Real-Time Cow Detection and Identification Using Enhanced Particle Filter

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Abstract. In this paper, demonstration of how an individual cow can be tracked and identified in a herd of cows using an enhanced particle filter is presented. In a typical agricultural setup, it is not uncommon to witness cases of cow swappi

1. Introduction

In an ideal practice, animal husbandry management involves applying monitoring techniques for identification accuracy and reliability of an individual cow to ensure individual cow traceability, health monitoring and performance recording [1, 2]. However, some of these techniques involve wearing of tags on the animal, embedding of chips on the animal, which induce injury and can even cause the animal’s death. Therefore, it is necessary to device injury-free techniques for monitoring cow activity in farm environments with diverse applications, such as detection of early cow lameness, improvement of animal welfare and lessening of cow management costs.

This work proposes a cow monitoring system where the algorithms for moving object detection are studied and enhanced. The approach of our case study involves installing camera on a pole near a passageway through which the cows passed almost every day and the video processing system was employed for the processing of the herd’s dynamic trajectory. Report was made on the model initialisation, mean shift algorithm, particle-Kalman filter, and the target model is updated in order to overcome the change in the target object appearance over time. To our utmost knowledge, this work is the first to apply combination of mean-shift based tracker and particle-Kalman filter as enhanced particle filter to real-time cow detection and identification to curtail occlusion and non-linear tracking problem.
The research objective is to enhance the motion tracking algorithm of particle filter for cow detection and identification in a real-time environment.

2. Motivation
Knowing how to interpret the behaviour exhibited by an individual cow in farm environments would be an appealing task. The behaviour exhibited by individual cow can greatly assist breeders in differentiating between wellness and illness of their cows thereby facilitating cow health and performance monitoring.

During grazing, especially in an open grazing, health status of individual cow can be easily noticed by mere observing their trajectory moving patterns thereby enabling early detection of illness in them such as lameness and hoof diseases. However, great effort is still involved in understanding the behaviour exhibited by these cows, and the available technologies are not yet improved to handle some of these tasks.

This paper is motivated by all the above mentioned challenges, and therefore directs its focus on detecting and identifying cow in real-time through an enhanced particle filter algorithm by incorporating mean shift and Kalman filter algorithm into particle filter algorithm in order to overcome the problem of occlusion and non-linear movement.

3. Background and related work
Research in visual objects tracking in the recent years has greatly received a boost by the computer vision community. Tracking of visual objects is still a herculean task to achieve despite the breakthrough that has led to the development of lots of visual object algorithms for tracking. Several factors could be responsible for the challenges arising in object tracking such as variation of illumination, instability of object posture, and similarity in colour of image’s objects and background. Method employed in visual objects tracking is categorised by [3] into deterministic and probabilistic methods in which mean-shift as one of the deterministic methods is often employed [4, 5, 6].

In this research, mean shift, particle filter algorithm, and Kalman filter algorithm have been studied for cow tracking. This is to enable the monitoring of individual cow against rustling and health challenges whether when in the feedlot or open grazing.

3.1. Mean shift
Among the several deterministic methods employed in visual object tracking, mean-shift is the most commonly employed method for its lustiness against partial occlusion, and its algorithm enables efficient and faster computational time making it suitable for real-time implementation. Nevertheless, tracking of full occluded object and fast moving object is not readily possible with mean-shift.

3.2. Kalman filter algorithm
Kalman filter [7, 8] is one of the most probabilistic methods employed for visual object tracking. The algorithm employed in developing and implementing Kalman filter is such that the location of any occluded and linearly moving object can be easily predicted during real-time tracking task making it suitable for estimating linear system [9]. Nevertheless, applying Kalman filter in tracking a non-linear moving object is not an ideal method because, practically, most of the target objects in a real life scenario usually move non-linearly [10] as a result of changes in their trajectory.

3.3. Particle filter algorithm
Particle filter algorithm [11, 12] as another probabilistic method of tracking visual object is able to handle non-linear moving problems unlike Kalman filter [13]. Nevertheless, tracking visual object with particle filter reduces tracking performance and it involves enormous computation due to huge number of particles as samples making it not suitable for real-time application.
3.4. Enhanced particle filter algorithm

In order to improve the limitations of the individual algorithms described in subsection 3.1, subsection 3.2 and subsection 3.3 for visual object tracking, many researchers have combined several of these algorithms to utilize their strong points. Among the researchers that combined these algorithms are Iraei [14], Zhao [15], and Zhou [16], they combined Kalman filter algorithm and mean-shift for the tracking of occluded object. Although the combination was able to handle occlusion, they could still not handle non-linear moving object. When particle filter was combined with mean shift by Chu [20], Qiao [17], Maggio [13], and Chen [18], non-linear moving objects and fast moving objects were able to be handled by only few particles. Re-appearing objects and fully occluded objects were unable to be tracked by this combination. In particle-Kalman filter, Kalman filter is used for global motion estimation to handle both linear moving objects and occluded objects, and particle filter is used for local view motion estimation in order to handle non-linear moving objects.

