with remotely sensed satellite images to understand animal interactions. [MET04] used GSM networks to gather GPS data from collars. [TUL*00] imported GPS data into a geographic information system (GIS) to assess animal behavior characteristics and pasture utilization. As far as we know, all these GPS based LMS can only provide maps or data, which is not as much user-friendly as AR applications.

2.2 Outdoor Tracking in AR

Tracking techniques in AR can be generally divided into three groups: sensor-based tracking, vision-based tracking and hybrid tracking [ZDB08]. Sensor-based tracking systems such as GPS and inertial sensors use different sensing technologies to track object's location. Vision-based tracking techniques use image-processing methods to calculate the camera position relative to real world objects which enable seamless visual alignment (via camera view) of the digital information and physical objects in the real world. However, with the lack of robustness of video-based tracking in an outdoor environment, drift problem in inertial sensors in a large area and lack of affordable high-precision and limited update rate of GPS modules, no single sensing technology can provide robust tracking in our application environments. Hybrid methods have been demonstrated that combined several sensing technologies [ZDB08].

3. Design of the AR Cow Tracker Application

For outdoor AR applications, GPS is the primary technology used for providing location data. [TCD*00]. While current GPS devices provide accurate data (within a few meters), they have a low refresh rate. This relatively low refresh rate is insufficient for AR applications, which in most cases require at least 20 frames per second. Therefore, our outdoor tracking application must integrate with other tracking technologies, which can provide higher refresh rates. Given that cameras are commonly used in AR systems, CV is one suitable option. CV-based algorithms generally have higher detection refresh rates than GPS refresh rates. However, outdoor CV-based algorithms are susceptible to problems generated by volatile lighting conditions, background objects and occlusion, which GPS sensors are not. As such, our AR application adopts a hybrid tracking approach by combing GPS and Computer Vision (CV).

3.1 Hybrid Outdoor Tracking

Figure 1 illustrates the workflow of tracking a targeted cow with a combination of GPS and CV. The reason for tracking only one cow at a time is for simplicity and efficiency in testing. Tracking multiple cows can be achieved by calculating each cow's GPS signal.

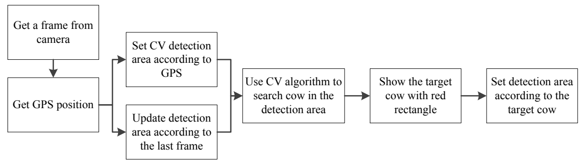

Figure 1 *Workflow of hybrid GPS tracking*

The flowchart illustrates that our tracking requires both CV detection and GPS. GPS is only accurate when updated; this is the time at which the CV algorithm can integrate the new GPS data. To improve CV detection speed, its detection area is restricted to a small window around the screen position provided by the most recent update. The detection area will be iteratively updated with every new GPS data and subsequent results of the CV detection.

3.2 Computer Vision Detection Algorithm

We implement a machine learning cascade classifier for CV detection of cows. The cascade classifier has been widely used in CV to track objects such as faces and bodies. Implementation of a cascade classifier includes two major stages: training and detection. For the training stage, we collected pictures containing cows, and pictures not containing cows. There are two applications in OpenCV to train the cascade classifier: 'Haartraining; and 'Traincascade'. The main difference between these two applications is that 'Traincascade' supports both Haar and LBP (Local Binary Patterns) features, while 'Haatraining' does not support LBP. As LBP uses integer features, its training and detection speed is faster than using Haar features. For this reason, we choose cascade training based on LBP features. As such, we use 'Traincascade'.

3.3 Functionalities of the AR Application

As earlier stated, there are two main functions of our AR application. First, the "Display Cow" function can allow users to check each cow by clicking her on the screen of the mobile AR application. Second, the "Locate Cow" function provides navigation clues for locating the cow that user wants to locate. This section will detail the overall design of these two functions.

3.3.1 Display Cow Function

This function allows users to click any cow on the screen, and the application will identify the cow's ID and shows its health information. To achieve this function, the application need to take the click position (on screen) as the input, compare to GPS data and CV detection results, and then return the best match of the cow. A flowchart is shown in Figure 2 to describe this function.