An object tracking algorithm that combines mean-shift and particle-Kalman filter algorithms in monitoring cow is developed and implemented, where mean-shift is used as master tracker when the target object is not occluded, and when occlusion occurred or the mean-shift tracking result is not convincing, particle-Kalman filter acts as master tracker to improve the tracking results.

4. Methodology

Shown in Figure 1 is the flowchart of the enhanced object tracking algorithm, and Figure 2 is the dimensional sketch of the dynamic trajectory of the herd captured by a camera installed on a pole near a passageway through which the cows passed almost every day and the video processing system was employed for the processing of the herd’s trajectory.

![Flowchart of the enhanced object tracking algorithm](image-url)

**Figure 1.** Flowchart of the enhanced object tracking algorithm.
To evaluate the enhanced algorithm, a prototype of cow monitoring system is implemented with Keteku and Muturu cow breeds chosen as case study. Keteku and Muturu cows are chosen as case study not only because they are indigenous to Nigeria, but their calving interval is short, they are resilient and tolerant to trypanosomiasis, also, they are widely known for fast maturity with reduced rate of mortality for the entire herd in which Muturu has 2% and Keteku has 4.7% [19]. Moreover, they enormously contribute to the income of the breeders in particular and the economy of the Nation in general.

5. Implementation
The implementation of the cow monitoring system is comprised of the tracking and detection algorithms of the mean-shift, and the particle-Kalman filter. As shown in Figure 3, the cow real-time tracking system (interface) tries as much as possible to detect and track individual cow when the necessary information about the video containing the cow is inputted and initialised. The use of bounding box helps in locating the regions of interest (RoI) on each video image for further processing (segmentation).

This work involves image processing, object detection and object tracking; so, its implementation is carried out on MATLAB R2019b, computer system running Microsoft Windows 10 as the operating system, and Microsoft Visual Studio 2019 as the integrated development environment (IDE). Based on the numerous algorithms embedded in the system it is able to track the cow non-linear movement although, with some reasons for improvement. The algorithms presently employed in this work are combined algorithms of mean-shift, particle filter and Kalman filter on which further research is still being carried out. The combined algorithms enable the utilisation of the strength of individual algorithm, and cover-up of their weaknesses.
6. Results and discussion

As shown in Figure 4, individual cow was manageably tracked from the enhanced algorithm. Shown in Figure 4(a) is the screenshot of a single-tracked cow’s video frame (frame number 2) and in Figure 4(b) is the screenshot of multiple-tracked cows’ video frame (frame number 28). Nevertheless, the performance of the system was affected by some detected constraints. These constraints are as a result of frequent change in position of the cow and assumption of unusual postures when active. The shape of the cow changes drastically when moving around, eating, lying down, and grooming in contrast to static objects like trees. Similarity that exists between two or more objects in videos and images often makes it difficult if not impossible to differentiate between two specific cows due to similarity in coat and colour patterns and absence of distinctive bodily markings. Whenever there is an incidence of partial occlusion, it is practically not possible even for individual human being to differentiate between the cows. The type of lighting employed in illuminating the environment where the cows were captured poses a threat to the algorithms as they can wrongly take these shadows or patches for features of the cow thereby affecting further processing such as segmentation.

All these will be overcome by a more advanced generalisation competence. Based on Figure 4, the detection accuracy of the cow still calls for further improvement as the non-linear movement of the moving cows could not be perfectly tracked. The bounding boxes representing the detection of cow could not classify all the objects in the image. The heterogeneous background information in the images will be segmented and the cow objects will be extracted by using instance segmentation technique for the sake of classification in the future work as this present work is merely carried out for cow location prediction and tracking. Cow detection and identification by enhanced particle filter in this paper is the initial stride towards monitoring of animal in real-time in husbandry environments with diverse applications, such as traceability, health monitoring and performance recording through a reduced cow maintenance cost [20], and other animal wellbeing improvements.
Figure 4. (a) Screenshot of single-tracked cow video frame (b) Screenshot of multiple-tracked cow video frame.

7. Conclusion and future work
The proposed method described in this study has shown tracking practicality. If combined with related works such as linear appraisal, lameness and mastitis detection, analysis of feeding and drinking behaviour, and image segmentation of individual cow; there is great tendency that utmost performance will be recorded. The approach employed in this paper can assist breeders to attain greater height in animal husbandry by reducing management cost, increasing performance recording, and guaranteeing cow traceability and health monitoring in addition to the detection and analysis of individual cow behaviour.

We seek to improve on the existing algorithms in our future work. This improvement might involve segmentation and classification of the target object using pixel-to-pixel instance segmentation technique.

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