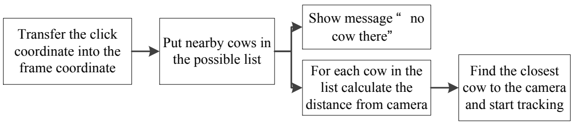

Figure 2 *Workflow of Display Cow Function*

When the user clicks on the screen, the system will transfer screen coordinates into video frame coordinates first, because the resolution of screen is usually different from the video's. Then GPS position will be used to select out the closest match. We also need to consider the situation that one or more cows may be hidden behind other cows. The algorithm will select the nearest cow as the cow that the user selected (clicked) on the screen. The system will compare GPS signals to determine which cow is the nearest and also close enough to the click point. The GPS position of the best match will be passed into the CV tracking algorithm and start tracking process.

3.3.2 Locate Cow Function

This function allows user to find a cow by its ID associated with its GPS collar. Users can use this function to locate a particular cow (who may need attention) by following the navigational instructions on screen. The workflow is shown in Figure 3.

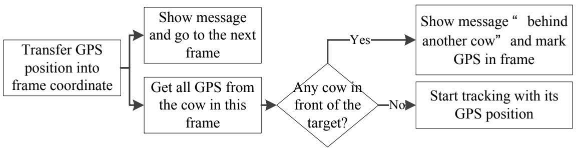

Figure 3 *Workflow of Locate Cow Function*

After receiving the users locate cow action, the application will search the GPS signal by the cow's ID. If the cow is outside the camera view, then the system will use an arrow to indicate a general direction to the cow's location to help users walk or turn to it. In the case that the cow is within the camera view, the application will determine if the cow is in a line of sight with the user. If it is behind other cows, or part of the cow is out of the camera frame, then we adopt the user-in-the-loop approach by prompting on-screen message to instruct the user to adjust his/her camera position to clear off those obstacles and be in a clear line of sight with the cow. If the cow is clearly shown on screen, the system will mark it out and start tracking with CV algorithm.

4. Conceptual Application Demonstration

In this experiment, we used a scenario-based video for proof-of-concept evaluation. A specific sequence of video is selected to demonstrate both display cow function and the locate cow function. Simulated GPS locations are also used for both cows and mobile devices. Also, we simulated locations of the mobile device. The video clip is 100 seconds long with 25 fps at which our AR application runs.

4.1 Augmented Reality Interface

AR is used in this application to help farmers effectively and efficiently manage cows. The interface is designed to provide augmented information on top of the camera views, as shown in Figure 4.

Figure 4 *Screenshot of the AR application interface.*

These pictures are screenshots of the application when tracking or indicating a cow. Information provided to users includes:

1. Cow's ID and GPS position
2. A red rectangle to mark the target cow
3. Cow's estimated consumption (e.g. pasture, feeding station or water)
4. Cow's movement
5. Mini map of the nearby cows
6. A red arrow indicating cow's direction (in locate cow function)
7. Text instructions (in locate cow function)

From the augmented information, users can monitor and check each cow's status and find a particular cow in the farm. This could be very helpful for a large herd size, achieving better cost control and work efficiency.

4.2 Display Cow Function

By using this function, farmers can click any cow on the screen to check its status. Figure 5 shows the scenario of a test for this function.

Figure 5 *Screenshots to show the display cow function*

If the click position is on a cow (black circle on the left figure of the Figure 5), our application will give back the cow's basic status, shown in the lower part of the screen on the right figure. Otherwise, the application will tell users that no cow is nearby.

4.3 Locate Cow Function

We used a scenario for this function as illustrated in Figure 6. At first, in Figure 6(a), an on-screen message of a cow pops up to instruct the user to find a cow (cow #5).

(a) (b)

(c) (d)

Figure 6 *Screenshots to show the locate cow function.*

This is a situation when a cow needs help or attention. When the user clicks on the message sign, our AR application will give navigational instructions guiding to that cow's position. According to our design, if the cow is out of the camera's view, the user can follow the red directional arrow on the edge of the screen to turn toward the suggested direction (Figure 6(b)). If the selected cow is behind some other cows, a message will be shown to tell the user to move closer (Figure 6(c)). When the cow is clear enough for users to see, our system will start tracking it and show its status (Figure 6(d)).

5. Conclusion

In this paper we present a new method to implement AR applications on precision agriculture and help livestock farming. To make livestock farming more efficient, we design and implement two functions. The hybrid GPS- CV tracking is used. Our AR application is a proof of concept demonstrating a conceptual design and feasibility in solving this real-world problem in precision farming.

There are future works to be researched. For example, there are different CV detection algorithms (e.g. deep learning) that are worth exploring for our AR tracking. Some other functions could be designed to better help farmers such as data visualization. This application could also be applied to other livestock.

References

[Azu97] Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators And Virtual Environments*, 6(4), 355-385

[BCL15] Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends® in Human–Computer Interaction*, Vol. 8: No. 2-3, pp 73-272. doi.org/10.1561/1100000049

[DSR*16] Dutta, R., Smith, D., Rawnsley, R., Bishop-Hurley, G., Hills, J., Timms, G., & Henry, D. (2015). Dnamic cattle behavioural classification using supervised ensemble classifiers. *Computers and Electronics in Agri-culture*, 111, 18-28. doi:10.1016/j.compag.2014.12.002

[EKC15] Erden, H., Kaya, İ. A., & Çamaşircioğlu, E. (2015, July). Livestock monitoring system. *In Agro-Geoinformatics (Agro-geoinformatics), 2015 Fourth Interna-tional Conference on*, pp. 73-76. IEEE doi.org/10.1109/agro-geoinformatics.2015.7248081

[GCP*06] Guo, Y., Corke, P., Poulton, G., Wark, T., Bishop-Hurley, G., & Swain, D. (2006, No-vember). Animal behaviour understanding using wireless sensor networks. *Local Computer Networks, Proceedings 2006 31st IEEE Conference on,* pp. 607-614. IEEE doi.org/10.1109/lcn.2006.322023

[HRH*16] Hills, J. L., Rawnsley, R. P., Harrison, M. T., Bishop-Hurley, G. J., Henry, D. A., Raedts, P., ... & Roche, D. (2016). Precision feeding and grazing management for temperate pasture-based dairy systems. *Conference on Precision Dairy Farming* 2016, pp. 25-31.

[MT04] Mayer, K., Ellis, K., & Taylor, K.. Cattle health monitoring using wireless sensor networks. *In Proceedings of the Communication and Computer Networks Conference (CCN 2004)* pp. 8-10.

[PCC*12] Perotto-Baldivieso, H. L., Cooper, S. M., Cibils, A. F., Figueroa-Pagán, M., Udaeta, K., & Black-Rubio, C. M. (2012). Detecting autocorrelation problems from GPS collar data in livestock studies. *Applied Animal Behaviour Science*, 136(2), 117-125. doi.org/10.1016/j.applanim.2011.11.009

[SDH*15] Smith, D., Dutta, R., Hellicar, A., Bishop-Hurley, G., Rawnsley, R., Henry, D., ... & Timms, G. (2015). Bag of class posteriors, a new multivariate time series classifier applied to animal behaviour identification. *Expert Systems with Applications*, 42(7), 3774-3784. doi.org/10.1016/j.eswa.2014.11.033

[SFB*11] Swain, D. L., Friend, M. A., Bishop-Hurley, G. J., Handcock, R. N., & Wark, T. (2011). Tracking livestock using global position-ing systems–are we still lost?. *Animal Production Science,* 51(3), 167-175. doi.org/10.1071/an10255

[SRB*16] Smith, D., Rahman, A., Bishop-Hurley, G. J., Hills, J., Shahriar, S., Henry, D., & Rawns-ley, R. (2016). Behavior classification of cows fitted with motion collars: Decom-posing multi-class classification into a set of binary problems. *Computers and Elec-tronics in Agriculture*, 40-50. doi.org/10.1016/j.compag.2016.10.006

[TCD*00] Thomas, B., Close, B., Donoghue, J., Squires, J., De Bondi, P., Morris, M., & Piekarski, W. (2000,October). ARQuake: An outdoor/indoor augmented reality first person application. *Wearable computers, the fourth international symposium on* (139-146). IEEE. doi.org/10.1109/iswc.2000.888480

[ZDB08] Zhou, F., Duh, H. B. L., & Billinghurst, M. (2008 September). Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. *Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality* (pp. 193-202). doi.org/10.1109/ismar.2008.4637362